MAR ATHANASIUS COLLEGE OF ENGINEERING

(Government Aided and Autonomous)

Kothamangalam-686666

Affiliated to APJ Abdul Kalam Technological University

Thiruvananthapuram

Master of Technology (M. Tech)

Curriculum - 2024

COLLEGE VISION AND MISSION

VISION

Excellence in education through resource integration.

MISSION

The institution is committed to transform itself into a centre of excellence in Technical Education upholding the motto "Knowledge is Power."

This is to be achieved by imparting quality education to mould technically competent professionals with moral integrity, ethical values and social commitment, and by promoting innovative activities in the thrust areas emerging from time to time.

MAR ATHANASIUS COLLEGE OF ENGINEERING

(GOVT. AIDED & AUTONOMOUS)

M.TECH CURRICULUM AND SCHEME-2024

Department of Electrical and Electronics

(Power Electronics)

PROGRAM OUTCOMES – PO

Outcomes are the attributes that are to be demonstrated by a graduate after completing the programme

PO1: An ability to independently carry out research/investigation and development work in engineering and allied streams

PO2: An ability to communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.

PO3: An ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher thanthe requirements in the appropriate bachelor program

PO4: An ability to apply stream knowledge to design or develop solutions for real world problems by following the standards

PO5: An ability to identify, select and apply appropriate techniques, resources and state-of-the-art tool to model, analyze and solve practical engineering problems.

PO6: An ability to engage in life-long learning for the design and development of the stream related problems taking into consideration sustainability, societal, ethical and environmental aspects. Also to develop cognitive skills for project management and finance which focus on Industry and Entrepreneurship.

The departments conducting the M.Tech programme shall define their own PSOs, if required, and evaluation shall also be done for the same.

SEMESTER I

Slot	Course Code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
A	M24EE1T101	Linear Algebra and Linear Systems	40	60	4-0-0-4	4	4
B	M24EE1T102	Analysis of Power Electronic Circuits	40	60	4-0-0-4	4	4
C	M24EE1T103	Switched Mode Power Converters	40	60	4-0-0-4	4	4
D	M24EE1E104A	Programme Elective 1	40	60	3-0-0-3	3	3
E	M24EE1E105A	Programme Elective 2	40	60	3-0-0-3	3	3
J	M24EE1R106	Research Methodology & IPR	40	60	2-0-0-2	2	2
G	M24EE1L107	Advanced Power Electronics Laboratory Lab	60	40	0-0-3-3	3	2
Total			**300**	**400**		**23**	**22**

Teaching Assistance: 7 hours
Self-study- 23 Hrs

PROGRAMME ELECTIVE 1

Slot	Course Code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
D	M24EE1E104A	Advanced Power Semiconductor Devices	40	60	3-0-0-3	3	3
D	M24EE1E104B	Dynamics of Linear Systems	40	60	3-0-0-3	3	3
D	M24EE1E104C	Soft Computing Techniques for PE Applications	40	60	3-0-0-3	3	3
D	M24EE1E104D	Classical and Special Electrical Machine Drives	40	60	3-0-0-3	3	3

PROGRAMME ELECTIVE 2

Slot	Course Code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
E	M24EE1E105A	Computer Applications in Power Systems	40	60	3-0-0-3	3	3
E	M24EE1E105B	Embedded Controllers for Power Converters	40	60	3-0-0-3	3	3

E	M24EE1E105C	Power Quality, EMI Issues and Remedial Techniques	40	60	3-0-0-3	3	3
E	M24EE1E105D	Power Systems Operation and Control	40	60	3-0-0-3	3	3

SEMESTER II

Slot	Course Code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
A	M24EE1T201	Optimization Techniques	40	60	4-0-0-4	4	4
B	M24EE1T202	Advanced Electric Drives	40	60	4-0-0-4	4	4
C	M24EE1E203A	Programme Elective 3	40	60	3-0-0-3	3	3
D	M24EE1E204A	Programme Elective 4	40	60	3-0-0-3	3	3
E	M24EE1S205	Industry Integrated Course-Electric Charging Systems for Electrical Vehicles	40	60	3-0-0-3	3	3
G	M24EE1P206	Mini project	60	40	0-0-3-3	3	2
H	M24EE1L207	Renewable Energy and Drives Laboratory	60	40	0-0-3-3	3	2
TOTAL			**320**	**380**		**23**	**21**

Teaching Assistance: 7 hours
Self-study- 23 Hrs

PROGRAMME ELECTIVE 3

Slot	Course code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
C	M24EE1E203A	FACTS and Custom Power Devices	40	60	3-0-0-3	3	3
C	M24EE1E203B	Solar and Wind Power Conversion Systems	40	60	3-0-0-3	3	3
C	M24EE1E203C	Distributed Generation and Protection	40	60	3-0-0-3	3	3
C	M24EE1E203D	Multilevel Inverters and Modulation Techniques	40	60	3-0-0-3	3	3

PROGRAMME ELECTIVE 4

Slot	Course Code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
D	M24EE1E204A	Digital Control System Design	40	60	3-0-0-3	3	3

D	M24EE1E204B	Power System Dynamics and Stability	40	60	3-0-0-3	3	3
D	M24EE1E204C	Design of Power Electronic Systems	40	60	3-0-0-3	3	3
D	M24EE1E204D	Electric Vehicle System Design	40	60	3-0-0-3	3	3

SEMESTER III

TRACK 1							
Slot	**Course Code**	**Courses**	**Marks**		**L-T-P-S**	**Hours**	**Credit**
			CIE	**ESE**			
A	M24EE1M301	*MOOC	To be completed successfully		--	--	2
B	M24EE1E302A	Programme Elective 5	40	60	3-0-0-3	3	3
K	M24EE1I303	**Internship	50	50	--	--	3
P	M24EE1P304	Dissertation Phase 1	100	--	0-0-16-16	16	11
TOTAL			**190**	**110**		**19**	**19**
TRACK 2							
A	M24EE1M305	* MOOC 1	To be completed successfully		--	--	2
B	M24EE1M306	* MOOC 2	To be completed successfully		-	-	2
K	M24EE1I307	## Internship	50	50	--	-	4
P	M24EE1P308	###Dissertation Phase 1	100	--	-	-	11
TOTAL			**150**	**50**			**19**

Teaching Assistance: 6 hours

*MOOC Course of minimum 8 weeks duration to be successfully completed before the end of fourth semester (starting from semester 1).

**Internship- mandatory internship of 6 to 8 weeks

Internship - mandatory internship of more than 16 weeks

###Dissertation Phase 1 – Should be done in Industry

TRACK 1 / TRACK 2

In second year, the students can choose either of the two tracks: TRACK 1 or TRACK 2. Track 1 is conventional MTech programme in which the dissertation Phase 1 is conducted in college. Track 2 is MTech programme designed for students who undergone long term internship (not less than 16 weeks) in industry. An aspirant in track 2 needs to do the dissertation in the industry. The candidates should also be good with performing in-depth research and colluding the conclusions of research led by them. Such students are expected to have the following skills: Technical Skills, Research Skills, Communication Skills, Critical Thinking Skills, and Problem-Solving Skills.

The eligibility for Track 2:

- Shall have qualified in the GATE or have a SGPA above 8.0 during the firstsemester, and
- Qualify an interview during the end of second semester by an expert committee constituted by the College.

PROGRAMME ELECTIVE 5

Slot	Course Code	Courses	Marks		L-T-P-S	Hours	Credit
			CIE	ESE			
B	M24EE1E302A	Energy Efficiency in Electrical Engineering	40	60	3-0-0-3	3	3
B	M24EE1E302B	Design and Installation of Solar PV Systems	40	60	3-0-0-3	3	3
B	M24EE1E302C	Industrial Automation	40	60	3-0-0-3	3	3
B	M24EE1E302D	Electrical System Modeling	40	60	3-0-0-3	3	3

SEMESTER IV

TRACK 1							
Slot	**Course Code**	**Courses**	**Marks**		**L-T-P-S**	**Hours**	**Credit**
			CIE	**ESE**			
P	M24EE1P401	Dissertation Phase II	100	100	0-0-27-24	27	18
TOTAL			**100**	**100**		**27**	**18**
TRACK 2							
P	M24EE1P402	##Dissertation Phase II	100	100			18
TOTAL			**100**	**100**			**18**
Total credits in all four semesters							**80**

##Dissertation Phase II- Should be done in Industry

COURSE NUMBERING SCHEME

The course number consists of digits/alphabets. The pattern to be followed is

For General Courses - MYYBBXCSNN

For Elective Courses - MYYBBXCSNNA

- M: MASTERS
- YY: Last two digits of year of regulation
- BB: DEPARTMENT

Sl.No	Department	Course Prefix
01	Civil Engg	CE
02	Computer Science	CS
03	Electrical & Electronics	EE
04	Electronics & Communication	EC
05	Mechanical Engg	ME
06	Any	GE
07	External (Industry/NPTEL etc)	EX

- X :Specialization number
- C: Course Type

T- Core Course

E- Elective Course

R- Research Methodology & IPR

L- Laboratory Course

S- Industry Integrated Course

I- Internship

M- MOOC

P- Project/Dissertation

- S : Semester of Study

1- Semesters 1

2- Semester 2

3- Semester 3

4- Semester 4

- NN: Course sequence number

- A: Elective sequence number - A/B/C/D/E

It is illustrated below: Examples:

M24EE1T202 is a second core course of first specialization offered by the Electrical Department in semester 2

M24EE1R106 is Research Methodology & IPR offered in semester 1

M24EE1E104A is the first subject of Elective 1 of first specialization offered by the Electrical Department in semester 1

EVALUATION PATTERN

(i) CORE COURSES

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation (CIE): 40 marks

Micro project/Course based project	:10marks
Course based task/Seminar/Quiz	:10marks
Test paper 1 (Module 1 and Module 2)	:10 marks
Test paper 2 (Module 3 and Module 4)	:10 marks

The project shall be done individually (Preferable).

End Semester Examination (ESE): 60marks

The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 8 marks. Total duration of the examination will be 3 Hrs.

(ii) ELECTIVE COURSES

Evaluation shall only be based on application, analysis or design based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: 40 marks

Seminar*	:	10 marks
Course based task/Micro Project//Data collection and interpretation/Case study	:	10 marks
Test paper 1 (Module 1 and Module 2)	:	10 marks
Test paper 2 (Module 3 and Module 4)	:	10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course.

End Semester Examination: 60 marks

The end semester examination will be conducted by the College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 4 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 8 marks. Total duration of the examination will be 3 Hrs.

(iii) RESEARCH METHODOLOGY & IPR

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed Original publications in the relevant discipline (minimum 10 publications shall be referred) : 10 marks

Course based task/Seminar/Quiz	: 10 marks
Test paper 1 (Module 1 and Module 2)	: 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

End Semester Examination : 60 marks

The end semester examination should be conducted by the college. The time duration will be for 3 Hrs and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

(iv) INTERNSHIP

Internships are educational and career development opportunities, providing practical experience in a field or discipline. They are structured, short-term, supervised placements often focused around particular tasks or projects with defined timescales. An internship may be compensated or non-compensated by the organization providing the internship. The internship has to be meaningful and mutually beneficial to the intern and the organization. It is important that the objectives and the activities of the internship program are clearly defined and understood. The internship offers the students an opportunity to gain hands-on industrial or organizational exposure; to integrate the knowledge and skills acquired through the coursework; interact with professionals and other interns; and to improve their presentation, writing, and communication skills. Internship often acts as a gateway for final placement for many students.

A student shall opt for carrying out the Internship at an Industry/Research Organization or at another institute of higher learning and repute (Academia). The organization for Internship shall be selected/decided by the students on their own with prior approval from the faculty advisor/respective PG Programme Coordinator/Guide/Supervisor. Every student shall be assigned an internship Supervisor/Guide at the beginning of the Internship. The training shall be related to their specialization after the second semester for a minimum duration of six to eight weeks. On completion of the course, the student is expected to be able to develop skills in facing and solving the problems experiencing in the related field.

Objectives

- Exposure to the industrial environment, which cannot be simulated in the classroom and hence creating competent professionals for the industry.
- Provide possible opportunities to learn understand and sharpen the real time

technical / managerial skills required at the job.

- Exposure to the current technological developments relevant to the subject area of training.
- Create conducive conditions with quest for knowledge and its applicability on the job.
- Understand the social, environmental, economic and administrative considerations that influence the working environment.
- Expose students to the engineer's responsibilities and ethics.

Benefits of Internship

Benefits to Students

- An opportunity to get hired by the Industry/ organization.
- Practical experience in an organizational setting & Industry environment.
- Excellent opportunity to see how the theoretical aspects learned in classes are integrated into the practical world. On-floor experience provides much more professional experience which is often worth more than classroom teaching.
- Helps them decide if the industry and the profession is the best career optionto pursue.
- Opportunity to learn new skills and supplement knowledge.
- Opportunity to practice communication and teamwork skills.
- Opportunity to learn strategies like time management, multi-tasking etc in an industrial setup.
- Makes a valuable addition to their resume.
- Enhances their candidacy for higher education/placement.
- Creating network and social circle and developing relationships with industry people.
- Provides opportunity to evaluate the organization before committing to a full time position.

Benefits to the Institute

- Build industry academia relations.
- Makes the placement process easier.
- Improve institutional credibility & branding.
- Helps in retention of the students.
- Curriculum revision can be made based on feedback from Industry/ students.
- Improvement in teaching learning process.

Benefits to the Industry

- Availability of ready to contribute candidates for employment.
- Year round source of highly motivated pre-professionals.
- Students bring new perspectives to problem solving.
- Visibility of the organization is increased on campus.
- Quality candidate's availability for temporary or seasonal positions and projects.
- Freedom for industrial staff to pursue more creative projects.
- Availability of flexible, cost-effective workforce not requiring a long-termemployer commitment.
- Proven, cost-effective way to recruit and evaluate potential employees.
- Enhancement of employer's image in the community by contributing to the educational enterprise.

Types of Internships

- Industry Internship with/without Stipend
- Govt / PSU Internship (BARC/Railway/ISRO etc)
- Internship with prominent education/research Institutes

- Internship with Incubation centres /Start-ups

Guidelines

- All the students need to go for internship for minimum duration of 6 to 8 weeks.
- Students can take mini projects, assignments, case studies by discussing itwith concerned authority from industry and can work on it during internship.
- All students should compulsorily follow the rules and regulations as laid by industry.
- Every student should take prior permissions from concerned industrial authority if they want to use any drawings, photographs or any otherdocument from industry.
- Student should follow all ethical practices and SOP of industry.
- Students have to take necessary health and safety precautions as laid bythe industry.
- Student should contact his /her Guide/Supervisor from college on weekly basis to communicate the progress.
- Each student has to maintain a diary/log book
- After completion of internship, students are required to submit
    - Report of work done
    - Internship certificate copy
    - Feedback from employer / internship mentor
    - Stipend proof (in case of paid internship).

Total Marks 100: The marks awarded for the Internship will be on the basis of (i) Evaluation done by the Industry (ii) Students diary (iii) Internship Report and (iv) Comprehensive Viva Voce.

Continuous Internal Evaluation: 50 marks

Student's diary - 25 Marks

Evaluation done by the Industry - 25 Marks

Student's Diary/ Daily Log: The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily training diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily training diary should be signed after every day by the supervisor/ in charge of the section where the student has been working. The diary should also be shown to the Faculty Mentor visiting the industry from time to time and got ratified on the day of hisvisit. Student's diary will be evaluated on the basis of the following criteria:

- Regularity in maintenance of the diary
- Adequacy & quality of information recorded
- Drawings, design, sketches and data recorded
- Thought process and recording techniques used
- Organization of the information.

The format of student's diary

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Brief description about the nature of internship:

Day	Brief write up about the Activities carried out: Such as design, sketches, result observed, issues identified, data recorded, etc.
1	

2	
3	

Signature of Industry Supervisor   *Signature of Section Head/HR Manager*

Office Seal

Attendance Sheet

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	...
Month & Year																					
Month & Year																					

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

Note:

- Student's Diary shall be submitted by the students along with attendance record and an evaluation sheet duly signed and stamped by the industry tothe Institute immediately after the completion of the training.
- Attendance Sheet should remain affixed in daily training diary. Do not remove or tear it off.
- Student shall sign in the attendance column. Do not mark 'P'.
- Holidays should be marked in red ink in the attendance column. Absent should be marked as 'A' in red ink.

Evaluation done by the Industry (Marks 25)

Format for Supervisor Evaluation of Intern

Student Name :___________________Date:___________________ Supervisor Name :__________________________Designation:______________

Company/Organization :____________________________________

Internship Address: ____ Dates of Internship: From__________________To ______________________

Please evaluate intern by indicating the frequency with which you observed the following parameters:

Parameters Marks	Needs improvement(0 – 0.25 mark)	Satisfactory(0.25 – 0.50 mark)	Good (0.75 mark)	Excellent(1 mark)
Behavior				
Performs in a dependable Manner				

Cooperates with coworkers and supervisor				
Shows interest in work				
Learns quickly				
Shows initiative				
Produces high quality work				
Accepts responsibility				
Accepts criticism				
Demonstrates organizational skills				
Uses technical knowledge and expertise				
Shows good judgment				
Demonstrates creativity/originality				
Analyzes problems effectively				
Is self-reliant				
Communicates well				
Writes effectively				
Has a professional attitude				
Gives a professional appearance				
Is punctual				
Uses time effectively				

Overall performance of student

Intern (Tick one) : Needs improvement (0 - 0.50 mark) / Satisfactory (0.50 – 1.0 mark) / Good (1.5 mark) / Excellent (2.0 mark)

Additional comments, if any (2 marks) :

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

End Semester Evaluation (External Evaluation): 50 Marks

Internship Report	-	25 Marks
Viva Voce	-	25 Marks

Internship Report: After completion of the internship, the student should prepare a comprehensive report to indicate what he has observed and learnt in the training period and should be submitted to the faculty Supervisor. The student may contact Industrial Supervisor/ Faculty Mentor for assigning special topics and problems and should prepare the final report on the assigned topics. Daily diary will also help to a great extent in writing the industrial report since much of the information has already been incorporated by the student into the daily diary. The training report should be signed by the Internship Supervisor, Programme Coordinator and Faculty Mentor.

The Internship report (25 Marks) will be evaluated on the basis of following criteria:

- Originality
- Adequacy and purposeful write-up
- Organization, format, drawings, sketches, style, language etc.
- Variety and relevance of learning experience
- Practical applications, relationships with basic theory and concepts taughtin the course

Viva Voce (25 Marks) will be done by a committee comprising Faculty Supervisor, PG Programme Coordinator and an external expert (from Industry or research/academic Institute). This committee will be evaluating the internship report also.

(v) LABORATORY COURSES

Lab work and Viva-voce	: 60 marks
Final evaluation Test and Viva voce	: 40 marks

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final evaluation shall be done by two examiners; one examiner will be a senior faculty from the same department.

(vi) INDUSTRY INTEGRATED COURSE

Engineering students frequently aspire to work in areas and domains that are key topics in the industry. There are concerns by recruiters that skill sets of engineering students did not match with the Industry requirements, especially in the field of latest topics. In response to their desires, the College has incorporated Industry integrated course in the curriculum.

The evaluation pattern for Industry based electives is as follows:

Continuous Internal Evaluation: 40 marks

Seminar	:	10 marks
Course based task/Seminar/		
Data collection and interpretation/Case study	:	10marks
Test paper 1 (Module 1 and Module 2)	:	10 marks
Test paper 2 (Module 3 and Module 4)	:	10 marks

End Semester Examination: 60 marks

The examination will be conducted by the College with the question paper provided by the Industry. The examination will be for 3 Hrs and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks. The valuation of the answer scripts shall be done by the expert in the Industry handling the course.

(vii) MOOC COURSES

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/NPTEL/SWAYAM or NITTTR. The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/offline end semester examination. The students can do the MOOC according to their convenience, but shall complete it before the end of fourth semester. The list of MOOC courses will be provided by theconcerned BoS if at least 70% of the course content match with the area/stream of study. The course shall not be considered if its content has more than

50% of overlapwith a core/elective course in the concerned discipline or with an open elective.

MOOC Course to be successfully completed before the end of fourth semester (starting from semester 1). A credit of 2 will be awarded to all students whoever successfully completes the MOOC course as per the evaluation pattern of the respective agency conducting the MOOC.

(viii) MINIPROJECT

Total marks: 100

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem-solving skills. The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Interim evaluation: 60 (30 marks for each review), final evaluation by a Committee (will be evaluating the level of completion and demonstration of functionality/specifications, clarity of presentation, oral examination, work knowledgeand involvement): 25, Report (the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level is not more than 25%): 10, Supervisor/Guide: 5

(ix) DISSERTATION

Dissertation: All Students should carry out the dissertation in the college or can work either in any CSIR/Industrial R&D organization/any other reputed Institute which have facilities for dissertation work in the area proposed.

Dissertation outside the Institute: For doing dissertation outside the Institution, the following conditions are to be met:

- They have completed successfully the course work prescribed in the approved curriculum up to the second semester.

- They should choose Track 2 in semester 3 and 4
- The student has to get prior approval from the DLAC and CLAC.
- Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
- They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degreein the related area.
- The student has to furnish his /her monthly progress as well as attendance report signed by the external guide and submit the same to the concerned Internal guide.
- The external guide is to be preferably present during all the stages of evaluation of the dissertation.

  Note1- Students availing this facility should continue as regular students of the College itself.

  Note 2-The course work in the 3rd semester is to be completed as per the curriculum requirements (i) MOOC can be completed as per the norms mentioned earlier

Internship leading to Dissertation: The M. Tech students who after completion of 6 to 8 weeks internship at some reputed organization are allowed to continue their work as dissertation for the third and fourth semester after getting approval from the DLAC. Such students shall make a brief presentation regarding the work they propose to carry out before the DLAC for a detailed scrutiny and to resolve its suitability for accepting it as an M.Tech dissertation. These students will be continuing as regular students of the Institute in third semester for carrying out all academic requirements as per the curriculum/regulation. However, they will be permitted to complete their dissertation in the Industry/Organization (where they have successfully completed their internship) during fourth semester.

Dissertation as part of Employment: Students may be permitted to discontinue the programme and take up a job provided they have completed all the courses till second semester (FE status students are not permitted) prescribed in the approved curriculum. The dissertation work can be done during a later period either in the organization where they work if it has R & D facility, or in the Institute. Such students should submit application with details (copy of employment offer, plan of completion of their project etc.) to the Dean (PG) through HoD. The application shall be vetted by CLAC before granting the approval. When the students are planning to do the dissertation work in the organization with R & D facility where they are employed, they shall submit a separate application having following details:

- Name of R&D Organization/Industry
- Name and designation of an external supervisor from the proposed Organization/Industry (Scientists or Engineers with a minimum post graduate degree in the related area) and his/her profile with consent
- Name and designation of a faculty member of the Institute as internal supervisor with his/her consent
- Letter from the competent authority from the Organization/Industry granting permission to do the dissertation
- Details of the proposed work
- Work plan of completion of project

DLAC will scrutinize the proposal and forward to CLAC for approval.

When students are doing dissertation work along with the job in the organization (with R & D facility) where they are employed, the dissertation work shall be completed in four semesters normally (two semesters of dissertation work along with the job may be considered as equivalent to one semester of dissertation work at the Institute). Extensions may be granted based on requests from the student and recommendation of the supervisors such that he/she will complete the M. Tech programme within four years from the date of admission as per the regulation. Method of evaluation and grading of the dissertation will be the same as in the case of regular students. The course work in the 3rd semester for such students are to be completed as per the curriculum requirements (i) MOOC can be completed as per the norms mentioned earlier. However, for self learning students, all evaluations shall be carried out in their parent Institution as in the case of regular students.

Mark Distribution:

Phase 1: Total marks: 100, only CIE

Phase 2: Total marks: 200, CIE = 100 and ESE = 100 marks

- Maximum grade (S grade) for the dissertation phase II will be awarded preferably if the student publishes the dissertation work in a peer reviewed journal.
- Final Evaluation (ESE) should be done by a three-member committee comprising of the Department Project coordinator, Guide and an External expert. The external expert shall be an academician or from industry.

(x) TEACHING ASSISTANCESHIP (TA)

All M.Tech students irrespective of their category of admission, shall undertake TA duties for a minimum duration as per the curriculum. Being a TA, the student will get an excellent opportunity to improve their expertise in the technical content of the course, enhance communication skills, obtain a hands-on experience in handling the experiments in the laboratory and improve peer interactions.

The possible TA responsibilities include the following: facilitate a discussion section or tutorial for a theory/ course, facilitate to assist the students for a laboratory course, serve as a mentor for students, and act as the course web-master. TAs maybe required to attend the instructor's lecture regularly. A TA shall not be employed asa substitute instructor, where the effect is to relieve the instructor of his or her teaching responsibilities.

For the tutorial session:

(i) Meet the teacher and understand your responsibilities well in advance, attend the lectures of the course for which you are a tutor, work out the solutions for all the tutorial problems yourself, approach the teacher if you find any discrepancy or if you need help in solving the tutorial problems, use reference text books, be innovative and express everything in English only.

(ii) Try to lead the students to the correct solutions by providing appropriate hints rather than solving the entire problem yourself, encourage questions from the students, lead the group to a discussion based on their questions, plan to ask them some questions be friendly and open with the students, simultaneously being firm with them.

(iii) Keep track of the progress of each student in your group, give a periodic feedback to the student about his/her progress, issue warnings if the student is consistently under-performing, report to the faculty if you find that a particular student is consistently underperforming, pay special attention to slow-learners and be open to the feedback and comments from the students and faculty.

(iv) After the tutorial session you may be required to grade the tutorials/ assignments/tests. Make sure that you work out the solutions to the questions yourself, and compare it with the answer key, think and work out possible alternate solutions to the same question, understand the marking scheme from the teacher. Consult the teacher and make sure that you are not partial to some student/students while grading. Follow basic ethics.

Handling a laboratory Session:

(i) Meet the faculty – in- charge a few days in advance of the actual lab class and get the details of the experiment, get clarifications from him/her regarding all aspects of the experiment and the expectations, prepare by reading about the theoretical background of the experiment, know the physical concepts involved in the experiment, go to the laboratory and check out the condition of the equipment/instrumentation, perform the laboratory experiment at least once one or two days before the actual laboratory class, familiarize with safety/ security aspects of the experiment / equipment/laboratory, prepare an instruction sheet for the experiment in consultation with the faculty, and keep sufficient copies ready for distribution to students for their reference.

(ii) Verify condition of the equipment/set up about 30 minutes before the students arrive in the class and be ready with the hand outs, make brief introductory remarks about the experiment, its importance, its relevance to the theory they have studied in the class, ask the students suitable questions to know there level of preparation for the experiment, discuss how to interpret results, ask them comment on the results.

(iii) Correct/evaluate/grade the submitted reports after receiving suitable instructions from the faculty in charge, continue to interact with students if they have any clarifications regarding any aspect of the laboratory session, including of course grading, Carefully observe instrument and human safety in laboratory class, Preparing simple questions for short oral quizzing during explanation of experiments enables active participation of students, facilitate attention, provides feedback and formative evaluation.

POINTS TO REMEMBER

1. Arrange an awareness programme to all M.Tech students on day 1 regarding the curriculum and the regulation.
2. The departments should prepare the list of MOOC courses suitable to their programmes and encourage the students to complete at the earliest.
3. Make a tie up with industries by the middle of semester for Industry Integrated Course. While choosing the course, it should be ensured that the programme is relevant and updated in that discipline. The Industry expert handling the course shall be a postgraduate degree holder. The evaluation procedure shall also be clearly explained to them.
4. Each department offering M.Tech programme should be careful in selecting the mini project in semester 2.
5. The departments should invite the Industries/research organizations during first semester and inform them about the mandatory 6-8 weeks internship that the students should undergo after their second semester. The possibility of doing their dissertation at the Industry shall also be explored. They should also be made aware about the evaluation procedure of the Internships. They may also be informed that it is possible to continue internship provided if it leads

to their dissertation. Proposals may be collected from them for allotting to students according to their fields of interest.

6. Make sure that all internal evaluations and the end semester examinations to be conducted by the college are carried out as per the evaluation procedure listed in the curriculum. Any dilution from the prescribed procedure shall be viewed seriously.
7. Teaching assistance shall be assigned to all students as per the curriculum. However, a TA shall not be employed as a substitute instructor, where the effect is to relieve the instructor of his or her teaching responsibilities.
8. The possible TA responsibilities include the following: facilitate a discussion section or tutorial for a theory/ course, facilitate to assist the students for a laboratory course, serve as a mentor for students, and act as the course web-master.

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MAR ATHANASIUS COLLEGE OF ENGINEERING

Government Aided, Autonomous Institution
Kothamangalam, Kerala, India

M.TECH POWER ELECTRONICS
ELECTRICAL & ELECTRONICS ENGINEERING DEPARTMENT

SYLLABUS -2024

SEMESTER 1

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1T101	LINEAR ALGEBRA AND LINEAR SYSTEMS	Core	4	0	0	4	4

Preamble: Linear Algebra and Linear Systems are fundamental disciplines within the realm of applied mathematics and engineering. This course provide students with a comprehensive understanding of key concepts in linear algebra and the study of linear systems including the system representation in state-space, stability analysis, and controller design techniques. This course lays a solid foundation for students pursuing careers in control engineering, applied mathematics, and related disciplines, providing them with the tools necessary to excel in a rapidly evolving technological landscape.

Prerequisite: Basic knowledge of engineering mathematics and linear control systems at UG level.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop a deep understanding of fundamental concepts in linear algebra & apply linear algebraic techniques to solve linear systems (Cognitive Knowledge Level : Understand ; Apply)
CO 2	Identify and analyze various properties of vector spaces, such as closure under vector addition and scalar multiplication, linear independence, and spanning set (Cognitive Knowledge Level : Analyze)
CO 3	Understand the concept of linear transformations between thevector spaces, including properties such as preservation of vector addition and scalar multiplication (Cognitive Knowledge Level : Understand)
CO 4	Analyze the dynamic behavior of systems and assess their controllability & to design controllers to meet desired specifications (Cognitive Knowledge Level : Analyze)
CO 5	Analyze observability using observability Grammians, develop proficiency in designing state observers and understand the Kalman decomposition theorem (Cognitive Knowledge Level : Analyze ; Understand)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	1		3	3	3	2
CO 2	1		3	3	3	2
CO 3	1		3	3	3	2
CO 4	1		3	3	3	2
CO 5	1		3	3	3	2

Evaluation Pattern

	LINEAR ALGEBRA AND LINEAR SYSTEMS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	50
Analyse	40	40	30
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	**CIE marks**	**ESE marks**	**ESE Duration**
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project :10 marks

Course based task/Seminar/Quiz :10 marks

Test paper 1 (Module 1 and Module 2) :10 marks

Test paper 2 (Module 3 and Module 4) :10 marks

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of the examination will be 3 Hrs.

SYLLABUS

MODULE 1 (8 hours)

System of linear equations, Row reduction and Echelon Forms, Pivot positions, Solution of linear systems , Parametric descriptions of solution sets, Homogeneous and Non homogeneous systems, Eigenvalues, Eigenvectors, Eigenspaces, Algebraic multiplicity, geometric multiplicity, Diagonalizability.

MODULE 2 (9 hours)

Vector Spaces - Spaces and Subspaces, Linear combination of vectors, Four Fundamental Subspaces: Column space, Null space, Row space and Left null space of matrix , Spanning sets, Linear Independence, Basis: Basis for Null A & column A, Dimension and Rank.

MODULE 3 (6 hours)

Linear Transformations – Space of Linear Transformations, Matrix representation of linear transformations, Change of Basis and Similarity transformation.

MODULE 4 (12 hours)

Linear Systems – State space modelling of physical system, controllable canonical form, observable canonical form, Solutions to Linear time invariant system, State Transition Matrix, effect of pole zero cancellation in transfer function - Transformation Of State Model To Canonical Form- Controllability, Controllability Grammians , State feedback Controller Design .

MODULE 5 (10 hours)

Observability, Observability Grammians, State Observer Design, Reduced state observer, combined observer controller configuration, Reachability and Constructability, Controllable and Observable subspaces, Kalman Decomposition.

Reference Books

1. Bhaskar Dasgupta, *Applied Mathematical Methods.* Pearson, 1st Ed.,2010
2. Chi-Tsong Chen, *Linear system theory and design.* Oxford, 4th Ed., 2013
3. Ogata K., *Modern Control Engineering*. Prentice Hall of India, 5th Ed., 2010.
4. Gopal M, *Modern Control System Theory.* New Age Publishers, 2nd Ed., 1984
5. Erwin Kreyszig, *Advanced Engineering Mathematics*. Wiley International EditionPress, 9th Ed.,
6. Arfken, Weber and Harris, *Mathematical Methods for Physicists A comprehensive guide*. Elsevier, 7th Ed., 2013
7. Thomas Kailath, *Linear Systems*, Prentice-Hall,2nd Ed., 1980
8. Nagarath I. J. and Gopal M., *Control System Engineering*. New Age Publishers, 5th Ed., 2007
9. Gilbert Strang, *Linear Algebra and its application.* Pearson, 5th Ed.,2016
10. David C Lay, *Linear Algebra and its application.* Pearson, 6th Ed., 2016

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (8 hours)	
1.1	System of linear equations, Row reduction and Echelon Forms , Pivot positions	2
1.2	Solution of linear systems, Parametric description of solution set, Homogeneous and Non homogeneous systems	2
1.3	Eigenvalues, Eigenvectors, Eigenspaces, Algebraic multiplicity, Geometric multiplicity	3
1.4	Diagonalizability	1
	Module 2 (9 hours)	
2.1	Vector Spaces - Spaces and Subspaces	2
2.2	Linear combination of vectors	1
2.3	Four Fundamental Subspaces: Column space, Null space, Row space and Left null space of matrix, Spanning sets	3
2.4	Linear Independence	1
2.5	Basis: Basis for Null A & column A, Dimension and Rank.	2
	Module 3 (6 hours)	
3.1	Linear Transformations – Space of Linear Transformations	2
3.2	Matrix representation of linear transformations	2
3.3	Change of Basis and Similarity transformation	2
	Module 4 (12 hours)	
4.1	Linear Systems - State space modelling of physical system, controllable canonical form, observable canonical form	2
4.2	Solutions to Linear time invariant system, State Transition Matrix	1
4.3	effect of pole zero cancellation in transfer function	1
4.4	Transformation Of State Model To Canonical Form	2
4.5	Controllability, Controllabilty Grammians	3
4.6	State feedback Controller Design	3
	Module 5 (10 hours)	
5.1	Observability, Observability Grammians	2
5.2	State Observer Design, Reduced state observer	2
5.3	Combined observer controller configuration	2
5.4	Reachability and Constructability	2
5.5	Controllable and Observable subspaces	1
5.6	Kalman Decomposition	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM
FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1T101

Course Name: Linear Algebra and Linear System

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Determine h and k such that system has a) no solution b) a unique solution and c) many solutions for the system of equations $x_1 + h\, x_2$ = 2, 4 x_1 + 8 x_2 = k
2. Show that the set of vectors V1 = (0,1,-2) , V2 = (1,-1,1) and V3 = (1,2,1) are linearly independent?
3. Examine the following transformation and prove T is linear
$$T: R^2 \rightarrow R^3 \; defined \;\; by \; T(a,b) = (a+b, a-b, b)$$
4. The state equation and initial condition vector of a linear time-invariant system are given below. Determine the solution of state equation.
$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} ; x_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$
5. The state model of the system represented by
X= $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -3 & -3 \end{bmatrix}x\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ + $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} u$ (t) and Y= $\begin{bmatrix} 1 & 2 & 1 \end{bmatrix}$ x(t)
Check whether the given system is completely state observable or not

PART B

Answer any five questions. Each question carries 8 marks.

6. Determine geometric multiplicity, algebraic multiplicity and basis for the eigen space of each eigen value
A= $\begin{bmatrix} 1 & 3 & 3 \\ -3 & -5 & -3 \\ 3 & 3 & 1 \end{bmatrix}$

7. Let $\mathbf{A} = \begin{bmatrix} -2 \\ 1 \\ 1 \end{bmatrix}$, $\mathbf{B} = \begin{bmatrix} 6 \\ -5 \\ -1 \end{bmatrix}$, $\mathbf{C} = \begin{bmatrix} -8 \\ 5 \\ 3 \end{bmatrix}$ and $\mathbf{D} = \begin{bmatrix} -4 \\ -5 \\ -1 \end{bmatrix}$

   Do A , B , C and D span R3. Justify your answer?
8. Find the matrix representation for the linear transformation T: R2→R2 defined by T(a,b) = (11a+3b , -5a-5b) with respect to the standard basis
   (a) B = {(1,0) , (0,1)}
   (b) B = {(1,1) , (1,-1)}
9. Consider the system represented by
   X= $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix}x\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$+$\begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} u$ (t) and Y= $\begin{bmatrix} 0 & 0 & 1 \end{bmatrix}$ x(t)

   Compute the state feedback gain matrix so that the control law u = -kx , places the closed loop poles at -2, -1$\pm j$.
10. What is the significance of Kalman Decomposition? Transform the state space equation into a canonical form using Kalman Decomposition.
11. What is the need of state observer? Explain the method to obtain the state observer gain matrix G using Ackermann's formula.
12. Differentiate the concept of reachability and controllability with the help of an example

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1T102	ANALYSIS OF POWER ELECTRONIC CIRCUITS	Core	4	0	0	4	4

Preamble: This course provides a comprehensive overview of power electronic converters and its applications. It aims to provide a strong foundation about gate drive circuits, Controlled Converters and PWM inverters. The content of the course helps to Identify and explore emerging applications of power electronic converters and its latest trends and advancements**.**

Prerequisite: A strong understanding of electrical machines, Drives and control, power electronics. Familiarity with control system principles, system modeling techniques using transfer functions and state-space representation.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop various gating circuits and illustrate the operation of choppers. (Cognitive Knowledge Level: Analyze)
CO 2	Analyze the operation of controlled and PWM rectifier circuits. (Cognitive Knowledge Level: Analyze)
CO 3	Select the control schemes for Voltage Source and Current Source inverters. (Cognitive Knowledge Level: Understand)
CO 4	Distinguish the operation and control schemes for Current regulated VSI, Z-source Inverter and Matrix converters. (Cognitive Knowledge Level: Analyze)
CO 5	Describe the performances of induction motor drives and various types of inverters. (Cognitive Knowledge Level: Understand)

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
CO 1	2	2	3	2	3	2
CO 2	3	2	3	3	3	2
CO 3	2	2	3	3	3	3
CO 4	3	2	3	2	2	2
CO 5	3	2	3	2	3	2

Evaluation Pattern

	ANALYSIS OF POWER ELECTRONIC CIRCUITS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (%Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	30	30	30
Apply	20	20	20
Analyze	30	30	30
Evaluate	20	20	20
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project :10 marks

Course based task/Seminar/Quiz :10 marks

Test paper 1 (Module 1 and Module 2) :10 marks

Test paper 2 (Module 3 and Module 4) :10 marks

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (9 hours)

Introduction to Modern Power Electronics - Gate drive circuits for Power Transistor, MOSFET and IGBT. Power dissipation and selection of heat sink. Choppers: Step-down and step-up choppers –PWM control – two-quadrant chopper – Regenerative braking of Separately Excited DC (SEDC) motor - four-quadrant chopper.

MODULE 2 (9 hours)

Controlled and PWM Rectifiers: Single-phase semi & full converters – analysis – inversion mode -3-phase full converters - Twelve-pulse converter- Single-phase dual converter fed SEDC motor drive – circulating & non-circulating current operation. Single phase and 3-phase PWM rectifier – control schemes – hysteresis and PWM control

MODULE 3 (9 hours)

PWM Inverters: Need for PWM - Voltage Source Inverter (VSI)- sinusoidal PWM – linear & over modulation - bipolar & unipolar PWM– DC link current - selection of filter capacitor– effect of blanking time- common mode voltage - Third harmonic injection PWM - Space Vector Modulation. Current source inverter - current control

MODULE 4 **(9 hours)**

Current Regulated PWM VSI - Variable Band and Fixed Switching frequency hysteresis current Control

Z-source inverter – equivalent circuit & operation – shoot through zero state – modulation index and boost factor- Simple boost control

Matrix converter –types- principle – switches for matrix converters - 3-phase matrix converter - Venturini control method.

MODULE 5 (9 hours)

Inverter fed three Phase Induction motor drives- Torque Equation- Equivalent circuit- V/F control using VSI

Multilevel inverters – Diode-clamped multilevel inverter – Flying-capacitors multilevel inverter – cascaded multilevel inverter – PWM for multilevel inverters.

Reference Books

1. Ned Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics*, Wiley, 4th Ed., 2012.
2. G. K. Dubey, *Fundamentals of Electric Drives,* Narosa Publishing House, 2nd Ed., 2015.
3. M. H. Rashid, *Power Electronics*, Pearson, 4th Ed., 2019.
4. William Shepherd and Li Zhang, *Power Converter Circuits*, Marcel Dekker Inc, 1st Ed., 2004.

5. D. Grahame Holmes and Thomas A. Lipo, *Pulse Width Modulation for Power Converters: Principles and Practice*, Wiley, 1st Ed., 2003.
6. Robert W. Erickson and Dragan Maksimovic, *Fundamentals of Power Electronics*, Springer, 2nd Ed., 2013.
7. Barry Williams, *Principles and Elements of Power Electronics*, University of Strathclyde, 1st Ed., 1992.
8. Fang Lin Luo and Hong Ye, *Power Electronics: Advanced Conversion Technologies*, , CRC Press, 1st Ed., 2010.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(9 hrs)	
1.1	Introduction to Modern Power Electronics	1
1.2	Gate drive circuits of Power Transistor	1
1.3	Gate drive circuits of MOSFET, IGBT	2
1.4	Power dissipation and selection of heat sink	1
1.5	Step-down and step-up choppers-PWM control	1
1.6	Two-quadrant chopper - four-quadrant chopper drive	1
1.7	Regenerative braking of Separately Excited DC motor drive	2
	Module 2(9 hrs)	
2.1	Single-phase semi & full converters – analysis	2
2.2	Inversion mode	1
2.3	3-phase full converters	1
2.4	Twelve-pulse converter	1
2.5	Single-phase dual converter fed SEDC motor drive	1
2.6	Circulating & non-circulating current operation	1
2.7	Single phase and 3-phase PWM rectifier	1
2.8	Control schemes – hysteresis and PWM control	1
	Module 3(9 hrs)	
3.1	Pulse Width Modulation (PWM) Strategies for Inverters: Need for PWM - sinusoidal PWM	2
3.2	bipolar & unipolar voltage switching – linear & over modulation	2
3.3	DC link current - selection of filter capacitor	1
3.3	effect of blanking time on voltage in PWM inverter	1

3.4	common mode voltage - Third harmonic injection PWM - Space Vector Modulation	2
3.5	Current source inverter - current control	1
	Module 4(9 hrs)	
4.1	Current Regulated PWM VSI - Variable Band and Fixed Switching frequency hysteresis current Control	2
4.2	Z-source inverter – equivalent circuit & operation – shoot through zero state	2
4.3	Modulation index and boost factor- Simple boost control	2
4.4	Matrix converter –types- principle – switches for matrix converters	1
4.5	3-phase matrix converter - Venturini control method.	2
	Module 5(9 hrs)	
5.1	Inverter fed three Phase Induction motor drives- Torque Equation-Equivalent circuit- V/F control using VSI	2
5.2	Multilevel inverters – Diode-clamped multilevel inverter	2
5.3	Flying-capacitors multilevel inverter	2
5.4	Cascaded multilevel inverter	1
5.5	PWM for multilevel inverters	2

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1T102

Course Name: Analysis of Power Electronic Circuits

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Illustrate two quadrant operation of chopper controlled separately excited DC motor drive with the circuit diagram and waveforms.
2. With the circuit diagram of a single-phase dual converter fed separately excited DC drive in circulating current mode, obtain the relationship between firing angles.
3. Compare unipolar and bipolar PWM techniques for single phase inverter
4. With the scheme of hysteresis current control, sketch the block diagram of the current regulated voltage source inverter. Also illustrate the principle of operation.
5. Compare the multilevel inverters diode clamped and flying capacitor type on its topologies.

PART B

Answer any five questions. Each question carries 8 marks.

6. Design and develop a digital gate drive circuit to trigger a MOSFET IRF540 suitable for a step-up converter with an input voltage of 24V, output voltage of 48V. Also explain the operation of the gate drive circuit.
7. a) Derive an expression for RMS output voltage of a single-phase semi converter with RL load.

   b) Obtain the firing angle for the above converter with an input sinusoidal voltage of 230V RMS and average output voltage of 193V.
8. a) With the circuit diagram and waveforms of the IGBT based current source inverter illustrate the working.

   b) Explain the control strategies of PWM rectifier.

9. How to overcome the drawbacks of traditional voltage source inverters using Z-source inverters. Draw the circuit diagram and illustrate the operation.

10. Explain the variable band fixed frequency current control of PWM VSI.

11. In variable frequency control of the induction motor drive the V/f ratio is kept constant below base speed and V is constant above base speed. Examine the reason.

12. Along with circuit diagram and waveforms discuss the working of cascaded multilevel inverter.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1T103	SWITCHED MODE POWER CONVERTERS	Core	4	0	0	4	4

Preamble: The key aspect of power electronics is the efficiency of power processing and switched converters offer power conversion at high efficiency. This course covers various control techniques and switching topologies used in power converters. This course equips the students to model and analyse the performance of isolated and non-isolated switched mode DC-DC converters.

Prerequisite: Basic Knowledge in Power Electronics at UG Level

Course Outcomes: After the completion of the course the student will be able to

CO 1	Analyse the performance of non-isolated switched mode dc-dc converters (Cognitive Knowledge Level: Apply)
CO 2	Model and analyse different second order switched mode power converters (Cognitive Knowledge Level: Apply)
CO 3	Analyze various isolated DC-DC converter topologies (Cognitive Knowledge Level: Evaluate)
CO 4	Describe the current control of switched mode power Converters (Cognitive Knowledge Level: Evaluate)
CO 5	Explain the various resonant converter topologies (Cognitive Knowledge Level: Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	3	3	3	1
CO 2	3	1	3	3	3	1
CO 3	3	1	3	3	3	1
CO 4	3	1	3	3	3	1
CO 5	3	1	3	3	3	1

Evaluation Pattern

	SWITCHED MODE POWER CONVERTERS M24EE1T103		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	30	30	30
Apply	30	30	30
Analyse	20	20	20
Evaluate	20	20	20
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project :10 marks

Course based task/Seminar/Quiz :10 marks

Test paper 1 (Module 1 and Module 2) :10 marks

Test paper 2 (Module 3 and Module 4) :10 marks

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (10hours)

DC-DC non-isolated converters: Buck, Boost, Buck-Boost converters in continuous and discontinuous conduction mode - analysis and design; CUK and SEPIC converters - operation in continuous conduction mode; Comparison of converters; Selection of components; Switching and conduction losses; Design of snubber and heat sink.

MODULE 2 (8 hours)

Modelling and Control of second order switched mode power converters: State space averaging and linearization, Small signal approximation and circuit averaged model; Voltage Mode control – Transfer Functions; Stability; Design of compensators.

MODULE 3 (11 hours)

Isolated DC-DC converters**:** Push-Pull Converter, Half and Full Bridge Converters- Basic Operation and Waveforms. Forward Converter continuous conduction mode only, Flyback Converter - continuous conduction mode only - Flux Imbalance issues - Design of Magnetics-Volt-Sec Balance Inductor Design -Transformer Design - Study of a typical Voltage Mode PWM Control IC-SG3525.

MODULE 4 (8 hours)

Current Mode Control**:** Advantages, Current Mode vs. Voltage Mode, Hysterisis control, one cycle control; -sub-harmonic instability-compensation to overcome sub-harmonic instability- Slope compensation, EMI issues, protection. Study of a typical Current Mode PWM Control IC - UC3842.

MODULE 5 (8 hours)

Resonant Converters: Classification, Resonant Switch Converter, Zero Voltage Switching- design, Zero current switching - design, Load Resonant Converter, LLC Resonant Converter - Study of a typical resonant Control IC-UCC256304.

Reference Books

1. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*. Wiley 3rd Ed., 2007.
2. Daniel W. Hart, *Power Electronics.* Tata McGraw-Hill 1st Ed., 2011.
3. Abraham Pressman, Keith Billings, and Taylor Morey, *Switching Power Supply Design.* McGraw-Hill, 3rd Ed., 2009.
4. M.H. Rashid, *Power Electronics: Circuits, Devices and Applications*. PHI/Pearson 4th Ed., 2017.
5. L. Umanand, *Power Electronics: Essentials and Applications.* Wiley India 1st Ed., 2009
6. Robert W. Erickson, *Fundamentals of Power Electronics*, Springer, 3rd Ed., 2020.
7. Philip T. Krein, *Elements of Power Electronics*, Oxford University Press, 2nd Ed., 2014.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(10)	
1.1	Buck converter in continuous and discontinuous conduction Analysis and Design	2
1.2	Boost converter in continuous and discontinuous conduction Analysis and Design	2
1.3	Buck-Boost converter in continuous and discontinuous conduction-Analysis and Design	2
1.4	CUK and SEPIC converters- operation in continuous conduction mode	2
1.5	Comparison of converters, Selection of components, switching and conduction losses	1
1.6	Design of Snubber and heat sink	1
	Module 2(8)	
2.1	State space averaging and linearization	2
2.2	Small signal approximation and circuit averaged model	2

2.3	Voltage Mode Control-Transfer Functions- Output to input transfer function, Output to state transfer function	2
2.4	Stability, Design of compensator	2
	Module 3(11)	
3.1	Push-Pull Converter - Basic Operation, Waveforms	1
3.2	Half and Full Bridge Converters- Basic Operation, Waveforms	1
3.3	Forward Converter -continuous conduction mode only	2
3.4	Flyback Converter - continuous conduction mode only	2
3.5	Flux Imbalance issues	1
3.6	Design of Magnetics-Volt-Sec Balance, Inductor Design	2
3.7	Transformer Design	1
3.8	Study of a typical Voltage Mode PWM Control IC-SG3525	1
	Module 4 (8)	
4.1	Current Mode Control: Advantages, Current Mode vs. Voltage Mode, Hysterisis control	2
4.2	one cycle control-sub-harmonic instability	2
4.3	compensation to overcome sub-harmonic instability- Slope compensation	2
4.4	EMI issues, protection	2
4.5	Study of a typical Current Mode PWM Control IC - UC3842	1
	Module 5(8)	
5.1	Resonant Converters: Classification, Resonant Switch Converter	1
5.2	Zero Voltage Switching converter- design	2
5.3	Zero current switching converter - design	2
5.4	Load Resonant Converter	1
5.5	LLC Resonant Converter	1
5.6	Study of a typical resonant Control IC-UCC256304.	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1T103

Course Name: Switched Mode Power Converters

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. For an ideal buck-boost converter, develop the value of L in terms of duty cycle, switching frequency and load at the boundary of discontinuous conduction mode (DCM) and continuous conduction mode (CCM).
2. Explain the voltage mode control of SMPS.
3. With figures explain the working of full bridge isolated dc-dc converter.
4. Compare the current mode control and the voltage mode control of SMPS.
5. Explain the advantages and applications of LLC resonant circuits.

PART B

Answer any five questions. Each question carries 8 marks.

6. A boost converter has an input of 5V and an output of 25W at 15V. The output voltage ripple must be less than 1 percent. The switching frequency is 300 kHz. Develop the duty ratio, minimum inductor value, and minimum capacitor value for continuous conduction.

7. Explain the state space averaging technique. For a buck converter construct the transfer function for voltage gain.

8. Examine the working of flyback converter and hence determine the minimum value of inductance to ensure continuous mode of operation.

9. A push-pull converter has the following parameters: Vs=30V NP /NS =2, D= 0.3, L= 0.5 mH, R=6Ω, C=50µF, f=10 kHz. Determine the output voltage, the maximum and minimum values of inductive current, and the output ripple voltage. Assume all components are ideal.

10. With figures explain the operation of Current Mode PWM Control IC - UC3842.

11. Give an outline of resonant converters? List their advantages over PWM converters. Classify the different types of resonant converters.

12. A ZCS resonant converter has the following parameters. Vs =12V, Io=1A, Lr = 10μH, and Cr= 0.1μF. Determine the output voltage for a switching frequency of 100kHz. Also determine the maximum switching frequency.

PROGRAM ELECTIVE 1

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E104A	ADVANCED POWER SEMICONDUCTOR DEVICES	Elective	3	0	0	3	3

Preamble : Power semiconductor devices are recognized as a key component for all power electronic systems. This course explores the underlying physics and electrical characteristics of power semiconductor devices. The course includes the study of basic silicon devices and the new generation wide band gap devices. After the completion of the course, students will be able to select suitable power semiconductor devices and design gate drive & protection circuits.

Prerequisite : Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop an in-depth knowledge about important Silicon (Si) power semiconductor devices. (Cognitive knowledge level: Understand)
CO 2	Analyse the characteristics and operational features of the selected power semiconductor device (Cognitive knowledge level: Analyse)
CO 3	Investigate the properties of wide bandgap devices for power electronic applications. (Cognitive knowledge level: Analyse)
CO 4	Familiarize the students with advanced power electronic devices for different applications(Cognitive knowledge level: Understand)
CO 5	Design gate driver and protection circuits for power electronic switching devices. (Cognitive knowledge level: Apply, Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	2	3	2	2	2
CO 2	3	2	3	2	2	2
CO 3	3	2	3	3	2	3
CO 4	3	3	3	3	3	2
CO 5	3	2	3	2	2	3

Evaluation Pattern

	Advanced Power Semiconductor Devices		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (8 hours)

Power switching devices- overview- ideal and typical power devices -characteristics- static and dynamic – unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection- EMI due to switching- reduction of EMI
Silicon Power Diodes- Types, forward and reverse characteristics, switching characteristics -losses- ratings –Schottky diodes.
Gate Turnoff Thyristor (GTO) - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off Transients - gate drive requirements- snubber requirements
Integrated gate-commutated thyristors (IGCTs)- device types- operation- turn on and turn off behaviour- applications

MODULE 2 (7 hours)

Current-Controlled Devices: BJTs- Constructional features and operation, static characteristics, switching characteristics- Secondary Breakdown - Safe Operating Area - Darlington Configuration- Comparison with GTO

Voltage-controlled Devices: Power MOSFETs and IGBTs- basic device physics- principle of operation-construction, types, static and switching characteristics.

MODULE 3 (7 hours)

Wide band-gap devices – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications

Silicon carbide (SiC) power diodes- Advantages- features- properties- comparison with Si power diodes - SiC Shottky diode- advantages

Silicon Carbide BJT – Structure – Operation – Static and Dynamic Characteristics.

Silicon Carbide MOSFET – Planar Power MOSFETs – Trench Gate Power MOSFETs – Structure – static and dynamic characteristics.

MODULE 4 (7 hours)

Silicon Carbide IGBT: n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure - p-Channel asymmetric structure- blocking characteristics- On-state voltage Drop - turn-off characteristics-switching energy - losses- maximum operating frequency

Gallium Nitride devices – Vertical Power Hetero Junction Field Effect Transistor (HFETs) – Lateral Power Hetero Junction Field Effect Transistor (HFETs) - High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics

MODULE 5 (7 hours)

Gate drive and Protection Circuits:

Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design - necessity of isolation- pulse transformer- optocoupler - overvoltage, over current and gate protection- turn-on and turn-off snubber circuit design

Power modules- typical internal structure- design challenges- features- design for reliability enhancement intelligent power modules (IPM)- features- study of typical power modules and IPM

References

1) B. W. Williams, *"Power Electronics- Devices, Drivers, Applications and passive components",* Macmillan, 2nd Ed., 2005
2) B. Jayant Baliga, *"Fundamentals of Power Semiconductor devices",* 2nd Ed., Springer, 2019
3) Francesco Iannuzzo, *"Modern Power Electronic Devices_ Physics, Applications, and Reliability",* Institution of Engineering & Technology (IET),3rd Ed., 2020
4) Mohan, Undeland and Robins, *"Power Electronics- Concepts, Applications and Design*", John Wiley and sons, Singapore, 1st Ed., 2000

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (8 hours)	
1.1	**Power switching devices-** overview- ideal and typical power devices	1
1.2	Unipolar and bipolar power devices - conduction and switching losses- thermal protection- heat sink selection	1
1.3	EMI due to switching- reduction of EMI	1
1.4	**Silicon Power Diodes**- Types, forward and reverse characteristics, switching characteristics -losses- ratings – schottky diodes	1
1.5	**Gate Turnoff Thyristor (GTO)** - Basic structure and operation - comparison with thyristors- switching Characteristics - turn-on and Turn-off transients - gate drive requirements- snubber requirements	2
1.6	**Integrated gate-commutated thyristors (IGCTs)-** device types- operation- turn on and turn off behaviour- applications	2
	Module 2 (7 hours)	
2.1	**Current-Controlled Devices:** BJTs- Constructional features and operation, static characteristics, switching characteristics	2
2.2	Secondary Breakdown in BJT - Safe Operating Area - Darlington Configuration - Comparison with GTO	2
2.3	**Voltage-controlled Devices:** Power MOSFETs and IGBTs- basic device physics- principle of operation	1
2.4	Construction, types, static and switching characteristics	2
	Module 3 (7 hours)	
3.1	**Wide band-gap devices** – Introduction - advantages over silicon devices – properties of wide band-gap devices - power density of wide bandgap devices- comparison- applications	2
3.2	**Silicon carbide (SiC) power diodes-** Advantages- features- properties-comparison with Si power diodes- SiC Shottky diode- advantages	2
3.3	**Silicon Carbide BJT** – Structure – Operation – Static and Dynamic Characteristics	1
3.4	**Silicon Carbide MOSFET** – Planar Power MOSFETs – Trench	2

	Gate Power MOSFETs – Structure – static and dynamic characteristics	
	Module 4 (7 hours)	
4.1	**Silicon Carbide IGBT:** n-Channel Asymmetric Structure - Optimized n-Channel asymmetric structure	2
4.2	P-channel asymmetric structure- blocking characteristics- On- state voltage Drop - turn-off characteristics	1
4.3	Switching energy - losses- maximum operating frequency	1
4.4	**Gallium nitride devices** – Vertical Power Hetero Junction Field Effect Transistor (HFETs) – Lateral Power Hetero Junction Field Effect Transistor (HFETs)	2
4.5	High Electron Mobility Transistors (HEMT) - Static and dynamic characteristics	1
	Module 5 (7 hours)	
5.1	**Gate drive and Protection Circuits:** Gate drive circuits for transistors, MOSFET, IGBT, SiC MOSFET and IGBT and GaN devices– challenges and design	2
5.2	Necessity of isolation- pulse transformer- optocoupler overvoltage, over current and gate protection	1
5.3	turn-on and turn-off snubber circuit design	1
5.4	**Power modules**- typical internal structure- design challenges- features- design for reliability enhancement	2
5.5	Intelligent power modules (IPM)- features- study of typical power modules and IPM	1

Model Question Paper

QP CODE: Pages: 2

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Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E104A

Course Name: Advanced Power Semiconductor Devices

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Discuss the factors to be considered for the selection and power handling capability of power semiconductor devices.
2. Compare current controlled and voltage-controlled devices in terms of gate drive design.
3. What are wide band gap devices and what are its advantages over silicon devices?
4. Explain the differences between Silicon Carbide and Gallium Nitride Transistors in terms of gate drive design.
5. Explain the design of IGBT driver circuit with over current protection.

PART B

Answer any five questions. Each question carries 8 marks.

6. Draw the reverse recovery characteristics of a power diode and explain the terms (i) Reverse recovery time (ii) Peak inverse current and (iii) S-Factor. Also derive the expressions for reverse recovery time and peak inverse current.
7. Explain the EMI phenomenon in power electronic drives and discuss the various methods to reduce it.
8. (a) Explain the switching characteristics of P channel MOSFET. (4 marks)
   (b)Calculate the total power loss for the MOSFET having the following parameters: VDS = 120V, ID = 4A, tr = 80ns, tf = 120ns, IDSS = 2mA, RDS(on) = 0.2Ω, duty cycle D=50%, and fswitching = 45kHZ. (4 marks)
9. Explain the constructional features, characteristics and gate drive requirements of IGCT.
10. Explain the static and switching characteristics of GaN switching devices.
11. Explain the snubber requirements in GTO.
12. Design a gate drive circuit for Silicon carbide MOSFET and describe the design challenges to be considered.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E104B	DYNAMICS OF LINEAR SYSTEMS	Elective	3	0	0	3	3

Preamble: This course includes state space description of continuous time systems, state observers, design of controllers using QFT, Analysis of system sliding mode control and optimal control. This course will equip students to design and analysis of controllers and/or observers for a given system.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Analyse different state space realisations of continuous and discrete time systems and choose appropriate forms for a given application (Cognitive knowledge level: Understand, Analyse)
CO 2	Design and analysis of controllers and/or observers for a given system (Cognitive knowledge level: Apply, Analyse)
CO 3	Design of controllers in the frequency domain / using Quantitative Feedback Theory and Study of controllability and observability for MIMO systems (Cognitive knowledge level: Apply)
CO 4	Design of sliding mode controller for continuous system (Cognitive knowledge level: Apply)
CO 5	Design of optimal controller and observer for a given system and evaluate its performance (Cognitive knowledge level: Apply, Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	3	2	2	1
CO 2	2	1	3	3	2	1
CO 3	2	1	3	3	2	1
CO 4	2	1	3	2	2	1
CO 5	2	1	3	2	2	1

Evaluation Pattern

	DYNAMICS OF LINEAR SYSTEMS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

Review of state space representation of continuous and discrete time systems, Basic Realization Theory: Similarity Transformation, Canonical Realizations, Jordan and real canonical forms, Minimal realization, Connections to Transfer Functions: Characteristic/Minimal Polynomials, matrix exponentials.

MODULE 2 (7 hours)

Observability and state Observers for un-measurable state measurement, Stability and time response, State Controllability, Canonical Realizations Duality, Decomposition of Uncontrollable and Unobservable realizations, Popov test, State Feedback Asymptotic Observers: Full and reduced order, Separation Principle and Pole Placement Theorem.

MODULE 3 (7 hours)

Direct transfer function design procedures – Design using polynomial equations - Direct analysis of the Diophantine equation. MIMO systems: Introduction, controllability, observability, different companion forms for MIMO.
Introduction to Quantitative feedback theory (QFT) and design of controllers using QFT.

MODULE 4 **(8 hours)**

Introduction to variable structure systems, definition of variable structure and sliding mode, examples of dynamics system with sliding modes, differential equations with discontinuous right-hand sides, Concept of a manifold, sliding surface, sliding mode motion and sliding mode control

MODULE 5 (7 hours)

Optimal control - formulation of optimal control problem - Minimum time control problem - minimum energy problem - minimum fuel problem - state regulator problem - output regulator problem – tracking problem - choice of performance measure - optimal control based on quadratic performance measure – optimal control system design using second method Lyapunov - solution of reduced Riccatti equation.

References

1. Thomas Kailath, "*Linear System*", Prentice Hall Inc., Eaglewood Cliffs, NJ, 2nd Ed., 1998
2. M. Gopal,"*Control Systems-Principles and Design*", Tata McGraw-Hill, 5th Ed., 2006
3. Richard C. Dorf & Robert H. Bishop, *"Modern Control Systems*", Pearson Education, Limited, 12th Ed., 2013
4. Gene K. Franklin & J. David Powell, "*Feedback Control of Dynamic Systems*", Pearson Education, 5th Ed., 2008
5. Friedland B., "*Control System Design: An Introduction to State Space Methods*", Courier Corporation, 2nd Ed., 2005
6. C.T. Chen, "*Linear System theory and design*", Holt, Rinehart and Winston, New York, 1st Ed.,1984.
7. Isaac M. Horowitz, *Quantitative feedback Design theory*, QFT publications, 1992
8. Hebertt Sira-Ramirez, *Sliding Mode Control: The Delta-Sigma Modulation Approach (Control Engineering)* , Springer Nature, 2nd Ed., (9 June 2015)
9. Panos J. Antsalis, Anthony N Michel," A linear Systems Primer" Birkhauser Boston, 1st Ed.,2000.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (7 hrs)	
1.1	state space representation review-Similarity Transformation	1
1.2	Canonical Realizations	1
1.3	Jordan and real canonical forms- Minimal realization	2
1.4	Connections to Transfer Functions- Characteristic/Minimal Polynomials	2
1.5	matrix exponentials	1
	Module 2 (7 hrs)	
2.1	Stability and time response, State Controllability	1
2.2	Canonical Realizations Duality	1
2.3	Decomposition of Uncontrollable and Unobservable realizations	2
2.4	Popov test	1
2.5	State Feedback Asymptotic Observers: Full and reduced order	1
2.6	Separation Principle and Pole Placement Theorem	1
	Module 3 (7 hrs)	
3.1	Design using polynomial equations	1
3.2	Direct analysis of the Diophantine equation.	1
3.3	MIMO systems: Introduction- controllability	1
3.4	Observability- different companion forms for MIMO	1
3.5	Introduction to Quantitative feedback theory	1
3.6	design of controllers using QFT	2
	Module 4 (8 hrs)	
4.1	definition of variable structure and sliding mode, examples of dynamics system with sliding modes	3
4.2	differential equations with discontinuous right-hand sides	2
4.3	Concept of a manifold, sliding surface, sliding mode motion and sliding mode control	3
	Module 5 (7 hrs)	

5.1	formulation of optimal control problem - Minimum time control problem -minimum energy problem	2
5.2	state regulator problem - output regulator problem – tracking problem	2
5.3	choice of performance measure - optimal control based on quadratic performance measure	1
5.4	optimal control system design using second method Lyapunov - solution of reduced Riccatti equation	2

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E104B

Course Name: Dynamics of Linear Systems

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Consider the system function given below G(s) = $(s+5)/(s+2)(s2+3s+4)$. Obtain state models by direct and cascade decompositions.
2. What do you mean by the duality principle related to controllability and observability? Analyse duality principle with an example.
3. Explain the pole placement problem of MIMO systems.
4. Explain the reaching laws associated with conventional sliding mode control.
5. Explain time optimal control of continuous time systems with unbounded control input.

PART B

Answer any five questions. Each question carries 8 marks.

6. How will you obtain the solution of a state equation? Obtain the solution, of the state equation given by,

$$\dot{x} = [0\ 1 - 2 - 3\ ]\dot{x} + [2\ 5\ ]u$$

$$y = [1\ 2]\ \dot{x}$$

7. A regulator system has the plant

$$\dot{X} = \begin{bmatrix} 0 & 20.6 \\ 1 & 0 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

The closed loop poles are to be placed at $s = -2 \pm j2\sqrt{3}$. Design a controller and observer so that observer error poles are placed at $s = -1.8 \pm j2.4s = -1.8 \pm j2.4$. Draw the complete state block diagram.

8. Design a state observer to the given system such that the observer eigen values are at μ = $-2 \pm j2\sqrt{3}$, μ = -5. The system is given as

$$\dot{x} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -6 & -11 & -6 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} x$$

9. Explain the steps involved in deriving the controllable companion form of MIMO systems.
10. Explain any one method of designing a sliding surface for SMC.
11. Design a stabilising variable structure control for a double integrator system
12. Determine the optimal control function u for the system described by

$$\dot{x} = Ax + Bu$$

Where,

$$x = [x_1\ x_2],\ A = [0\ 1\ 0\ -1],\ B = [0\ 1]$$

Such that the following performance equation is minimised:

$$J = \int_0^\infty (x'x + u'u)dt$$

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E104C	SOFT COMPUTING TECHNIQUES FOR PE APPLICATIONS	Elective	3	0	0	3	3

Preamble: This course provides the fundamentals of soft computing techniques for Power Electronic Applications. It covers Fuzzy logic systems, Artificial Neural Networks, Genetic Algorithm and Hybrid systems. This course will equip the students with the soft computing techniques necessary for engineering systems for various applications.

Prerequisite: B. Tech level Power Electronics.

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Analyze power electronics systems with fuzzy logic controller. (Cognitive Knowledge Level : Analyze)
CO 2	Demonstrate methods of Artificial Neural Networks for the application of Power Electronic converters. (Cognitive Knowledge Level : Apply)
CO 3	Analyze Back propagation neural networks for the application of Power Electronic converters. (Cognitive Knowledge Level : Analyze)
CO 4	Differentiate GA architectures and describe GA operators and multi objective GA for the application of Power Electronic converters. (Cognitive Knowledge Level : Analyze)
CO 5	Apply hybrid techniques as per the required environment for the application of Power Electronic converters. (Cognitive Knowledge Level : Apply)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	3	2	1	2
CO 2	2	1	3	2	1	2
CO 3	2	1	3	2	1	2
CO 4	2	1	3	2	1	2
CO 5	2	1	3	2	1	2

Evaluation Pattern

	SOFT COMPUTING TECHNIQUES FOR PE APPLICATIONS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	-	-	-
Apply	40	40	40
Analyse	60	60	60
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* :10 marks

Course based task/ Micro project /
Data collection and interpretation/ Case study :10 marks

Test paper 1 (Module 1 and Module 2) :10 marks

Test paper 2 (Module 3 and Module 4) :10 marks

*Seminar shall be conducted in additional hours with topics in recent technologies.

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 8 marks. Total duration of the examination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)
Fuzzy Systems: Introduction to Fuzzy Logic (FL), Classical Sets and Fuzzy Sets - Classical Relations and Fuzzy Relations -Membership Functions -Defuzzification -Mamdani and Sugeno type- Fuzzy Rule Base and Approximate Reasoning - Introduction to Fuzzy Decision Making, Special forms of fuzzy logic models – Fuzzy logic controllers for Engineering applications - Case studies related to power electronic applications.

MODULE 2 (7 hours)
Artificial Neural Networks (ANN): Biological neurons and its working. ANN models - Types of activation function - Introduction to Network architectures - Multi Layer Feed Forward Network (MLFFN) - Radial Basis Function Network (RBFN) - Recurrent Neural Network (RNN)- Case studies related to power electronic applications.

MODULE 3 (8 hours)

Other Types of ANN: Back propagation Neural Networks - Kohonen Neural Network -Learning Vector Quantization -Hamming Neural Network – Hopfield Neural Network- Bi- directional Associative Memory -Adaptive Resonance Theory Neural Networks- Case studies related to power electronic applications.

MODULE 4 **(7 hours)**

Genetic Algorithm: Concept of "Genetics" and "Evolution", Basic GA framework and different GA architectures, GA operators: Encoding, Crossover, Selection, Mutation. Solving single objective optimization problems using GAs, Multi objective GA - Case studies related to power electronic applications.

MODULE 5 (7 hours)

Hybrid Systems: Adaptive Neuro fuzzy Inference System (ANFIS), Neuro –Genetic, Fuzzy Genetic systems. Coactive Neuro-Fuzzy Modelling: Towards Generalized ANFIS. GA Based Weight Determination - LR-Type Fuzzy Numbers - Fuzzy Neuron - Fuzzy BP Architecture - Case studies related to power electronic applications.

References

1. S. Rajasekaran and G. A. Vijayalakshmi Pai, *"Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications"*, PHI Learning Pvt. Ltd., 2nd Ed.,2017
2. Teresa Orlowska and Blaabjerg and Rodriguez, *"Advanced and Intelligent Control in Power Electronics and Drives*", Springer,1st Ed.,2014
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4. S. N. Sivanandam and S. N. Deepa, *"Principles of Soft Computing"*, Wiley India, 2nd Ed., 2008
5. Marcian Cirstea, Andrei Dinu, Malcolm McCormick and Jeen Ghee Khor, *"Neural and Fuzzy Logic Control of Drives and Power Systems"*, Newness, 1 st Ed., 2002
6. Melanie Mitchell, *"An Introduction to Genetic Algorithm"*, PHI, 4th Ed., 2002
7. George J. Klir, Ute St. Clair and Bo Yuan, *"Fuzzy Set Theory: Foundations and Applications"* Prentice Hall, 1st Ed., 1997.
8. J. M. Zurada, *"Introduction to Artificial Neural Systems"*, Jaico Publishers, 3rd Ed., 2004.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (7 hrs)	
1.1	Introduction to Fuzzy Logic (FL), Classical Sets and Fuzzy Sets.	1
1.2	Classical Relations and Fuzzy Relations, Membership Functions	1
1.3	Defuzzification	1
1.4	Mamdani and Sugeno type	1
1.5	Fuzzy Rule Base and Approximate Reasoning	1

1.6	Introduction to Fuzzy Decision Making, Special forms of fuzzy logic models.	1
1.7	Fuzzy logic controllers for Engineering applications, Case studies.	1
	Module 2 (7 hrs)	
2.1	Artificial Neural Networks (ANN): Biological neurons and its working. ANN models	2
2.2	Types of activation function - Introduction to Network architectures -	1
2.3	Multi Layer Feed Forward Network (MLFFN).	1
2.4	Radial Basis Function Network (RBFN).	1
2.5	Recurrent Neural Network (RNN)- Case studies related to power electronic applications.	2
	Module 3 (8 hrs)	
3.1	Back propagation Neural Networks.	1
3.2	Kohonen Neural Network.	1
3.3	Learning Vector Quantization -Hamming Neural Network.	2
3.4	Hopfield Neural Network.	1
3.5	Bi- directional Associative Memory.	1
3.6	Adaptive Resonance Theory Neural Networks	1
3.7	Case studies related to power electronic applications.	1
	Module 4 (7 hrs)	
4.1	Genetic Algorithm: Concept of "Genetics" and "Evolution".	1
4.2	Basic GA framework and different GA architectures.	1
4.3	GA operators: Encoding, Crossover, Selection, Mutation.	2
4.4	Solving single objective optimization problems using GA.	1
4.5	Multi objective GA	1
4.6	Case studies related to power electronic applications.	1
	Module 5 (7 hrs)	
5.1	Hybrid Systems: Adaptive Neuro fuzzy Inference System (ANFIS).	1
5.2	Neuro –Genetic, Fuzzy Genetic systems.	1
5.3	Coactive Neuro-Fuzzy Modelling.	1
5.4	Towards Generalized ANFIS- GA Based Weight Determination	1
5.5	LR-Type Fuzzy Numbers.	1
5.6	Fuzzy Neuron - Fuzzy BP Architecture	1
5.7	Case studies related to power electronic applications.	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, APRIL 2025

***Course Code:* M24EE1E104C**

Course Name: Soft Computing Techniques for PE Applications

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Draw and explain the important features of a membership function.
2. Describe the Mc Culloch model of a neuron with a neat diagram.
3. Derive the weight updation equation of a Kohonen's net.
4. Derive the three cases of binary crossover with an example.
5. Describe the features of the neuro genetic hybrid system with a block diagram.

PART B

Answer any five questions. Each question carries 8 marks.

6. Design a fuzzy controlled washing machine with one input.
7. Consider the fuzzy sets
   A = {0.3/1 + 0.6/2 + 0.2/3 + 0.5/4}
   B = {0.2/1 + 0.5/2 + 0.7/3 + 0.9/4}
   Prove De Morgan's theorem.
8. Describe the Back propagation network configuration, write the weight updation equations and explain the training process in detail.
9. Evaluate the role of the following genetic operators in finding solution for optimization problems. a) Selection b) crossover c) encoding and d) Mutation
10. Draw the ANFIS architecture of Mamdani's model and describe the features.
11. Describe how Bidirectional associative memory is implemented using recurrent neural network.
12. Compute the weight matrix for Hopfield net for the following fundamental memories. Also compute the energy states for these fundamental memories.
    $\xi 1 = [1\ -1\ -1\ 1\ -1]$, $\xi 2 = [-1\ 1\ 1\ -1\ 1]$, $\xi 3 = [1\ 1\ -1\ 1\ -1]$, $\xi 4 = [-1\ -1\ 1\ -1\ 1]$

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E104D	CLASSICAL AND SPECIAL ELECTRICAL MACHINE DRIVES	Elective	3	0	0	3	3

Preamble: Electrical Machine drive is an important component in highly efficient versatile systems and products in industries, domestic appliances and e-mobility applications. The course intends to provide a strong background on various methods of speed control schemes in classical and commonly used special electrical machines. After successful completion of this course, the students will be able to apply different speed control schemes for the control of DC motors, Induction motors, Synchronous motors, Stepper motors, Switched reluctance Motors & BLDC motors. They will also be able to select suitable power electronic converters and motors for specific speed control applications.

Prerequisite : Basic courses on Electrical machines and Power Electronics

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop speed control schemes for different types of Electrical Machines after understanding pertinent limitations of simple drive schemes. (Cognitive knowledge level: Understand)
CO 2	Analyse different speed control schemes. (Cognitive knowledge level: Apply, Analyse)
CO 3	Select suitable power converters. (Cognitive knowledge level: Apply, Evaluate)
CO 4	Compare the performance of different speed control schemes and power converters. (Cognitive knowledge level: Apply, Evaluate)
CO 5	Design suitable drive schemes. (Cognitive knowledge level: Apply)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	2	1	3	1
CO 2	2	1	2	1	3	1
CO 3	2	1	2	1	3	1
CO 4	2	1	2	1	3	1
CO 5	2	1	2	1	3	1

Evaluation Pattern

	CLASSICAL AND SPECIAL ELECTRICAL MACHINE DRIVES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

Electric Drives –Introduction- DC motor drives – single phase half and fully controlled rectifier fed separately excited DC (SEDC) motor – discontinuous and continuous modes – regenerative braking-three-phase fully controlled drives- continuous conduction- Dual converter fed drive– rectifier control of series motor – Chopper control of SEDC motor–multiquadrant operation- closed loop speed control.

MODULE 2 (8 hours)

Three Phase Induction motor drives- Torque Equation- Equivalent circuit- V/F control - Slip speed controlled VSI and CSI drive – analysis of induction motor fed from non-sinusoidal voltage supply-Static rotor resistance control - Slip power recovery schemes for below and above base speed – Synchronous motor drives - True synchronous mode and self-synchronous mode- load commutated drive.

MODULE 3 (7 hours)

Stepper Motor and Drives- Variable reluctance, permanent magnet and hybrid motors- Principle of operation - torque production - Static position error- pull-in and pull-out characteristics- resonance issues- Unipolar and Bipolar drive schemes- Bifilar drives- open loop position control- Starting/stopping rate- Velocity profiling.

MODULE 4 (6 hours)

Switched Reluctance Motors (SRM) and Drives- Principle of operation, Inductance profile -Torque equation- motoring and regeneration- low speed and high-speed operation- torque- speed characteristics- Energy conversion loop- Energy effectiveness- Power controllers, control schemes- Six switch converter- Split dc supply converter-R dump- C dump converters.

MODULE 5 (8 hours)

Brushless DC Motors (BLDC) and drives- Permanent magnet materials and characteristics - principle- Speed-Torque characteristics- Torque Pulsation - Power controllers- Full wave and Half wave- Regeneration- Hall Sensor based control - Sensor less control- third harmonic voltage detection – starting- Permanent Magnet Synchronous Motors (PMSM) and drives - Principle - SPM and IPM machines-Torque equation - Phasor Diagram - Power controllers.

References

1. G. K Dubey, “Power Semiconductor Controlled Drives”, Prentice Hall, 2nd Ed., 2000
2. G. K Dubey, “Fundamentals of Electrical Drives”, Narosa Publishers , 2nd Ed., 2002
3. Bimal K Bose, “Modern Power Electronics & AC Drives”, Prentice Hall of India
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6. Paul Acarnley, “Stepping motors - a guide to theory and practice”, 4th Edn. IET UK, 2002
7. Miller T J E, “Switched Reluctance Motor and their Control”, Clarendon Press, Oxford, 2nd Ed., 2008
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COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(7 hours)	
1.1	Introduction to Electric Drives- Drive components- Efficiency Improvements compared to fixed speed drives	1

1.2	DC motor drives – single phase fully controlled rectifier fed separately excited DC (SEDC) motor - Discontinuous and continuous modes - Analysis	1
1.3	DC motor drives – single phase half-controlled rectifier fed separately excited DC (SEDC) motor - continuous conduction - power factor improvements- Analysis	1
1.4	Regenerative braking of controlled rectifier fed separately excited DC (SEDC) motor- commutation issues	1
1.5	Three-phase fully controlled drives- continuous conduction	1
1.6	Dual converter fed drive- four quadrant operation- dc and ac circulating currents	1
1.7	Rectifier control of series motor, Chopper control of SEDC motor–multiquadrant operation- closed loop speed control	1
	Module 2(8 hours)	
2.1	Three Phase squirrel cage Induction motor drives- Introduction- basic equations and equivalent circuit	1
2.2	V/F control - open loop and closed loop	1
2.3	Slip speed controlled VSI and CSI drive	1
2.4	Slip speed controlled VSI and CSI drive	1
2.5	harmonic equivalent circuit- analysis of induction motor fed from non- sinusoidal voltage supply	1
2.6	Three Phase squirrel wound rotor Induction motor drives-Introduction- Static rotor resistance control	1
2.7	Slip power recovery schemes for below and above base speed , Synchronous motor drives - Introduction- Basic equations- True synchronous mode and self-synchronous mode	1
2.8	Load commutated synchronous motor drive	1
	Module 3(7 hours)	
3.1	Stepper Motor and Drives- Variable reluctance, permanent magnet and hybrid motors- Introduction	1
3.2	Principle of operation- torque production	1

3.3	Static position error,	1
3.4	Pull-in and pull-out characteristics- resonance issues	1
3.5	Bifilar, Unipolar and Bipolar drive schemes	1
3.6	Open loop position control- Starting/stopping rate	1
3.7	Velocity profiling	1
	Module 4(6 hours)	
4.1	Switched Reluctance Motors (SRM) and Drives- Principle of operation	1
4.2	Inductance profile - Torque equation	1
4.3	Motoring and regeneration- low speed and high-speed operation- torque vs speed characteristics	1
4.4	Energy conversion loop- Energy effectiveness	1
4.5	Power controllers, control schemes- Six switch converter	1
4.6	Split dc supply converter-R dump- C dump converters	1
	Module 5(8 hours)	
5.1	Permanent magnet materials and characteristics	1
5.2	Brushless DC Motors (BLDC) and drives- Introduction- Principle of operation- modelling	1
5.3	Speed-Torque characteristics- Torque Pulsation	1
5.4	Power controllers- Full wave and Half wave- Regeneration	1
5.5	Hall Sensor based control	1
5.6	Sensorless control- third harmonic voltage detection –Starting	1
5.7	Permanent Magnet Synchronous Motors (PMSM) and drives - Principle - SPM and IPM machines	1
5.8	Torque equation - Phasor Diagram - Power controllers	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E104D

Course Name: Classical and Special Electrical Machine Drives

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. With necessary circuit diagrams, explain how a non- circulating type dual converter fed separately excited DC drive can outperform a circulating current dual converter. Compare the demerits also.
2. Compare V/F control scheme of IM with slip speed control scheme.
3. A three phase, 2 NM, 0.0005Kgm2, VR stepping motor has 16 stator teeth and 20 rotor teeth and is used to drive a frictional load of 0.2 Nm (a) Draw the approximate holding torque curve and mark the no load equilibrium points (b) What is the static position error at load? (c) What is the stepping rate corresponding to a speed of 30 RPM
4. What do you mean by airgap line, recoil line, and magnet stabilization? Explain why the maximum energy product point is not a preferred operating point. Compare NdFeB, SmCo, Alnico and ceramic magnets for use in permanent magnet machines in terms of the above terms
5. Explain the difference between SPM and IPM in terms of machine inductances and extended speed of operation. Also explain the term 'self-control' in connection with PMSM.

PART B

Answer any five questions. Each question carries 8 marks.

6. a. Explain how possibilities of discontinuous conduction are minimized in chopper fed dc drives. Illustrate with a two-quadrant drive. (3 marks)

b. Draw the circuit schematic of (i) a three-phase half controlled separately excited dc motor drive (ii) three phase full controlled drive and compare the performance in terms of torque ripple and supply power factor. (4 marks)

7. a. Prove that the starting current is approximately constant in V/F control. Compare with stator voltage control. (3 marks)

b. A 400V, 60 Hz, 1155 RPM, 6 pole, Y connected, 3 phase wound rotor induction motor has the following parameters referred to the stator:Rs=0.12Ω, Rr�OE =0.1Ω, Xs=0.2Ω, Xr‟ =0.15Ω. The stator to rotor turns ratio is 1.2 and the dc link inductor has a resistance of 0.025Ω. The motor speed is controlled by static scherbius drive designed for a speed range of 25% below the synchronous speed. Maximum permissible value of firing angle is $168A$. Calculate (i) Transformer turns ratio (ii) Torque for a speed of 900 rpm and α=$120A$ (iii) Firing angle for rated motor torque and speed of 800 RPM. (4 marks)

8. a. With necessary sketches, explain the difference between unifilar drive and bifilar stepper motor drivers. (3 marks)

b. A three phase VR stepping motor with 50 rotor teeth is operated in one phase on scheme. The pull in rate of the motor on no load is 500 steps/sec. A light load having negligible inertia is directly coupled to the motor shaft. Using a microcontroller/microprocessor the motor is to be controlled such that the shaft is rotated 180˚ in the forward direction exactly in 50ms and back to the original position in the next 100ms . Draw the drive circuit, give sequences for full step operation and write an algorithm for the operation. (4 marks)

9. a. With necessary sketches and waveforms, explain the difference between R dump and C dump converters for SRM. (3 marks)

b. A three-phase switched reluctance motor with six stator poles and four rotor poles has a stator pole arc of 28° and a rotor pole arc of 32°. The aligned inductance is 10 mH and the unaligned inductance is 5 mH. Neglect fringing and saturation (a) Draw the cross section of the motor at the aligned and unaligned positions (b) Draw the phase inductance vs. rotor position for all the phases (c) Assuming ideal current waveforms with peak phase current of 2A, plot the instantaneous torque developed vs. rotor position for motoring operation and breaking operation for all the phases. (4 marks)

10. a. Explain how third harmonic voltages can be used for sensorless control of BLDC motor (3 marks)

b. A brushless PM sine-wave motor has an open-circuit voltage of 173 V at its corner-point speed of 3000 r.p.m. It is supplied from a p.w.m. converter whose maximum voltage is 200 V r.m.s. Neglecting resistance and all other losses, estimate the maximum speed at which maximum current can be supplied to the motor. (4 marks)

11. a. Model a BLDC motor in state space and show how simulations can be done in SIMULINK. (3 marks)

    b. Derive the torque-speed characteristics of a BLDC motor and compare with that of a dc shunt motor. If a PM brushless d.c. motor has a torque constant of 0.12 N m/A (i) Estimate its no-load speed in rpm when connected to a 48 V d.c. supply. (ii) If the armature resistance is 0.15 Ω/phase and the total voltage drop in the controller transistors is 2 V, determine the stall current and the stall torque. (4 marks)

12. a. A 100V, 1000 RPM, 50A separately excited dc motor has an armature resistance of 0.2Ω. It is fed from a chopper with a source voltage of 120V. Assuming continuous conduction, draw the circuit topology and calculate the duty ratio for (i) motoring and (ii) braking operation at rated torque and 600 rpm. (3 marks)

    b. Discuss the harmonic equivalent circuit of a three phase Induction motor and compare the effect of harmonics due to (i) square wave operation and (ii) sine triangle PWM. (4 marks)

PROGRAM ELECTIVE 2

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E105A	COMPUTER APPLICATIONS IN POWER SYSTEMS	Elective	3	0	0	3	3

Preamble: This course introduces the strategies and methods related to Integration of computer applications in load flow and short circuit studies in power system. This course will equip students to apply computational techniques to analyse and solve load flow studies. Also, to analyse the solution methods and techniques involved in short circuit studies.

**Prerequisite : **Basic course in power systems

Course Outcomes: After the completion of the course the student will be able to

CO 1	Apply the concepts of sparse matrix in computer applications for large scale power system analysis. (Cognitive knowledge level: Apply)
CO 2	Apply computational techniques to analyse and solve load flow studies. (Cognitive knowledge level: Apply)
CO 3	Describe the effects of FACTs devices in load flow studies. (Cognitive knowledge level: Understand)
CO 4	Evaluate optimal power flow problem using various solution methods. (Cognitive knowledge level: Evaluate)
CO 5	Analyse the solution methods and techniques involved in short circuit studies. (Cognitive knowledge level: Analyse)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	3	3	3	-
CO 2	3	-	3	3	3	-
CO 3	2	-	1	1	1	-
CO 4	2	-	2	2	1	1
CO 5	3	-	3	3	3	-

Evaluation Pattern

	COMPUTER APPLICATIONS IN POWER SYSTEMS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	40
Evaluate	10	10	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

Sparsity and Sparse Matrix techniques for large scale power systems- Optimal Ordering, Gaussian Elimination and Triangular factorization- LU Decomposition method, Node Elimination (Kron Reduction Technique).

MODULE 2 (7 hours)

Load Flow Studies: Newton - Raphson Method- Decoupled Newton Load Flow. Fast Decoupled Load Flow- AC DC load flow- simultaneous and sequential method - 3-Φ AC-DC Load flow concept, Problem formulation.

MODULE 3 (7 hours)

FACTS devices in Load Flow - Power Flow Equation of FACTS devices -operating constraint-Implementation in Power Flow: Static Tap Changing, Phase Shifting (PS), Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC), Unified Power Flow Controller (UPFC).

MODULE 4 (**8 hours)**

Optimal load flow in power Systems-constrained and unconstrained OPF -problem formulation-solution by Gradient method- Newtons method, Particle Swarm Optimization for OPF, Security and Environmental Constrained OPF (overview).

MODULE 5 (7 hours)

Z bus formulation with and without mutual coupling, Short circuit study of a large power system using Z-bus matrix. Unsymmetrical fault analysis using Z-bus- SLG Fault-LL Fault- DLG Fault.

References

1. Singh L P, "*Advanced Power Systems Analysis and Dynamics*", New Age Intl. Publishers, 1983.
2. Arrillaga J and Watson NR, "*Computer Modelling of Electric Power Systems",* John Wiley and sons,2001
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12. Das J. C," *Load Flow Optimization and Optimal Power Flow*": 2 (Power Systems Handbook), CRC Press, 2017
13. K.R.Padiyar," *FACTS Controllers in Power Transmission and Distribution*", New Age International(P) Ltd., Publishers New Delhi, Reprint 2007

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (7 hours)	
1.1	Sparse matrix, Sparse Matrix techniques for large scale power systems, advantages and disadvantages of sparse matrix in power systems	1
1.2	Optimal Ordering	1
1.3	Gaussian Elimination	1
1.4	Triangular factorization- LU Decomposition method	2
1.5	Node Elimination Method (Kron Reduction Technique)	2
	Module 2 (7 hours)	
2.1	Newton - Raphson Method of Load Flow	2
2.2	Decoupled Newton Load Flow, Fast Decoupled Load Flow	2
2.3	AC/DC load flow- simultaneous and sequential method	2
2.4	3-Φ Three phase Load Flow	1
	Module 3 (7 hours)	
3.1	Incorporation of FACTS devices in Load Flow: Static Tap Changing, Phase Shifting (PS)	1
3.2	Static Var Compensator (SVC)- Power Flow Equation of SVC, Implementation of SVC in Power Flow	2
3.3	Thyristor Controlled Series Compensator (TCSC). Power Flow Equation and implementation in Power Flow	2
3.4	Unified Power Flow Controller (UPFC), Power Flow Equation and implementation in Power Flow	2
	Module 4 (8 hours)	
4.1	Optimal load flow in power Systems- constrained and unconstrained OPF	1
4.2	Objective Function, Problem formulation	2
4.3	solution by Gradient method- Newtons method	2
4.4	Particle Swarm Optimization for OPF	2
4.5	Security and Environmental Constrained OPF	1
	Module 5 (7 hours)	
5.1	Z bus formulation with and without mutual coupling	2
5.2	Short circuit study of a large power system using Z-bus matrix	2
5.3	Unsymmetrical fault analysis using Z-bus- SLG Fault-LL Fault- DLG Fault	3

Model Question Paper

QP CODE: Pages: 3

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E105A

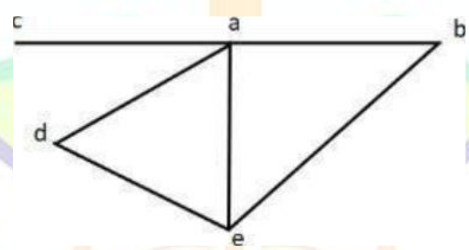
Course Name: Computer Applications in Power Systems

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Order the nodes of the given graph in an optimal manner, indicating the necessary steps.



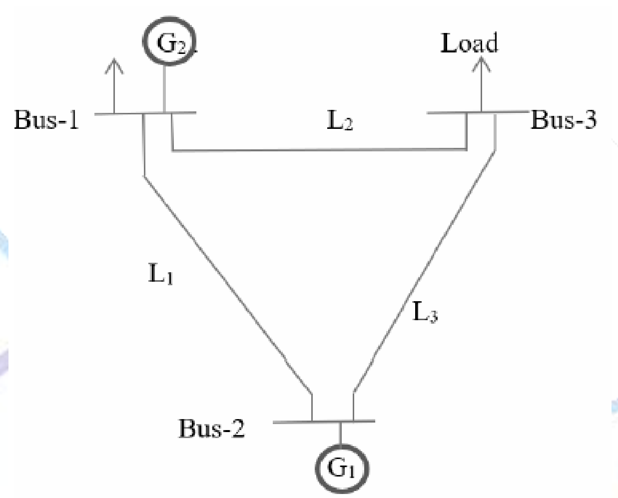
2. Compare Newton Raphson and Fast Decoupled Load flow algorithm.
3. Explain the operation of TCSC in a power system.
4. Explain the salient features of Environmental Constrained OPF.
5. Build the Z bus for a three-phase short circuit fault in a power system.

PART B

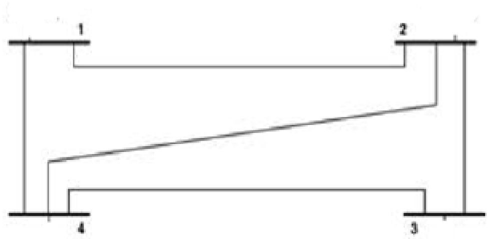
Answer any five questions. Each question carries 8 marks.

6. For the network shown, draw the oriented graph and find the following.
   a) Element-node incidence matrix
   b) Bus incidence matrix
   c) Basic cutset incidence matrix

d) Basic loop incidence matrix



7. Obtain the load flow solution at the end of the first iteration of the power system shown in the figure. The data is provided in the Table. The solution is to be obtained for the following cases .
   a) All buses except one are PV buses.
   b) Bus 2 is a PV bus where voltage magnitude is specified as 1.04

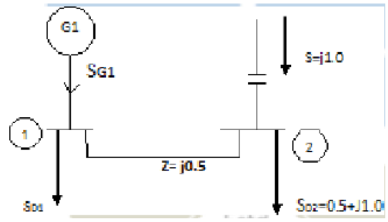


SB	EB	R(pu)	X(pu)
1	2	0.05	0.15
1	3	0.1	0.30
2	3	0.15	0.45
2	4	0.10	0.3
3	4	0.05	0.15

Bus No	P_i(pu)	Q_i(pu)	V_i
1			$1.04\angle 0$
2	0.5	-0.2	
3	-1.0	0.5	
4	-0.3	-0.1	

8. Explain three advantages of incorporating FACTS devices in a power system. Support with an example.

9. Obtain the voltage at Bus-2 for the power system shown in the figure. Use the Gradient method, if V1 =1+ j0.0 (3 iterations).



10. How is Particle Swarm Optimization useful while arriving at an optimal Power Flow?

11. The positive, negative and zero sequence bus impedance matrices of a power system are shown below. A double line to ground fault with Zf=0, occurs at Bus 4. Find the fault current and voltages at faulted buses.

$$Z_{bus}^{(1)} = Z_{bus}^{(2)} = j\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array}\begin{array}{c} \begin{array}{cccc} \quad 1 \quad & \quad 2 \quad & \quad 3 \quad & \quad 4 \quad \end{array} \\ \begin{bmatrix} 0.1437 & 0.1211 & 0.0789 & 0.0563 \\ 0.1211 & 0.1696 & 0.1104 & 0.0789 \\ 0.0789 & 0.1104 & 0.1696 & 0.1211 \\ 0.0563 & 0.0789 & 0.1211 & 0.1437 \end{bmatrix} \end{array}$$

$$Z_{bus}^{(0)} = j\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array}\begin{array}{c} \begin{array}{cccc} \quad 1 \quad & \quad 2 \quad & \quad 3 \quad & \quad 4 \quad \end{array} \\ \begin{bmatrix} 0.19 & 0 & 0 & 0 \\ 0 & 0.08 & 0.08 & 0 \\ 0 & 0.08 & 0.58 & 0 \\ 0 & 0 & 0 & 0.19 \end{bmatrix} \end{array}$$

12. A 20MVA, 13.8 kV generator has a direct axis sub transient reactance of 0.25pu. Its negative sequence reactance is 0.35 pu and the zero-sequence reactance is 0.1pu. The neutral of the generator is grounded. Find the single line fault current, line to ground voltage.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E105B	EMBEDDED CONTROLLERS FOR POWER CONVERTERS	Elective	3	0	0	3	3

Preamble : The course provides a solid foundation for the PIC18F4580 controller and it is used to develop embedded systems for various power converter circuits. Additionally, the course gives an overview of advanced DSP controllers and FPGA-based systems. After the completion of the course, students will be to design a controller to perform a specific set of tasks for real time applications.

Prerequisite: Basic knowledge about Power Electronics, 8051 and PIC16F87XA Micro controller

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the fundamentals of PIC18 Microcontroller (Cognitive Knowledge Level : Understand)
CO 2	Design and develop embedded systems using PIC18F4580 controller (Cognitive Knowledge Level : Apply)
CO 3	Design and develop various power converter circuits using embedded system (Cognitive Knowledge Level : Apply)
CO 4	Design and evaluate various methods of control schemes for power converters (Cognitive Knowledge Level : Analyze)
CO 5	Develop and implement the solutions for power converters using any high performance C28X microcontrollers and FPGA based system (Cognitive Knowledge Level : Analyze)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	1	2	3	2
CO 2	3	1	1	2	3	2
CO 3	3	1	1	2	3	2
CO 4	3	1	1	2	2	2
CO 5	3	1	1	2	3	2

Evaluation Pattern

	EMBEDDED CONTROLLERS FOR POWER CONVERTERS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project/Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (9 hours)

Microchip PIC 18F4580: Architecture of PIC18F4580 microcontroller, PIC memory organization, Interrupt structure, Timers Counters, Capture, compare and PWM modules, Master Synchronous Serial Port (MSSP) module, A/D Converter module, Comparator module.

MODULE 2 (6hours)

Typical functions and Assembly/C-language programming of PIC18F4580 microcontrollers: Measurement of voltage, current, power and power factor of RL load, speed, frequency measurement, ADC programming with polling and interrupt- PWM generation- Interfacing of LCD Display- familiarization of programming tools.

MODULE 3 (6 hours)

Application and programming of PIC18F4580 microcontroller in power converters: Zero Crossing Detectors- generation of gating signals for single and three phase-controlled rectifiers- Enhanced PWM- Half bridge and Full Bridge- Dead time generation- PWM generation for single phase square wave and sine wave inverters.

MODULE 4 (6 hours)

PIC18F4580 based system control: Implementation of PI, PID controller- power factor correction using capacitor switching and boost front end converter- solar MPPT- P&O and incremental conductance - V/F control of single-phase induction motor- Interfacing of DAC converter- Miscellaneous examples.

MODULE 5 (9 hours)

Introduction to high performance Microcontroller and FPGA based system design: C2000 microcontrollers- overview of architecture and peripherals of any selected C28X FPU microcontroller such as F28069/280049/28335/28379- GPIO, SCI, ADC, PWM and Encoder- Programming with C/Simulink embedded coder FPGA Based System Design- Introduction- VHDL programming- test bench- design of basic combinational, sequential and finite state machines- realization using any FPGA board (altera/xilinx/altium/efinix etc.) Case studies of power electronic converter control using any C28x microcontroller and/ FPGA board.

Reference Books

1. Muhammad Ali Mazidi, Rolind D. Mckinlay, Danny Causey., *PIC microcontroller and Embedded Systems – using assembly and C for PIC18.* Pearson, 1st Ed., 2013.
2. Mattia Rossi, Nicola Toscani, Marco Mauri, Francesco Castelli Dezza, *Introduction to Microcontroller Programming for Power Electronics Control Applications_ Coding with MATLAB and Simulink*. CRC Press, 1st Ed., 2022.
3. Volnei A Pedroni, *Circuit Design with VHDL.* MIT Press Cambridge, 1st Ed., 2004.
4. Daniel W Hart, *Power Electronics*. McGraw Hill, 3rd Ed.,2010
5. Richard H. Barnett, Larry O'Cull, Sarah Alison Cox, *Embedded C Programming and the Microchip PIC, Volume 1.* Thomson Delmar Learning, 1st Ed., 2005
6. Kenjo.T, *Power electronics for microprocessor Age*. Clarendon press, Oxford, 1st Ed., 1999
7. GourabSen Gupta, Subhas Chandra Mukhopadhyay, *Embedded Microcontroller Interfacing, Designing Integrated Projects.* Springer, 1st Ed., 2010.
8. Bekkay Hajji, Adel Melli, Loubna Bouselham, *Practical Guide For Simulation and FPGA Implementation of Digital Design.* Springer, 1st Ed., 2022.
9. Jayaram Bhasker, *A VHDL Primer*. PTR Prentice Hall, AT&T, 3rd Ed., 2009

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module1 (9hrs)	
1.1	Architecture of PIC18F4580 microcontroller, memory organization	2
1.2	Timer & counter programming	2
1.3	Capture, compare and PWM modules	2
1.4	A/D Converter module	1
1.5	Master Synchronous Serial Port (MSSP) module	1
1.6	Interrupt structure, Comparator module	1
	Module 2(6hrs)	
2.1	Measurement of voltage, current, power	2
2.2	Measurement of Power factor of RL load	1
2.3	Measurement of speed, frequency	1
2.4	ADC programming with polling and interrupt, PWM generation	1
2.5	Interfacing of LCD Display	1
	Module 3(6hrs)	
3.1	Zero Crossing Detectors- generation of gating signals for single and three phase-controlled rectifiers	2
3.2	Enhanced PWM- Half bridge and Full Bridge- Dead time generation	2
3.3	PWM generation for single phase square wave and sine wave inverters	2
	Module 4(6hrs)	
4.1	Implementation of PI, PID controller	1
4.2	Power factor correction using capacitor switching and boost front end converter	1
4.3	Solar MPPT- P&O and incremental conductance	2
4.4	V/F control of single-phase induction motor- Interfacing of DAC converter	2
	Module 5(9hrs)	
5.1	C2000 microcontrollers- overview of architecture and peripherals of any selected C28X FPU microcontroller such as F28069/280049/28335/28379	1
5.2	GPIO, SCI, ADC, PWM and Encoder	2
5.3	Programming with C/Simulink embedded coder	1
5.4	FPGA Based System Design- Introduction- VHDL programming	2
5.5	Test bench- design of basic combinational, sequential and finite state machines. Realization using any FPGA board (altera/xilinx/altium/efinix etc.)	2
5.6	Case studies of power electronic converter control using any C28x microcontroller and/FPGA board	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E105B

Course Name: Embedded Controllers for Power Converters

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Write a program to get the x value from port A and send (x2+2x+3) to port B. Assume that RA0-RA7 has the x value of 0 – 9.
2. Write an assembly language or C program to measure the frequency of a pulse, XTAL = 20MHz.
3. Control a DC-to-DC converter using PIC18F4580 with switching frequency = 8 kHz, duty cycle = 55%. Use port C as output port and XTAL = 16MHz.
4. Write a program to implement the PI controller using PIC 18F.
5. Describe the PWM module of C28X microcontroller.

PART B

Answer any five questions. Each question carries 8 marks.

6. Describe the PWM module of PIC 18F and explain how a 10KHz, 25% duty cycle PWM can be generated. The crystal frequency is 20MHz.
7. Design a microcontroller-based voltage measurement system with LCD display.
8. Draw the flowchart and write a program to measure the power factor of an RL load using PIC 18F4580
9. Write a program to generate the firing pulses for a single-phase full-converter with firing angle of 450 using PIC 18F microcontroller

10. In a boost converter based solar PV system, the PV panel voltage varies from 10V to 15V depending on the solar radiation. Design an MPPT based control system (PIC18F4580). Use the P & O algorithm for MPPT
11. Describe the PWM module of C28X and explain how a 10KHz, 25% duty cycle PWM can be generated using embedded coder/C-program
12. (a) Explain why FPGA is preferred in some applications when compared to microcontrollers

    (b) Write a VHDL code to insert a 1us delay for a pulse input at the rising edge. Explain how this could be used for dead time generation

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E105C	POWER QUALITY, EMI ISSUES AND REMEDIAL TECHNIQUES	Elective	3	0	0	3	3

Preamble : The course attempts to impart knowledge about power quality issues, and mitigation techniques. It also covers the EMI issues, measurement and Electromagnetic compatibility (EMC) compliance in power electronics and electronic circuits. This course will equip students to analyse power system harmonics and examine its effect on performance parameters. Students are trained to select suitable custom power devices and design using suitable control strategies.

Prerequisite : A basic course in power electronics

Course Outcomes: After the completion of the course the student will be able to

CO 1	Classify and Illustrate power quality issues (Cognitive knowledge level: Understand)
CO 2	Analyse power system harmonics and examine its effect on performance parameters (Cognitive knowledge level: Analyse)
CO 3	Select suitable custom power devices and design using suitable control strategies like PQ theory (Cognitive knowledge level: Apply)
CO 4	Identify the EMI causes, measurement and mitigation methods (Cognitive knowledge level: Understand, Evaluate)
CO 5	Select suitable PCB layout and decoupling to reduce EMI (Cognitive knowledge level: Apply, Analyse)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	3	2	2	2
CO 2	2	1	3	2	2	2
CO 3	2	1	3	2	2	2
CO 4	2	1	3	2	2	2
CO 5	2	1	3	2	2	2

Evaluation Pattern

	POWER QUALITY, EMI ISSUES AND REMEDIAL TECHNIQUES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (6 hours)

Power Quality (PQ) issues- causes and effects- power frequency disturbances-voltage sag, swell, flicker, IEEE 1453 standard- voltage imbalance and low frequency noise- remedies- isolation transformers- voltage regulators and uninterruptible power supplies-voltage tolerance criteria- power system transient model- transients due to atmospheric conditions, load switching, interruption of fault currents, capacitor bank switching- neutral voltage swing

MODULE 2 (6 hours)

Power system harmonics- causes of current and voltage harmonics- individual and total harmonic distortion- harmonic signature of different loads- lighting- adjustable speed drives, single phase-controlled converters, switch mode power supplies, battery chargers and arc furnaces- effect of harmonics on power system devices- IEEE519 and IEEE1159 harmonic standards, harmonic current mitigation-harmonic cancellation- filters- power quality instrumentation and measurements- case studies

MODULE 3 (8 hours)

Overview of mitigation methods- shunt active filters and series active filters- single-phase two- wire, three-phase three-wire, and three-phase four-wire- principle of operation- case studies- D-STATCOM- mitigation of poor power factor, unbalanced currents, and increased neutral current-VSI based three-phase three-wire and four wire DSTATCOM- principle of operation and control - VSI based three-phase three-wire Dynamic voltage restorer- unified power quality conditioner

MODULE 4 **(8 hours)**

Electromagnetic Interferences (EMI) and Electro Magnetic Compatibility (EMC) regulations- IEC61800-3 - CISPR25- conducted and radiated emission mechanisms in power electronic circuits- typical noise path- methods of reducing interference- Capacitive and inductive coupling, Shielding of cables and transformers - ground loops- testing of conducted EMI- LISN- Near and far fields, characteristic and wave impedances, shielding effectiveness- conducted emissions- power line filters-common mode choke - design- magnetic field emissions- system design for EMC

MODULE 5 (8 hours)

Power supply decoupling- transient power supply current and load current- Fourier spectrum decoupling capacitors- target impedance- effect of decoupling on radiated emissions- PCB layout considerations- PCB to chassis ground connection- multilayer boards, mixed-signal.
PCB layout considerations- mixed-signal power distribution- Electrostatic Discharge (ESD) - Static generation, human body model, ESD protection in equipment design, Transient and Surge Protection Devices

References

1. C. Sankaran - *Power Quality*, CRC, 2nd edition 2001
2. Alexander Kusko, Marc T.Thompson, *"Power Quality in Electrical Systems*", McGrawHill, 4th edition 2007
3. Francois Costa et al., "*Electromagnetic compatibility in Power Electronics*", Wiley Iste,
4. 2nd edition , 2014
5. Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, *Power Quality Problems and Mitigation Techniques",* Wiley, 5th edition 2015
6. Henry W.Ott, "*Electromagnetic Compatibility Engineering*", Wiley Interscience,2009
7. H.W. Whittington, *"Switched Mode Power Supplies: Design and Construction*", Wiley, 2nd edition, 1997
8. A Ghosh, G. Ledwich, *Power Quality Enhancement Using Custom Power Devices*. Kluwer Academic, 2002
9. Jos Arrillaga, Neville R Watson, *Power system harmonics,* Wiley, 2nd edition 2995

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(6 hours)	
1.1	Power Quality (PQ) issues- causes and effects	1
1.2	power frequency disturbances-voltage sag, swell, flicker, voltage imbalance and low frequency noise- remedies	1
1.3	isolation transformers- voltage regulators and uninterruptible power supplies	1
1.4	Voltage tolerance criteria- power system transient model transients due to atmospheric conditions, load switching	1
1.5	Interruption of fault currents, capacitor bank switching neutral voltage swing	2
	Module 2(6 hours)	
2.1	Power system harmonics- causes of current and voltage harmonics	1
2.2	Individual and total harmonic distortion- harmonic signature of different loads- lighting- adjustable speed drives, single phase-controlled converters, switch mode power supplies, battery chargers and arc furnaces	1
2.3	Effect of harmonics on power system devices- IEEE519 harmonic standards	1
2.4	Harmonic current mitigation-harmonic cancellation- filters	1
2.5	Power quality instrumentation and measurements- case studies	2
	Module 3(8 hours)	
3.1	Overview of mitigation methods- shunt active filters and series active filters	1
3.2	single-phase two-wire, three-phase three-wire, and three phase four-wire- principle of operation- case studies	2
3.3	D-STATCOM- mitigation of poor power factor, unbalanced currents, and increased neutral current	1
3.4	VSI based three-phase three-wire and four wire DSTATCOM principle of operation and control	2
3.5	VSI based three-phase three-wire Dynamic voltage restorer	1
3.6	Unified power quality conditioner	1
	Module 4(8 hours)	
4.1	Electromagnetic Interferences (EMI) and Electromagnetic Compatibility (EMC) regulations- IEC61800-3- CISPR25	1
4.2	Conducted and radiated emission mechanisms in power electronic circuits- typical noise path- methods of reducing interference	1
4.3	Capacitive and inductive coupling	1

4.4	Shielding of cables and transformers- ground loops	1
4.5	Testing of conducted EMI- LISN	1
4.6	Near and far fields, characteristic and wave impedances, shielding effectiveness- conducted emissions	1
4.7	Power line filters-common Mode Choke - design- magnetic field emissions- system design for EMC	2
	Module 5(8 hours)	
5.1	Power supply decoupling- transient power supply current and load current-Fourier spectrum- decoupling capacitors	2
5.2	Target impedance- effect of decoupling on radiated emissions	1
5.3	PCB layout considerations- PCB to chassis ground connection- multilayer boards, mixed-signal PCB layout considerations	2
5.4	Mixed-signal power distribution	1
5.5	Electrostatic Discharge (ESD) - Static generation, human body model, ESD protection in equipment design	1
5.6	Transient and Surge Protection Devices	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E105C

Course Name: Power Quality, EMI Issues and Remedial Techniques

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Explain the various types of transients and issues associated with them.
2. Explain the harmonics in single phase-controlled converters.
3. Explain the principle of shunt active filter for harmonic mitigation.
4. Calculate the conducted noise emission through the capacitance of the heat sink in SMPS. Design a suitable filter to reduce this noise below the limit.
5. What are the advantages of using multilayer PCBs for digital circuits? Explain the mechanism of cross talk in multilayer PCBs and methods to reduce cross talk.

PART B

Answer any five questions. Each question carries 8 marks.

6. Explain the voltage magnification at load end due to capacitor switching, its effect on equipment and how it can be avoided.
7. Explain the voltage magnification at load end due to capacitor switching, its effect on equipment and how it can be avoided.
8. Describe the principle of operation and any one control scheme of DVR.
9. Calculate the required copper metal thickness to attenuate the radiated electromagnetic field (far field) of 1kHz by 100dB? Given that the shield impedance of copper at 1 kHz is 11.6 μΩ and the skin depth of copper at this frequency is 2mm.

10. Design a line filter to reduce common mode noise by 40dB at 150kHz and differential mode noise by 40dB at 100kHz. Separate common mode and differential mode chokes may be used. Also explain the use of LISN.
11. Explain any two techniques to reduce conducted noise pick up in PWM converters (ii) Explain PCB layout considerations to reduce conducted noise.
12. Draw the circuit diagram of a forward converter operating at 50kHz, power being drawn from 230V, 50Hz mains. Identify the possible conducted noise emission sources and explain the means to reduce EMI.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E105D	POWER SYSTEMS OPERATION AND CONTROL	Elective	3	0	0	3	3

Preamble : The course comprises the concept of coordinating different generating units, along with computation of production costs, security controls, and corrective measures. This course will equip students to analyse the types of power generation production cost programs and to apply the various algorithms for power system state estimation. Training is provided on power system automation based on SCADA system.

Prerequisite : Basic course in power system

Course Outcomes: After the completion of the course the student will be able to

CO 1	Examine the coordination and optimization of different generating stations. (Cognitive knowledge level: Understand)
CO 2	Analyse the types of power generation production cost programs (Cognitive knowledge level: Analyse)
CO 3	Apply the various algorithms for power system state estimation (Cognitive knowledge level: Apply)
CO 4	Evaluate the security control and corrective methods (Cognitive knowledge level: Evaluate)
CO 5	Analyse the power system automation based on SCADA system (Cognitive knowledge level: Analyse)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	3	3	2	1
CO 2	3	1	3	3	2	1
CO 3	3	1	3	3	2	1
CO 4	3	1	3	3	2	1
CO 5	3	1	3	3	2	1

Evaluation Pattern

	POWER SYSTEMS OPERATION AND CONTROL		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	30	30	40
Analyse	40	40	40
Evaluate	10	10	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (8 hours)

Characteristics of power generation units, Hydro thermal co-ordination- Problem definition and mathematical model of long- and short-term problems.
Dynamic programming – Hydro thermal system with pumped hydro units – Solution of hydro thermal scheduling using Linear programming.

MODULE 2 (7 hours)

System optimization - strategy for two generator system – generalized strategies – effect of Transmission losses - Sensitivity of the objective function- Formulation of optimal power flow solution by Gradient method-Newton's method.

MODULE 3 (7 hours)

Production cost programs: -Uses and types of production cost programs, probabilistic production cost programs. Sample computation -No forced outages – Forced outages included – interchange of power and energy and its types.

MODULE 4 **(7 hours)**

State estimation: Least square estimation – Basic solution. Sequential form of solution. Static State estimation of power system by different algorithms – Tracking state estimation of power system. Computer consideration – External equivalencing – Treatment of bad data.

MODULE 5 (7 hours)

Power system security: - System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis – Corrective controls (preventive, emergency, and restorative) – Islanding scheme.
SCADA system: **-** Energy control centre – Various levels – National – Regional and state level

References

1. Allen J Wood, Bruce F Wollenberg, "*Power Generation, Operation and Control*", John
2. Wiley& Sons, New York, 2nd Edition, 1984.
3. S Sivanagaraju, G Sreenivasan, *"Power System Operation and Control*", Pearson
4. Education India, 3rd Ed., 2009
5. Mahalanabis AK, Kothari DP and Ahson SI, *"Computer Aided Power System Analysis and Control",* McGraw Hill Publishing Ltd., 1st edition1984.
6. Kundur P, "*Power System Stability and Control",* McGraw Hill, 2006
7. http://nptel.ac.in/courses/108101040/by Dr.A M Kulkarni (IIT Bombay)

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(8 hours)	
1.1	Characteristics of power generation units	1
1.2	Hydro thermal co-ordination- Problem definition and mathematical model of long and short-term problems.	3
1.3	Dynamic programming	1
1.4	Hydro thermal system with pumped hydro units	1
1.5	Solution of hydro thermal scheduling using Linear programming	2
	Module 2(7 hours)	
2.1	Strategy for two generator system, generalized strategies, effect of Transmission losses	3
2.2	Sensitivity of the objective function- Formulation of optimal power flow solution by Gradient method	2
2.3	Newton's method	2

	Module 3(7 hours)	
3.1	Uses and types of production cost programs	1
3.2	Probabilistic production cost programs	2
3.3	Sample computation -No forced outages – Forced outages included	3
3.4	Interchange of power and energy and its types	1
	Module 4(7 hours)	
4.1	Least square estimation – Basic solution, Sequential form of solution	2
4.2	Static State estimation of power system by different algorithms – Tracking state estimation of power system	3
4.3	Computer consideration – External equivalencing – Treatment of bad data	2
	Module 5(7 hours)	
5.1	System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis	2
5.2	Corrective controls (preventive, emergency, and restorative) – Islanding scheme	3
5.3	SCADA system: - Energy control centre – Various levels – National – Regional and state level	2

Model Question Paper

QP CODE: Pages: 2

Reg No.:_______________

Name:_________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E105D

Course Name: Power Systems Operation and Control

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Explain the characteristics of hydro and thermal generation units
2. Explain the transmission losses in two generator system with suitable example
3. Describe probabilistic production cost model
4. What do you mean by external equivalencing?
5. Explain the functions of energy control centre with neat block diagram.

PART B

Answer any five questions. Each question carries 8 marks.

6. A hydro plant and a steam plant are to supply a constant load of 90MW for 1wk (168h). The unit characteristics are

Hydro plant: q= 300+15PH acre-ft/h

0 ≤PH ≤ 100MW

Steam plant: Hs=53.25+11.27Ps +0.0213P2

12.5 ≤Ps ≤ 50MW

7. Explain the Formulation of optimal power flow solution by Newton's method.
8. Compute the production cost for a 3unit system without considering outages using load duration curve method. The energy is 43680 MWHr. The generation data is as follows:

Unit No	Maximum Rating(kW)	Input Qutput Characteristics (R/Hr)	Full forced outage rate (pu)
1	60	60+ 3P1	0.2
2	50	70+3.5P2	0.1
3	20	80+4 P3	0.1

The load data is as follows:

Load level (x MW)	Duration (Hrs)
30	134.4
50	134.4
70	134.4
80	168.0
100	100.8

9. Explain static state estimation using line only algorithm.
10. Explain weighted least square form of solution in state estimation.
11. Write short note on Preventive, Emergency and Restorative control
12. Explain the different levels of SCADA with neat diagram.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1R106	RESEARCH METHODOLOGY & IPR	Theory	2	0	0	2	2

Preamble : This course introduces the strategies and methods related to scientific research. It covers salient aspects of publication and patenting along with the crucial role of ethics in research. This course will equip students to define research problem and to adopt suitable methodologies for the solution of problem. The students are trained in the oral presentation with visual aids and writing technical thesis/reports/research papers.

Prerequisite: NIL

Course Outcomes: After the completion of the course the student will be able to

CO 1	Approach research projects with enthusiasm and creativity. (Cognitive knowledge level: Understand)
CO 2	Conduct literature survey and define research problem. (Cognitive knowledge level: Analyse)
CO 3	Adopt suitable methodologies for solution of the problem. (Cognitive knowledge level: Apply, Evaluate)
CO 4	Deliver well-structured technical presentations and write technical reports. (Cognitive knowledge level: Apply)
CO 5	Publish/Patent research outcome. (Cognitive knowledge level: Understand)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	3	1		1	3
CO 2	3	3	1		1	3
CO 3	3	3	1		1	3
CO 4	3	3	1		1	3
CO 5	3	3	1		1	3

Evaluation Pattern

	Research Methodology & IPR		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (%Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	30	30	30
Analyse	40	40	40
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications in the relevant discipline (minimum 10 publications shall be referred) : 10 marks

Course based task/Seminar/Quiz : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

End Semester Examination Pattern: The end semester examination should be conducted by the college. The time duration will be for 3 Hrs and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

SYLLABUS

MODULE 1 (4 hours)

Meaning and objective of research, Types of research, Research Approaches, significance of research, Characteristics of good research, Research process.
Thinking skills: Types and Levels of thinking - scientific thinking and logical thinking.
Creativity: Definitions, intelligence versus creativity, creative process, requirements for creativity.

MODULE 2 (4 hours)

Literature survey and Problem definition:
Information gathering – reading, searching and documentation-Types of literature.
Integration of research literature and identification of research gaps- Attributes and sources of research problems, problem formulation, Research question, multiple approaches to a problem, Problem solving strategies – reformulation or rephrasing, techniques of representation, Importance of graphical representation, examples.

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MODULE 3 (6 hours)

Experimental and modelling skills :
Scientific method- role of hypothesis in experiment, dependent and independent variables, control in experiment
Precision and Accuracy- need for precision-definition, detection, estimation and reduction of random errors- definition, detection and elimination of systematic errors.

Statistical treatment of data-Descriptive and inferential statistics - Data analysis and interpretation -testing of hypothesis, testing of population mean, variance and proportion- Z test- t test- F test - chi square test. Test for correlation and regression-Testing goodness of fit.

MODULE 4 (5 hours)

Effective communication - oral and written
Examples illustrating the importance of effective communication, stages and dimensions of a communication process.
Oral communication –verbal and non-verbal, casual, formal and informal communication, interactive communication, listening, form, content and delivery, various contexts for speaking- conference, seminar etc.
Guidelines for preparation of good presentation slides.
Written communication – Rules of scientific writing, form, content and language, layout, typography and illustrations, nomenclature, reference and citation styles, contexts for writing – paper, thesis, reports etc. Tools for document preparation-LaTeX.
Common errors in typing and documentation.

MODULE 5 (5 hours)

Publication and Patents:
Relative importance of various forms of publication, Choice of journal and reviewing process, Stages in the realization of a paper.
Research metrics-Journal level, Article level and Author level, Plagiarism and research ethics.
Introduction to IPR, Concepts of IPR, Types of IPR, Types and Features of IPR Agreement, Trademark.
Patents- Concept, Objectives and benefits, features, Patent process – steps and procedures.

References

1. R. Panneerselvam, *Research Methodology*. PHI Learning Pvt Ltd, 2nd Ed., 2014
2. C. R. Kothari and Gaurav Garg, *Research Methodology: Methods and Techniques*. New Age International, 5th Ed., 2024
3. G. L. Squires, *Practical physics*. Cambridge University Press, 4th Ed., 2001
4. Antony Wilson, Jane Gregory, Steve Miller and Shirley Earl, *Handbook of Science Communication*. Overseas Press India Pvt Ltd, 1st Ed., 2005
5. Paul D. Leedy and Jeanne Ellis Ormrod., *Practical Research: Planning and Design.* Pearson, 12th Ed., 2018
6. Barbara Gastel and Robert A. Day, *How to Write and Publish a Scientific Paper*. Cambridge University Press, 8th Ed., 2017
7. P. B. Medawar, *Advice to Young Scientist.* Basic Books, Revised Ed., 1981
8. R. Hamming, *You and Your Research*, Bell Communications Research Colloquium Seminar, 1986

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (4 hrs)	
1.1	Meaning, and objective of research, Types of research, Research Approaches.	1
1.2	Significance of research, Characteristics of good research, Research process.	1
1.3	Thinking skills: Types and Levels of thinking - scientific thinking, and logical thinking.	1
1.4	Creativity: Definitions, intelligence versus creativity, creative process, requirements for creativity.	1
	Module 2 (4 hrs)	
2.1	Information gathering – reading, searching and documentation, types of literature	1
2.2	Integration of research literature and identification of research gaps	1
2.3	Attributes and sources of research problems, problem formulation, Research question, multiple approaches to a problem	1
2.4	Problem solving strategies – reformulation or rephrasing, techniques of representation, Importance of graphical representation, examples	1
	Module 3 (6 hrs)	
3.1	Scientific method, role of hypothesis in experiment, dependent and independent variables, control in experiment	1
3.2	Precision and accuracy, need for precision, definition, detection, estimation and reduction of random errors, definition, detection and elimination of systematic errors	1
3.3	Statistical treatment of data-Descriptive and inferential statistics - Data analysis and interpretation -testing of hypothesis, testing of population mean, variance and proportion- Z test- t test- F test - chi square test.	3
3.4	Test for correlation and regression -Testing goodness of fit.	1
	Module 4 (5 hrs)	
4.1	Examples illustrating the importance of effective communication, stages and dimensions of a communication process	1
4.2	Oral communication –verbal and non-verbal, casual, formal and informal communication, interactive communication, listening, form, content and delivery, various contexts for speaking- conference, seminar etc.	1
4.3	Guidelines for preparation of good presentation slides.	1
4.4	Written communication – Rules of scientific writing, form, content and language, layout, typography and illustrations, nomenclature, reference and citation styles, contexts for writing – paper, thesis, reports etc. Tools for document preparation-LaTeX.	1

4.5	Common errors in typing and documentation	1
	Module 5 (5 hrs)	
5.1	Relative importance of various forms of publication, Choice of journal and reviewing process, Stages in the realization of a paper.	1
5.2	Research metrics-Journal level, Article level and Author level, Plagiarism and research ethics	1
5.3	Introduction to IPR, Concepts of IPR, Types of IPR	1
5.4	Types and Features of IPR Agreement, Trademark	1
5.5	Patents- Concept, Objectives and benefits, features, Patent process – steps and procedures	1

Model Question Paper

QP CODE: Pages: 1

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M. TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1R106

Course Name: Research Methodology & IPR

Max. Marks:60 Duration: 3 hours

Answer any five questions. Each question carries 12 marks.

1. (a) Explain the different levels of thinking. (4 marks)

   (b) Classify different types of researches. (8 marks)

2. (a) Outline the different steps for identification of research gaps. (6 marks)

   (b) Classify various types of literature. (6 marks)

3. A sample of 400 male students is found to have a mean height of 67.47 inches. Can it be reasonably regarded as a sample from a large population with mean height 67.39 inches and standard deviation 1.30 inches? Test at 5% significance level. (12 marks)

4. (a) Illustrate the importance of effective communication. (4 marks)

   (b) List out the Guidelines for preparation of good presentation slides. (8 marks)

5. (a) Examine the requirements for patentability? (6 marks)

   (b) Contrast between copyright and trademark protection. (6 marks)

6. Weight of 10 students is as follows:

Sl No.	1	2	3	4	5	6	7	8	9	10
Weight(kg)	38	40	45	53	47	43	55	48	52	49

   Can we say that the variance of the distribution of weight of all students from which the above sample of 10 students was drawn is equal to 20 Kg? Test this at 5 % and 1% level of significance. (12 marks)

7. (a)Explain the various stages and dimensions of communication process. (6 marks)

   (b) Compare Journal level, Article level and Author level research metrics. (6 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1L207	ADVANCED POWER ELECTRONICS LABORATORY	Laboratory	0	0	3	3	2

Preamble : Power electronics is extensively used in the processing and controlling of high voltages and currents in large industrial equipments. The syllabus imparts practical knowledge about various power electronic circuits and its applications. It also introduces the application of electronic devices for conversion and control conditioning of electric power.

Prerequisite: Fundamentals of power electronics course

Course Outcomes: After the completion of the course the student will be able to

CO 1	Demonstrate the practical knowledge on design and development of power electronic converters and drives (Cognitive knowledge level: Understand)
CO 2	Solve engineering problems related to power converters to provide feasible solutions(Cognitive knowledge level: Apply)
CO 3	Examine the performance of various power electronic converters in open and closed loop through simulation software like MATLAB. (Cognitive knowledge level: Evaluate)
CO4	Analyse the experiment efficiently as an individual and as a member in the team to solve various problems (Cognitive knowledge level: Analyse)
CO 5	Build laboratory reports as a document that clearly communicate experimental information (Cognitive knowledge level: Understand)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	3	3	3	1
CO 2	3	1	3	3	3	1
CO 3	3	1	3	3	3	1
CO 4	2	2	2	3	2	2
CO 5	1	3	2	1	1	2

Mark distribution

Total Marks	CIE Marks
100	100

Continuous Internal Evaluation Pattern:
Lab work and Viva-voce : 60 marks
Final evaluation Test and Viva voce : 40 marks

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final evaluation shall be done by two examiners; one examiner will be a senior faculty from the same department.

SYLLABUS

LIST OF EXPERIMENTS

	SIMULATION EXPERIMENTS
1	Single phase and three phase half converter using RL and RLE loads.
2	Single phase and three phase full converter using RL and RLE loads.
3	Single phase inverter with square wave, sine triangle PWM with RL load.
4	Three phase square inverters at 120 and 180 degree modes.
5	Three phase inverters with sine triangle PWM.
6	Open loop control of CUK DC-DC Converter
	HARDWARE EXPERIMENTS
7	Single Phase Semi-converter and Full Converter with R-L load for continuous / discontinuous conduction modes.
8	Single Phase Full Converter with R-L load for continuous / discontinuous conduction modes.
9	Half bridge square wave inverter feeding R load.
10	Grid synchronization and firing circuit for SCR using analog ICs.
11	Open loop control of Buck, Boost and Buck-Boost converters using discrete IC-SG352.
12	Speed control of chopper fed DC motor drive.

References

1. M.H. Rashid, *Power Electronics: Circuits, Devices and Applications*. PHI/Pearson 4th Ed., 2017.
2. N. Mohan, T. M. Undulant, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*. Wiley 3rd Ed., 2007.
3. L. Umanand, *Power Electronics: Essentials and Applications.* Wiley India 1st Ed., 2009
4. Daniel W. Hart, *Power Electronics.* Tata McGraw-Hill 1st Ed., 2011.

SEMESTER 2

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1T201	OPTIMIZATION TECHNIQUES	Core	2	2	0	3	4

Preamble: This course provides a foundation to different kinds of optimization techniques. It covers optimization techniques for linear and nonlinear systems with and without constraints. This course will equip the students with the mathematical framework necessary for optimization of engineering systems for various applications.

Prerequisite: B. Tech level Mathematics.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand basic principles in linear optimization techniques and algorithms and solve linear optimization problems. (Cognitive Knowledge Level : Apply)
CO 2	Formulate, implement and analyze unconstrained one dimensional optimization models. (Cognitive Knowledge Level : Analyze)
CO 3	Understand unconstrained n dimensional optimization techniques and solve complex power electronics problems. (Cognitive Knowledge Level : Apply)
CO 4	Use constrained optimization techniques for engineering practice. (Cognitive Knowledge Level : Analyze)
CO 5	Implement appropriate optimization algorithms for solving Engineering Problems and be familiar with recent developments in optimization techniques. (Cognitive Knowledge Level : Analyze)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	3	3	3	1
CO 2	2	1	3	3	3	1
CO 3	2	1	3	3	3	1
CO 4	2	1	3	3	3	1
CO 5	2	1	3	3	3	1

Evaluation Pattern

Course name	OPTIMIZATION TECHNIQUES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	-	-	-
Apply	60	60	60
Analyse	40	40	40
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project :10 marks

Course based task/Seminar/Quiz :10 marks

Test paper 1 (Module 1 and Module 2) :10 marks

Test paper 2 (Module 3 and Module 4) :10 marks

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will betwo parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (9 hours)

Formulation of optimization problems - Classification of Optimization Problems - Linear Programming Problems- Graphical method – Iso - profit (or Iso-cost) line method - Extreme point evaluation method- Types of optimal solution - Standard Form - Definitions and Theorems - Simplex method – Big M Method –Duality in Linear Programming.

MODULE 2 (7 hours)

Unconstrained one dimensional optimization techniques- Unimodal functions – Unimodal maximum and minimum - Search methods - Fibonacci search - Golden section search - Interpolation methods- Quadratic interpolation - Cubic interpolation.

MODULE 3 (9 hours)

Unconstrained one-dimensional optimization using direct root methods - Newton method - Quasi Newton method - Secant method.

Unconstrained n dimensional optimization techniques - Gradient methods- Steepest descent method - Conjugate gradient method – Newton's method – Davidon Fletcher Powell method.

MODULE 4 **(10 hours)**
Direct search methods for Unconstrained n dimensional optimization - Univariate search - Powell's pattern search method.
Constrained optimization techniques - Necessary and sufficient conditions - Equality and inequality constraints- Kuhn Tucker conditions – Solution of optimization problems using Kuhn – Tucker conditions.

MODULE 5 (10 hours)
Constrained optimization using Rosen's gradient projection method - Sequential Linear Programming method – Penalty method – Interior penalty method – Exterior penalty method.
Recent developments in optimization techniques : Genetic algorithm, Neural network based optimization techniques.
Case study : MATLAB/ Python programming for solution to optimization problems in Electrical Engineering.

References

1. R Panneerselvam, *"Operational Research"*, PHI, 3rd Ed., 2023.
2. Rao S. S., *"Engineering Optimization: Theory and Practice"*, Wiley, New York, 5th Ed., 2019.
3. Mohammad Fathi, Hassan Bevrani, *"Optimization in Electrical Engineering"*, Springer, 1st Ed., 2019.
4. Raju N V S, *"Optimization methods for Engineers"*, PHI, 1st Ed., 2014.
5. Kalyanmoy Deb, *"Optimization for Engineering Design"*, 2 nd Ed., PHI, 2012.
6. Edwin K P Chong and Stanislaw H Zak, *"An Introduction to Optimization"*, Wiley, India, 1st Ed., 2010.
7. Bazaara M. S., Sherali H.D., Shetty C.M., "*Non-linear Programming*", John Wiley and Sons, 3rd Ed., 2006.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (9 hrs)	
1.1	Formulation of optimization problems	1
1.2	Classification of Optimization Problems	1
1.3	Linear Programming Problems- Graphical method – Iso - profit (or Iso-cost) line method - Extreme point evaluation method.	3
1.4	Standard Form - Definitions and Theorems	1
1.5	Simplex method	1
1.6	Big M Method	1
1.7	Duality in Linear Programming.	1
	Module 2 (7 hrs)	

2.1	Unconstrained one dimensional optimization techniques – Introduction.	1
2.2	Unimodal functions – Unimodal maximum and minimum	1
2.3	Search methods - Fibonacci search	1
2.4	Golden section search	1
2.5	Interpolation methods- Quadratic interpolation	2
2.6	Cubic interpolation.	1
	Module 3 (9 hrs)	
3.1	Unconstrained one dimensional optimization using direct root methods - introduction	1
3.2	Newton's method	1
3.3	Quasi Newton method	1
3.4	Secant method.	1
3.5	Unconstrained n dimensional optimization techniques	1
3.6	Gradient methods- Steepest descent method	1
3.7	Conjugate gradient method	1
3.8	Newton's method	1
3.9	Davidon Fletcher Powell method.	1
	Module 4 (10 hrs)	
4.1	Direct search methods for Unconstrained n dimensional optimization - Introduction	1
4.2	Univariate search	2
4.3	Powell's pattern search method.	2
4.4	Constrained optimization techniques - Introduction	1
4.5	Necessary and sufficient conditions - Equality and inequality constraints.	1
4.6	Kuhn Tucker conditions	1
4.7	Solution of optimization problems using Kuhn – Tucker conditions	2
	Module 5 (10 hrs)	
5.1	Constrained optimization using Rosen's gradient projection method	2
5.2	Sequential Linear Programming method	2
5.3	Penalty method – Interior penalty method – Exterior penalty method.	2
5.4	Recent developments in optimization techniques : Genetic algorithm	2
5.5	Neural network based optimization techniques.	1
5.6	Case study : MATLAB/ Python programming for solution to optimization problems in Electrical Engineering.	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

SECOND SEMESTER M.TECH DEGREE EXAMINATION, APRIL 2025

Course Code: **M24EE1T201**
Course Name: **OPTIMIZATION TECHNIQUES**

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Evaluate the optimal solution using Simplex method

Minimize $Z = x_1-3x_2+2x_3$

Subject to $3x_1-x_2+2x_3 \leq 7$

$-2x_1+4x_2 \leq 12$

$-4x_1+3x_2+8x_3 \leq 10$

$x_1,x_2,x_3 \geq 0$

2. Maximize $f(x) = \begin{cases} \frac{5x}{4} & x \leq 4 \\ 9-x & x \geq 4 \end{cases}$ in the range 3 to 6 with n=8 by fabonacci method.

3. Enumerate the principle of Newton's method for unconstrained one dimentional optimization problems.

4. Analyse the features of Powell's pattern search algorithm.

5. Artificial Neural network can be used as an optimization tool to solve engineering problems. Justify.

PART B

Answer any five questions. Each question carries 8 marks.

6. Evaluate the optimal solution using Big-M method

Maximize Z = 5x1+3x2

Subject to 2x1+ x2 ≤ 1

x1+4x2 ≥ 6

x1,x2 ≥ 0

7. Obtain the minimum of the function $f(x) = x^5-10x^3+2x+10$ in (1,6) using quadratic interpolation method.

8. Minimize the function, $f(x)= x_1- x_2+2x_1^2+2x_1x_2+x_2^2$ starting from point $x_1= \begin{bmatrix}0\\0\end{bmatrix}$ using Steepest descend method.

9. Minimize the function $f(x)= 2x_1^2+x_2^2 - 8x_1x_2 - 16x_1+ 25x_2+ 10$ using conjugate gradient method with starting point $X_1= \begin{bmatrix}2\\0\end{bmatrix}$

10. Minimize the function, $f(x) = x_1- x_2+2x_1^2+2x_1x_2+x_2^2$ using Newton method

11. Derive the optimal solution from the Kuhn-Tucker conditions for the problem.
    Minimize $Z=2x_1+3x_2-x_1^2-2x_2^2$
    subject to the condition $x_1 + 3x_2 \le 6$, $5x_1+ 2x_2 \le 10$,, $x_1,x_2 \ge 0$.

12. Derive the equations and explain the algorithm of Rosen's Gradient Projection method.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1T202	ADVANCE ELECTRIC DRIVES	Core	4	0	0	4	4

Preamble:

The syllabus focuses on the dynamic modeling and advanced drive-control schemes applicable to induction machines, permanent magnet synchronous motors (PMSM), and brushless DC (BLDC) motors. Students will gain knowledge to model and electrical machine using the modelling equations and analyze the control techniques of the drives.

Prerequisite:

A strong understanding of electrical machines, power electronics fundamentals, familiarity with control system principles, including feedback control, PID controllers, stability analysis, and system modeling techniques using transfer functions and state-space representation.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the concepts of power equivalence, three phase to two phase transformation and generalized modelling of electric machines in different reference frames. (Cognitive Knowledge Level: Understand)
CO 2	Understand vector control schemes and perform the dynamic modelling of induction machine in rotor flux-oriented reference frame. (Cognitive Knowledge Level: Apply)
CO 3	Analyze the performance of stator flux-oriented control and direct torque control (DTC) of induction machine. (Cognitive Knowledge Level: Analyze)
CO 4	Analyze the characteristic features of PMSM and its control strategies. (Cognitive Knowledge Level: Analyze)
CO 5	Design suitable control strategies for BLDC motor and examine the sensor less control methods. (Cognitive Knowledge Level: Analyze)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	2	3	3	3	2
CO 2	3	2	3	3	3	2
CO 3	3	2	3	3	3	2
CO 4	3	2	3	3	3	2
CO 5	3	2	3	3	3	2

Evaluation Pattern

	ADVANCE ELECTRIC DRIVES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (%Marks)**
	Test 1 (% Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	30	30	30
Apply	20	20	20
Analyze	30	30	30
Evaluate	20	20	20
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project :10 marks

Course based task/Seminar/Quiz :10 marks

Test paper 1 (Module 1 and Module 2) :10 marks

Test paper 2 (Module 3 and Module 4) :10 marks

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (9 hours)

Generalized machine theory- Basic two-pole machine- Transformer and rotational voltages in the armature- Kron's primitive machine- Voltage, power and torque equations- Resistance, inductance and torque matrices.

Modelling of Induction Machine: Air gap MMF due to sinusoidal winding distribution- Space vector representation- Power equivalence- 3-phase to 2-phase transformation- Dynamic modelling of induction machines in arbitrary reference frame– electromagnetic torque – Stator reference frame, rotor reference frame and synchronously rotating reference frame models- dynamic and steady state equivalent circuits.

MODULE 2 (9 hours)

Field Oriented Control: Principle of vector or field-oriented control – Comparison with separately excited dc motor- direct rotor flux-oriented vector control – Selection of Flux level- Estimation of rotor flux and torque- Indirect rotor flux-oriented vector control scheme- Flux weakening- Parameter sensitivity - implementation with current regulated VSI and PWM VSI- Speed controller design.

MODULE 3 (9 hours)

Stator flux-oriented vector control- decoupling requirements- implementation of with current regulated inverters- Parameter sensitivity in stator flux orientation- Selection of Flux level - Flux weakening - Direct torque control (DTC) of induction motor.

MODULE 4 **(9 hours)**

Permanent magnet synchronous machine (PMSM) drives – types of permanent magnets and characteristics–radial and parallel magnetization- Halbach arrays- SPM and IPM machines- Modelling of PMSM- Vector control strategies – constant torque-angle control- unity power factor control- maximum torque per ampere- constant mutual flux linkage control- flux weakening.

MODULE 5 (9 hours)

PM brushless (BLDC) DC motor – modeling of BLDC motor – operating principle- Speed-Torque characteristics- Torque Pulsation- Six switch converter- Split supply Converter- Drive scheme without field weakening- Current and Speed Control- Regenerative braking- Sensor less control- back emf detection method

References

1. R Krishnan**,** *Electric Motor Drives: Modeling, Analysis, and Control***, 2nd** Ed., 2017
2. B. K. Bose, *Modern Power Electronics and AC Drives*, Pearson, 1st Ed., 2002
3. R. Krishnan, *Permanent Magnet Synchronous and Brushless DC Drives*, CRC Press, 1st Ed., 2010.
4. P. C. Krause, Wasynczuk, and Sudhoff, *Analysis of Electric Machinery and Drive Systems*, IEEE Press/Wiley, 3rd Ed. 2013.
5. A.M. Trzynadlowski , *Field Orientation Principles in the Control of Induction Motors*, Kluwer Academic Publishers, 1st Ed., 1994.
6. Ned Mohan, *Advanced Electric Drives: Analysis, Control, and Modeling*, Wiley, 1st Ed., 2009.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(9 hrs)	
1.1	Generalized machine theory- Basic two-pole machine	1
1.2	Transformer and rotational voltages in the armature	1
1.3	Kron's primitive machine- Voltage, power and torque equations- Resistance, inductance and torque matrices	1
1.4	Modelling of Induction Machine: Air gap MMF due to sinusoidal winding distribution- Space vector representation	1
1.5	Power equivalence- 3-phase to 2-phase transformation	1
1.6	Dynamic modelling of induction machines in arbitrary reference frame – electromagnetic torque	2
1.7	Stator reference frame, rotor reference frame and synchronously rotating reference frame models	1
1.8	Dynamic and steady state equivalent circuits	1
	Module 2(9 hrs)	
2.1	Direct rotor flux-oriented vector control	2
2.2	Selection of Flux level- Estimation of rotor flux and torque	1
2.3	Indirect rotor flux-oriented vector control scheme	1
2.4	Parameter sensitivity	1
2.5	Implementation with current regulated VSI and PWM VSI	2
2.6	Flux weakening	1
2.7	Speed controller design	1
	Module 3(9 hrs)	
3.1	Stator flux-oriented vector control- decoupling requirements	2
3.2	Implementation with current regulated inverters	2
3.3	Parameter sensitivity in stator flux orientation	2
3.4	Direct torque control (DTC) of induction motor	3
	Module 4(9 hrs)	
4.1	Permanent magnet synchronous machine (PMSM) drives- constant mutual flux linkage control	2
4.2	Types of permanent magnets and characteristics	1
4.3	Radial and parallel magnetization- Halbach arrays	1
4.4	SPM and IPM machines	1
4.5	Modelling of PMSM	1
4.6	Vector control strategies – constant torque-angle control- unity power factor control- maximum torque per ampere- constant mutual	2

	flux linkage control	
4.7	Flux weakening	1
	Module 5(9 hrs)	
5.1	PM brushless (BLDC) DC motor – modeling of BLDC motor Current and Speed Control	2
5.2	operating principle- Speed-Torque characteristics- Torque Pulsation	2
5.3	Six switch converter- Split supply Converter	2
5.4	Drive scheme without field weakening	1
5.5	Regenerative braking	1
5.6	Sensor less control- back emf detection method	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

SECOND SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: **M24EE1T202**

Course Name: Advanced Electric Drives

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Derive the Clarke and Park transformation equations using the concept of power invariance.
2. Why indirect field-oriented control is parameter sensitive?
3. What is the need for the requirement of decoupling circuits in stator flux-oriented control of induction motor?
4. Compare and contrast between IPM and SPM machines on the basis of construction and performance characteristics.
5. Explain the forward motoring operation of a BLDC motor.

PART B

Answer any five questions. Each question carries 8 marks.

6. Derive the dynamic equations of induction machine in stationary reference frame.
7. Discuss the impact of current control (hysteresis control) and PWM control on the performance of vector-controlled induction motor drive.
8. Explain the direct vector control scheme of induction motor drive and how torque and flux references are estimated.
9. Describe the stator flux-oriented vector control scheme using the phasor diagram and block schematic. Mention the limitations.
10. Compare between FOC and DTC control schemes of induction motor drive on the basis of performance.
11. Illustrate in detail the various vector control strategies used in permanent magnet synchronous motor.
12. Select suitable drive scheme for a BLDC motor and explain the performance during rated and extended speed operations.

PROGRAM ELECTIVE 3

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E203A	FACTS AND CUSTOM POWER DEVICES	Elective	3	0	0	3	3

Preamble: To familiarize the students with the transmission challenges of modern electrical power systems and the need of FACTS controllers. The course presents the basic concept of Flexible AC Transmission Systems (FACTS) that enhances power system stability and effectively increase the transmission capacity. After the completion of the course, students will develop a deeper knowledge on various control and implementation techniques of FACTS devices and the Custom power devices.

Prerequisite : Fundamental of Power System and Power Electronics

Course Outcomes: After the completion of the course the student will be able to

CO 1	Use FACT controllers for various power quality issues (Cognitive Knowledge Level : Understand)
CO 2	Solve the reactive power problems in power systems using Shunt Compensators. (Cognitive Knowledge Level : Apply)
CO 3	Design and Analyze Series Compensators for solving reactive power problems in power systems (Cognitive Knowledge Level : Analyze)
CO 4	Learn to Optimize the performance of power system using combination of Series and Shunt Compensators (Cognitive Knowledge Level : Apply)
CO 5	Develop and promote research interests in controllers for reducing consumer end problems in power systems. (Cognitive Knowledge Level : Apply)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	3	3	3	2
CO 2	3	1	3	3	3	2
CO 3	3	1	3	3	3	2
CO 4	3	1	3	3	3	2
CO 5	3	1	3	3	3	2

Evaluation Pattern

	FACTS AND CUSTOM POWER DEVICES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember			
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create			

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (8 hours)

Power transmission problems and emergence of facts solutions: Fundamentals of ac power transmission, transmission problems, power flow, controllable parameters. Power quality – basic concept. Voltage regulation and reactive power flow control- Needs, emergence of FACTS- Types of FACTS controllers-Advantages and disadvantages - shunt compensation - Series compensation -Phase angle control –basic relationships.

MODULE 2 (7 hours)

Shunt compensators**:** Objectives of shunt compensation-shunt SVCTCR – TSC – Effect of initial charge - combined TCR and TSC configurations – characteristics - Analysis -Elimination of harmonics – Control schemes - Static synchronous compensator (STATCOM) configuration and control, comparison between SVC and STATCOM - Applications- case studies.

MODULE 3 (7 hours)

Series compensators: Static series compensation –Objectives- GCSC – TSSC – TCSC characteristics – Basic Control Schemes - Sub synchronous characteristics- Basic NGH SSR Damper - Static Synchronous Series Compensator (SSSC): Principle of operation – Analysis and characteristics - control scheme..

MODULE 4 **(7 hours)**

Unified power flow controller (UPFC): Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC to the controlled series compensators, control structure and dynamic performance. Interline Power Flow Controller (IPFC) – Basic operating Principles and Characteristics and control schemes.

MODULE 5 (7 hours)

Custom Power Devices**:** Types – configuration – SSCL – SSCB – SSTS – compensation – Filters - Static voltage & phase angle regulator - TCVL- TCVR- TCBR -Distribution STATCOM – Dynamic Voltage Restorer – Unified Power Quality Conditioner – Application of D-STATCOM, DVR and UPQC- case studies.

Reference Books

1. Song, Y.H and Allan. T. Johns, *Flexible AC Transmission Systems (FACTS).* Institution of Electrical Engineers Press, 1st Ed., 1999.
2. Hingorani, L Gyugyi, *Concepts and Technology of Flexible AC Transmission System.* IEEE Press New York, 1st Ed., 2000
3. K R Padiyar, *FACTS Controllers in Power Transmission and Distribution.* New Age International Publishers, 1st Ed., 2007.
4. S Denesh Kumar, *Flexible AC Transmission System.* Anuradha Publishers, 1st Ed., 2013.
5. Ned Mohan, *Advanced Electronics drives- Analysis, Control and Modeling.* John Willey, 1st Ed., 2014
6. Nagrath I J and Kothari S D P, *Modern Power System Analysis*. TMH, 4th Ed., 2011

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (8hrs)	
1.1	Power transmission problems and emergence of facts solutions: Fundamentals of ac power transmission, transmission problems, power flow, controllable parameters.	2
1.2	Power quality – basic concept. Voltage regulation and reactive power flow control- Needs, emergence of FACTS	1
1.3	Types of FACTS controllers - Advantages and Disadvantages	1
1.4	shunt compensation	1

1.5	Series compensation	1
1.6	Phase angle control –basic relationships	2
	Module 2 (7hrs)	
2.1	Shunt compensators: Objectives of shunt compensation-shunt SVCTCR – TSC- Numerical problems	2
2.2	Effect of initial charge	1
2.3	Combined TCR and TSC configurations – characteristics - Analysis	1
2.4	Elimination of harmonics	1
2.5	Static synchronous compensator (STATCOM) configuration and control	1
2.6	Comparison between SVC and STATCOM - Applications- case studies	1
	Module 3 (7hrs)	
3.1	Static series compensation –Objectives- GCSC – TSSC – TCSC characteristics –Numerical problems	2
3.2	Basic Control Schemes - Sub synchronous characteristics	2
3.3	Basic NGH SSR Damper	1
3.4	Static Synchronous Series Compensator (SSSC): Principle of operation – Analysis and characteristics - control scheme.	2
	Module 4 (7hrs)	
4.1	Unified power flow controller (UPFC): Principles of operation and characteristics, independent active and reactive power flow control	2
4.2	Comparison of UPFC to the controlled series compensators, control structure and dynamic performance.	2
4.3	Interline Power Flow Controller (IPFC) – Basic operating Principles and Characteristics and control schemes.	3
	Module 5 (7hrs)	
5.1	Custom Power Devices: Types – configuration – SSCL – SSCB – SSTS – compensation - Filters	2
5.2	Static voltage & phase angle regulator - TCVL- TCVR- TCBR	2
5.3	Distribution STATCOM	1
5.4	Dynamic Voltage Restorer	1
5.5	Unified Power Quality Conditioner – Application of D-STATCOM, DVR and UPQC- case studies	1

Model Question Paper

QP CODE: Pages: 1

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

SECOND SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E203A

Course Name: FACTS AND CUSTOM POWER DEVICES

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. What is power quality? Explain its significance in the power system.
2. Explain the working of TSR and compare it with TCR.
3. What is meant by Sub synchronous Resonance? How is it avoided in series compensation.
4. Explain the basic concept of UPFC control scheme.
5. With a neat diagram, explain the principle of operation of D-STATCOM.

PART B

Answer any five questions. Each question carries 8 marks.

6. What is the purpose of using FACTS devices in a power system? List the different types of FACTS controllers.
7. Explain the effect of initial charge of capacitor in TSC.
8. The particulars of a transmission line with TCR are V=220V, f = 50Hz, X=1.2Ω, Power = 56kW. The maximum current of TCR is 120A. Find i). Phase angle ii). Line current iii)Reactive Power iv).Current through TCR v). Inductive reactance of TCR and delay angle of TCR if the current is 50% of the maximum current.
9. Derive the expression for real and reactive power (P&Q) in UPFC and plot the variation with load angle.
10. Explain the characteristics and control scheme of IPFC
11. What is the need of custom power devices in a power system? What are its advantages
12. What are the objectives of a static voltage regulator? Explain the working principle.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E203B	SOLAR AND WIND POWER CONVERSION SYSTEMS	Elective	3	0	0	3	3

Preamble : Solar and wind power conversion systems together take a lion's share in the whole of renewable energy conversion systems today. This course focuses on the selection, design and utilization of solar and wind power conversion systems. This course equips students to design solar PV and wind power conversion systems.

Prerequisite : Basic course in Power Electronics

Course Outcomes: After the completion of the course the student will be able to

CO 1	Get a solid foundation of solar and wind energy conversion systems (Cognitive knowledge level: Understand)
CO 2	Analysis and design of standalone and grid connected solar PV systems (Cognitive knowledge level: Apply, Analyse)
CO 3	Design various MPPT algorithms of solar PV in detail (Cognitive knowledge level: Apply, Analyse)
CO 4	Analysis and design of grid connected wind conversion systems (Cognitive knowledge level: Apply, Analyse)
CO 5	Understand selection and performance analysis of various aerogenerators (Cognitive knowledge level: Analyse, Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	2	1	3	1
CO 2	2	1	2	1	3	1
CO 3	2	1	2	1	3	1
CO 4	2	1	2	1	3	1
CO 5	2	1	2	1	3	1

Evaluation Pattern

	SOLAR AND WIND POWER CONVERSION SYSTEMS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	10	10	10
Apply	40	40	40
Analyse	40	40	40
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

Solar Cells: Sun and earth- Basic characteristics of solar radiation- solar Cell characteristics- construction- generation of photo electricity- equivalent circuit- losses in solar cells, energy conversion efficiency, effect of variation of solar insolation and temperature on efficiency- types of solar PV- monocrystalline, polycrystalline and thin film- Performance and comparison.

MODULE 2 (7 hours)

Solar PV modules - Series and parallel connection of cells - design and selection of PV module - partial shading of solar cells and modules- measurement of voltage and current- protection- batteries for PV systems- lead acid and lithium-ion batteries- characteristics - charging and discharging rate- protection

MODULE 3 (8 hours)

MPPT Algorithms: open circuit voltage and short circuit current- Perturb and Observe-Incremental conductance- Realisation of MPPT using dc-dc converters- buck, boost and buck-boost- comparison-single axis and dual axis tracking- System level design of standalone and grid connected systems-Inverter topologies – LCL filter- Net Metering- Isolation- grounding and protection- relevant IEEE standards.

MODULE 4 (7 hours)

Wind energy – energy in the wind – aerodynamics - rotor types – forces developed by blades - Aerodynamic models – braking systems – tower - control and monitoring system- design considerations- power curve - power speed characteristics.

MODULE 5 (7 hours)

Choice of electrical generators - wind turbine generator systems- fixed speed induction generator-semi variable speed induction generator-variable speed induction generators with full and partial rated power converter topologies- performance analysis.

References

1. Chetan Singh Solanki, "*Solar Photovoltaics-Fundamentals, Technologies and Applications*", PHI Learning Pvt. Ltd., New Delhi, 2011
2. Anne Labouret and Michel Villoz, "*Solar Photovoltaic Energy*", IET, 2010
3. S.N. Bhadra, D. Kastha and S. Banerje, "*Wind Electrical Systems*", Oxford Uni Press, 2005.
4. Siegfried Heier, Rachel Waddington, "*Grid Integration of Wind Energy Conversion Systems*", Wiley, 2006,
5. John F.Walker & Jenkins. N , "*Wind Energy Technology*", John Wiley and sons, Chichester, UK, 1997.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(7 hours)	
1.1	Sun and earth- Basic characteristics of solar radiation	1
1.2	Solar Cells: solar Cell characteristics- construction- generation of photo electricity- diode equivalent circuit	2
1.3	Losses in solar cells, energy conversion efficiency, effect of variation of solar insolation and temperature on efficiency	2
1.4	Types of solar PV- monocrystalline, polycrystalline and thin film- Performance and comparison	2

	Module 2(7 hours)	
2.1	Solar PV modules - Series and parallel connection of cells - design and selection of PV module	2
2.2	Partial shading of solar cells and modules- measurement of voltage and current- protection	2
2.3	Batteries for PV systems- lead acid and lithium-ion batteries- characteristics - charging and discharging rate- protection	3
	Module 3(8 hours)	
3.1	MPPT Algorithms: open circuit voltage and short circuit current	1
3.2	Perturb and Observe, Incremental conductance	1
3.3	Realisation of MPPT using dc-dc converters- buck, boost and buck-boost- comparison	2
3.4	Single axis and dual axis tracking	1
3.5	System level design of standalone and grid connected PV systems	1
3.6	Inverter topologies - LCL filter	1
3.7	Net Metering- Grounding and protection- relevant IEEE standards	1
	Module 4(7 hours)	
4.1	Wind energy – energy in the wind, aerodynamics	1
4.2	Rotor types – forces developed by blades - Aerodynamic models – braking systems	2
4.3	Tower - control and monitoring system	1
4.4	Design considerations- power curve - power speed characteristics	3
	Module 5(7 hours)	
5.1	Choice of electrical generators	1
5.2	Wind turbine generator systems- fixed speed induction generator- semi variable speed induction generator	3
5.3	Variable speed induction generators with full and partial rated power converter topologies- performance analysis.	3

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E203B

Course Name: SOLAR AND WIND POWER CONVERSION SYSTEMS

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Plot the spectral distribution of extra-terrestrial and terrestrial solar radiation and explain.
2. Discuss about important battery performance parameters of a lead-acid battery to be used in a solar PV stand-alone inverter system.
3. At certain irradiation and ambient temperature, a solar panel has its maximum power point at a panel voltage of 18.5V and current of 4.2A. A boost converter is used for MPPT, delivering power to a 10Ω resistive load. Determine the duty cycle needed for the converter for operation at MPPT at this operating condition.
4. Explain the Power Vs rotor speed characteristics of a typical wind turbine for a fixed pitch wind turbine. Also explain how maximum wind power can be tracked.
5. Explain the significance of Lift and Drag coefficients of wind air-foils.

PART B

Answer any five questions. Each question carries 8 marks.

6. Explain the principle of operation of PN junction solar cell and discuss any realistic equivalent circuit. Also discuss the methods used to improve the solar cell efficiency.
7. Calculate the efficiency and peak power of Si solar cell operating at 27 deg.C, with short circuit current of 2.2 A and operating under standard illumination of 1000W/m2. The area of the solar

cell is 100 cm2. If the operating temperature of the solar cell increases to 35 deg. C, Calculate the efficiency. (Assume FF = 0.75, I0 = 10-12 A).

8. Explain in detail the series-parallel mismatch in PV module configuration and possible remedies.

9. Design a Standalone PV (SPV) system to be used at Cochin (9.9312° N, 76.2673° E) for which the load requirements are given in the table. The system should allow the use of non-sunshine hours for ONE day. The operating hours and power rating of these loads are also given.

Load	**Rating (watts)**	**Hours/day**	**Quantity**
LED Bulb	9	5	3
TV	2000	1	1
BLDC Fan	40	5	2
Computer	250	2	1

10. Explain the circuit configuration and operation of a permanent magnet synchronous generator-based wind power plant.

11. A wind turbine is operating with a tip speed ratio of 5. If the angle of attack is 6 and the wind speed is 10 m/s, determine the blade pitch angle at the tip of the blade.

12. With necessary circuit schematics, explain variable speed induction generators with partial rated power converter topologies.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E203C	DISTRIBUTED GENERATION AND PROTECTION	Elective	3	0	0	3	3

Preamble : The penetration of renewable energy sources into the power system grid is increasing by leaps and bounds. The course will discuss the concept of distributed generation, analyse the impact of grid integration & power quality issues and the design of grid integration of DG sources with dc and ac microgrids. This course will equip students to design grid integration systems for dc and ac micro grids.

**Prerequisite : **Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Review of energy sources and storage devices for distributed generation (Cognitive knowledge level: Understand)
CO 2	Analyze grounding and protection in distributed generation (Cognitive knowledge level: Analyse)
CO 3	Design grid integration systems for dc and ac micro grids (Cognitive knowledge level: Apply)
CO 4	Analyze the power quality issues and control of power flow in dc/ ac microgrids/smart grids (Cognitive knowledge level: Analyse, Evaluate)
CO 5	Analyze power converters and design current control and protection schemes for dc/ ac microgrids/smart grids (Cognitive knowledge level: Apply, Analyse)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	3	2	2	2
CO 2	2	1	3	2	2	2
CO 3	2	1	3	2	2	2
CO 4	2	1	3	2	2	2
CO 5	2	1	3	2	2	2

Evaluation Pattern

	DISTRIBUTED GENERATION AND PROTECTION		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	10	10	10
Apply	40	40	40
Analyse	40	40	40
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (6 hours)

Distributed generation (DG)- DG vs Traditional bulk power generation- Distributed Energy Resources (DER) in DG – Overview of wind power, solar PV, solar thermal- fuel cell, micro CHP and small hydro- basic properties and challenges as DG source- Requirement of energy storage- stabilization- Ride through- dispatchability- Energy storage elements in DG – batteries, ultracapacitors, flywheels, superconducting magnet energy storage

MODULE 2 (7 hours)

Requirements for grid interconnection- IEEE 1547 standard- local electric power system (EPS), area EPS, point of common coupling (PCC)- bulk power system (Macrogrid), DER, planning of DGs – siting and sizing of DGs – limits on operational parameters- enter service- real and reactive power control requirements- response to area EPS abnormal conditions- voltage and frequency ride through requirements- Flicker limit- Total Rated-Current Distortion (TRD)- Grounding considerations.

MODULE 3 (8 hours)

Fault analysis- types of faults- Overview of symmetrical components- sequence representation of distribution networks- fault analysis- overcurrent protection- coordination of relays, reclosers, and sectionalizers and fuses- solid state circuit breaker- digital overcurrent detection (directional)- blinding of protection- sympathetic tripping- Islanding- intentional and unintentional- islanding detection and anti-islanding protection- passive, active and communication based techniques- Case studies.

MODULE 4 **(8 hours)**

Concept and definition of Microgrid- typical structure and configuration of ac microgrid- modes of operation and control- grid connected and islanded mode- Power converter topologies and control schemes for power sharing- droop control- communication based control- grid interactive power converters- features - current control- phase locked loops (PLL) and frequency locked loops (FLL)- Interconnection to grid- current control- Filter design- passive and active damping- active load management, DG active and reactive power dispatch, control of transformer taps- radial, loop and network distribution- voltage regulation and system reconfiguration.

MODULE 5 (7 hours)

DC microgrid- structure- grid connected and isolated modes of operation- overview of power electronic converters for DC microgrid - droop control- active load sharing- Hierarchical Control in DC microgrids

Introduction to smart grids- smart metering- smart grid communication infrastructure, wide area monitoring systems (WAMS)- micro phasor measurement unit (PMU)- power quality issues in smart grids, regulatory standards- Impact of plug in EV- smart grid economics, demand side management and demand response analysis of smart grid- Case studies.

References

1. IEEE Std 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces, DOI: 10.1109/IEEESTD.2015.7317469
2. Distributed Energy Resources: Connection Modeling and Reliability Considerations, Technical Report (NERC 2017)
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11. Mohammad A. Abusara, Georgios I. Orfanoudakis, Babar Hussain, "*Power Electronic Converters for Microgrids*", John Wiley & Sons Singapore, 2014
12. A Keyhani, M Marwali, *"Smart power grids*", Springer, 2011

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(6 hours)	
1.1	Distributed generation (DG)- DG vs Traditional bulk power generation- Distributed Energy Resources (DER) in DG	1
1.2	Overview of wind power, solar PV, solar thermal- fuel cell, micro CHP and small hydro- basic properties and challenges as DG source	2
1.3	Requirement of energy storage- stabilization- Ride through-dispatchability	1
1.4	Energy storage elements in DG – batteries, ultracapacitors, flywheels, superconducting magnet energy storage	2
	Module 2(7 hours)	
2.1	Requirements for grid interconnection- IEEE 1547 standard- local electric power system (EPS), area EPS, point of common coupling (PCC)- bulk power system (Macrogrid)	2
2.2	Planning of DGs – siting and sizing of DGs – limits on operational parameters- enter service- real and reactive power control requirements	2
2.3	Response to area EPS abnormal conditions- voltage and frequency ride through requirements	1
2.4	Flicker limit- Total Rated-Current Distortion (TRD)	1
2.5	Grounding considerations	1
	Module 3(8 hours)	
3.1	Fault analysis- types of faults- Overview of symmetrical components	1
3.2	sequence representation of distribution networks- fault analysis	1
3.3	overcurrent protection- coordination of relays, reclosers, and sectionalizers and fuses	1
3.4	solid state circuit breaker- digital overcurrent detection (directional)-	2

	blinding of protection- sympathetic tripping	
3.5	Islanding- intentional and unintentional- islanding detection and anti-islanding protection- passive, active and communication-based techniques	2
3.6	Case studies	1
	Module 4(8 hours)	
4.1	Concept and definition of Microgrid- typical structure and configuration of ac microgrid	1
4.2	modes of operation and control- grid connected and islanded mode	1
4.3	Power converter topologies and control schemes for power sharing-droop control- communication based control	1
4.4	Grid interactive power converters- features - current control	1
4.5	Phase locked loops (PLL) and frequency locked loops (FLL)	1
4.6	Interconnection to grid- current control- Filter design- passive and active damping	1
4.7	Active load management, DG active and reactive power dispatch, control of transformer taps	1
4.8	radial, loop and network distribution- voltage regulation and system reconfiguration	1
	Module 5(7 hours)	
5.1	DC microgrid- structure- grid connected and isolated modes of operation- overview of power electronic converters for DC microgrid	1
5.2	Droop control- active load sharing- Hierarchical Control in DC microgrids	1
5.3	Introduction to smart grids- smart metering- smart grid communication infrastructure	1
5.4	Wide area monitoring systems (WAMS)- micro phasor measurement unit (PMU)	1
5.5	Power quality issues in smart grids, regulatory standards-Impact of plug in EV	1
5.6	smart grid economics, demand side management and demand response analysis of smart grid	1
5.7	Case studies	1

Model Question Paper

QP CODE: Pages: 1

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E203C

Course Name: DISTRIBUTED GENERATION AND PROTECTION

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Explain the Architecture of Smart Grid System and compare with conventional utility grid.
2. Explain any suitable method for frequency estimation in microgrid.
3. Explain the need for grounding in DG, different grounding schemes and grounding considerations.
4. Explain radial, loop and network distribution in DG.
5. What is meant by Fault Ride-Through Capability of Distributed Generation in Microgrid? How can it be enhanced?

PART B

Answer any five questions. Each question carries 8 marks.

6. Explain any one active anti-islanding detection method in ac microgrid.
7. Explain (i) active load sharing (ii) droop control in DC microgrid and compare.
8. Explain (i) the need for grounding in DG (ii) different grounding schemes and (iii) grounding considerations for DG.
9. Explain micro PMU and the use of wide area monitoring system in Smart Grid.
10. Explain the selection and coordination of relays, reclosers, sectionalizers and fuses for the protection of a radial DG system.
11. Explain a power converter suitable for plug-in EV charger to be used in an ac microgrid.
12. Explain any current control scheme with good dynamic performance in grid connected inverter.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E203D	MULTILEVEL INVERTERS AND MODULATION TECHNIQUES	Elective	3	0	0	3	3

Preamble : This course aims to impart knowledge on the operation, control and operational issues and mitigation techniques of various multilevel inverters and modular multilevel inverters. This course equipy students to identify suitable Multilevel Inverter topology for various applications.

Prerequisite : Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Identify suitable Multilevel Inverter topology (Cognitive knowledge level: Understand)
CO 2	Analyze the performance of the multilevel inverter topology (Cognitive knowledge level: Analyse)
CO 3	Analyze the performance of the multilevel inverter topology (Cognitive knowledge level: Apply, Analyse)
CO 4	Analyze the operational issues and identify suitable mitigation methods (Cognitive knowledge level: Analyse)
CO 5	Identify suitable Modular multilevel Inverter topology and control schemes (Cognitive knowledge level: Analyse, Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	2	1	3	1
CO 2	2	1	2	1	3	1
CO 3	2	1	2	1	3	1
CO 4	2	1	2	1	3	1
CO 5	2	1	2	1	3	1

Evaluation Pattern

	MULTILEVEL INVERTERS AND MODULATION TECHNIQUES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	10	10	10
Apply	40	40	40
Analyse	40	40	40
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (8 hours)

Multilevel (ML) Inverters- Advantages- comparison with two-level inverters - Diode Clamped ML Inverter- Three level and Five level- Flying Capacitor multilevel inverter- Three level and Four levels-Cascaded multilevel inverters-Symmetrical and asymmetrical Topologies of CHB- Derived Multilevel Topologies- ANPC- T-type Multilevel Inverters- Packed U- cell topology- Hybrid Multilevel Topologies- open end winding scheme.

MODULE 2 (6 hours)

Modulation of Two level and Multilevel Inverters – Sinusoidal PWM- Third harmonic and Triple-n harmonic injection PWM- Concept of Space Vectors (SV) - Space Vector Modulation- Discontinuous PWM- basic schemes- advantages - SVM for ML inverters based on two level SVM algorithm.

MODULE 3 (8 hours)

Selection of voltage vectors for PWM- Identification of nearest vectors- duty cycle computation-vector selection and switching- classical approach- Hexagon decomposition method- Method based on hexagonal coordinate system- Identification of nearest vectors and dwell timings- Carrier based space vector modulation- Level shifted and phase shifted PWM-Fundamental frequency control schemes- Introduction to selective harmonic elimination for ML inverters.

MODULE 4 (7 hours)

Operational Issues- Neutral point voltage balancing in Diode Clamped Multilevel inverter- Losses- Capacitor voltage balancing in Flying capacitor Inverters - Charge Balance Using Phase shift PWM- Dynamic voltage balancing- Common mode voltage and reduction of bearing currents.

MODULE 5 (7 hours)

Modular multilevel Converters- Introduction- Advantages- principle of operation-submodule configurations, classical control methods- pulse width modulation schemes- Phase shifted carrier modulation scheme- voltage control- capacitor voltage balancing strategies, circulating current issues and control of circulating current- applications of Multilevel and modular multilevel inverters- applications in power systems- traction and automotive applications- case studies.

References

1. D. Grahame Holmes, Thomas A Lipo, "*Pulse Width Modulation for Power converters- Principles and Practice*", John Wiley and sons, 2003
2. Ersan Kabalc, "*Multilevel Inverters Introduction and emergent topologies"* Academic Press, 2021
3. Daniel W. Hart, *"Power Electronics*", McGrawHill, 2011
4. Bin Wu, " *High Power Converters and AC Drives*". Wiley -IEEE 2006
5. S. Gonzales, S. Verne, M. Valla, "*Multilevel Converters for Industrial Applications*", CRC 2014
6. A.M. Trzynadlowski, "*Introduction to Modern Power Electronics*", Wiley, 2010
7. Nikola Celanovic, and Dushan Boroyevich, "*A Fast Space-Vector Modulation Algorithm for Multilevel Three-Phase Converters*", IEEE Transactions on Industry Applications, Vol. 37, No. 2, March/April 2001
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COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (8 hours)	
1.1	Multilevel (ML) Inverters- Advantages- Comparison with two-level inverters	1
1.2	Diode Clamped ML Inverter- Three level and Five level	1
1.3	Flying Capacitor multilevel inverter- Three level and Four levels	1
1.4	Cascaded multilevel inverters-Symmetrical and asymmetrical Topologies of CHB	1
1.5	Derived Multilevel Topologies- ANPC	1
1.6	T-type Multi-level Inverters- Packed U-cell topology	1
1.7	Hybrid Multilevel Topologies	1
1.8	Open end winding scheme for ML inverters	1

	Module 2 (6 hours)	
2.1	Modulation of Two level and Multilevel Inverters – Sinusoidal PWM	1
2.2	Third harmonic and Triple-n harmonic injection PWM	1
2.3	Concept of Space Vectors (SV) - Space Vector Modulation (SVM) for multilevel inverters	1
2.4	Discontinuous PWM- Basic schemes- Advantages	1
2.5	SVM for ML inverters based on two level SVM algorithm	2
	Module 3 (8 hours)	
3.1	Selection of voltage vectors for PWM- Identification of nearest vectors- duty cycle computation- vector selection and switching-classical approach	2
3.2	Hexagon decomposition method- Identification of nearest vectors and dwell timings	2
3.3	Hexagonal Coordinate System- Identification of nearest vectors and dwell timings	1
3.4	Carrier based space vector modulation- Level shifted and phase shifted PWM	1
3.5	Fundamental frequency control schemes	1
3.6	Selective harmonic Elimination for ML inverters- Introduction	1
	Module 4 (7 hours)	
4.1	Operational Issues- Neutral point voltage balancing in Diode Clamped Multilevel inverter	2
4.2	Losses in ML inverters	1
4.3	Capacitor voltage balancing in Flying capacitor Inverters - Charge Balance Using Phase shift PWM- Dynamic voltage balancing	2
4.4	Common mode voltage and reduction of bearing currents	2
	Module 5 (7 hours)	
5.1	Modular multilevel Converters- Introduction- Advantages- principle of operation-submodule configurations	1
5.2	Classical control methods- Pulse width modulation schemes- Phase shifted carrier modulation scheme- voltage control	2
5.3	Capacitor voltage balancing strategies	1
5.4	Circulating current issues and control of circulating current	1
5.5	Applications of Multilevel and modular multilevel inverters-applications in power systems- traction and automotive applications-case studies	2

Model Question Paper

QP CODE: Pages: 1

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Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E203D

Course Name: MULTILEVEL INVERTERS AND MODULATION TECHNIQUES

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Compare and contrast three level NPC and T-type multilevel inverters.
2. Explain carrier based SPWM technique used in multi-level inverter.
3. With the help of a neat figure, explain phase shifted carrier modulation scheme. Mention the advantages compared to level shifted PWM.
4. Discuss the effect of common mode currents on the bearings and the use of ML inverters to reduce the common mode currents.
5. With a neat figure, explain the space vector modulation of three level inverter based on two-level mapping of space vector diagram.

PART B

Answer any five questions. Each question carries 8 marks.

6. Illustrate the circulating current issues in Modular multilevel inverters and the control of circulating current.
7. Explain different types of voltage control techniques used in Modular Multilevel Converters.
8. Explain discontinuous PWM in two-level and Multi-level inverters.
9. Illustrate the operation of four-level flying capacitor inverter and any capacitor balancing scheme
10. Explain hexagonal decomposition PWM for three level inverters.
11. Draw the circuit of a five-level cascaded multilevel inverter and explain its working. Also explain any fundamental frequency voltage control scheme.
12. Explain the neutral point voltage balancing issues in NPC inverters and discuss any one of the one possible remedy.

PROGRAM ELECTIVE 4

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E204A	DIGITAL CONTROL SYSTEM DESIGN	Elective	3	0	0	3	3

Preamble: This course aims to introduce the design process and state space analysis for a digital control system, and its significance in modern engineering. It outlines the Z-Plane analysis of discrete-time Systems, design of digital controllers in frequency domains and design using state space approach. .After completion of this course student is equipped to design a robust digital controller capable of meeting the demands of diverse applications and also to meet the performance requirements.

Prerequisite: Signals And Systems, Linear Control Systems, Advanced Control Systems

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand Z-transforms and components of digital control systems. .(Cognitive Knowledge Level – Understand)
CO 2	Analyze discrete-time system and evaluate its performance .(Cognitive Knowledge Level – Analyze)
CO 3	Design suitable digital controller for the system to meet the performance specifications in time domain . (Cognitive Knowledge Level – Apply)
CO 4	Design a digital controller for the system to meet its performance in frequency domain (Cognitive Knowledge Level – Apply)
CO 5	Design suitable digital controller for discrete time systems by using state space approach and analyse its performance .(Cognitive Knowledge Level – Analyse)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	2	2	2	2
CO 2	3	1	3	2	2	2
CO 3	3	1	3	2	2	2
CO 4	3	1	3	2	2	2
CO 5	3	1	3	2	2	2

Evaluation Pattern

	DIGITAL CONTROL SYSTEM DESIGN		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	40	40	40
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (6 hours)

Z-Plane Analysis of Discrete-Time Systems: Review of Z Transforms- Basic digital control system- Examples - mathematical model - choice of sampling and reconstruction-ZOH and FOH - Mapping between the s-plane and the z-plane

MODULE 2 (6 hours)

Pulse transfer function- Different configurations for the design- Stability analysis of closed-loop system in the z-plane- Jury's test, Schur-Cohn test, Bilinear Transformation, Routh-Hurwitz method in w-plane

MODULE 3 (7 hours)

Digital Controller Design Based on Root locus Approach: Direct design based on root locus. Design of

Lag Compensator-Design of Lead Compensator-Design of Lead-Lag Compensator

MODULE 4 (7 hours)

Digital Controller Design in Frequency Domain: Direct design based on frequency response - Design of Lag Compensator-Design of Lead Compensator-Design of Lag-Lead Compensator-

MODULE 5 (10 hours)

Design using State Space approach: Introduction to state space - state space modelling of discrete time SISO system -Computation of solution of state equation and state transition matrix. Controllability and observability of discrete time systems- Loss of controllability and observability due to sampling. Digital controller and observer design -state feedback – pole placement - full order observer - reduced order observer -placing poles in a multivariable system.

References

1. K. Ogata, *Discrete-Time Control Systems*. Pearson Education, Asia, 2nd Ed., 2010
2. M. Gopal, *Digital Control and State Variable Methods*. Tata McGraw-Hill, 1st Ed. ,1997
3. C. L. Philips, H. T. Nagle, A Chakrabortty , *Digital Control Systems Analysis and Design*. Pearson Education Limited, 3rd Ed., 2015
4. Benjamin C. Kuo, *Digital Control Systems*. Oxford University Press, 3rd Ed., 2007
5. Gene F. Franklin, J. David Powell, Michael Workman, *Digital Control of Dynamic Systems*. Pearson, Asia, 6th Ed.,2015
6. M .Sami Fadali ,Antonio Visoli , *Digital Control Engineering.* Academic Press, 1st Ed., 2009
7. James R. Leigh, *Applied Digital Control: Theory, Design, and Implementation*. Prentice-Hall, 2nd Ed., 2001
8. Frank L. Lewis, *Applied Optimal Control & Estimation*. Prentice-Hall, 2nd Ed., 2009

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(6 hours)	
1	z-Plane Analysis of Discrete-Time Systems	
1.1	Review of Z Transforms	2
1.2	Inverse Z transform	1
1.3	Basic digital control system- Examples - mathematical model -	1
1.4	Choice of sampling and reconstruction-ZOH and FOH	1
1.5	Relation between s and z - Mapping between s-domain and z-domain	1
	Module 2(6 hours)	
2.1	Pulse transfer function- Different configurations for the design	2
2.2	Stability analysis of closed-loop system in the z-plane- Jury’s test, Schur-Cohn test	2
2.3	Bilinear Transformation, Routh-Hurwitz method in w-plane	2
	Module 3(7 hours)	
3	Digital Controller Design Based on Root locus Approach	
3.1	Direct design based on root locus	2
3.2	Design of Lag Compensator	2
3.3	Design of Lead Compensator	2

3.4	Design of Lag-Lead Compensator (Theory only)	1
	Module 4(7 hours)	
4	Digital Controller Design in Frequency Domain:	
4.1	Direct design based on frequency response	1
4.2	Design of Lag Compensator	2
4.3	Design of Lead Compensator	2
4.4	Design of Lag-Lead Compensator (Theory only)	2
	Module 5(10 hours)	
	Design using State Space approach:	
5.1	Introduction to state space	1
5.2	Computation of solution of state equation and state transition matrix. (Second order systems)	2
5.3	Controllability and Observability of systems	2
5.4	Loss of controllability and observability due to sampling	1
5.5	State feedback controller based on pole placement.	1
5.6	Observer design based on pole placement.	2
5.7	Pole placement in multivariable system (Algorithm only)	1

Model Question Paper

QP CODE: Pages: 3

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E204A

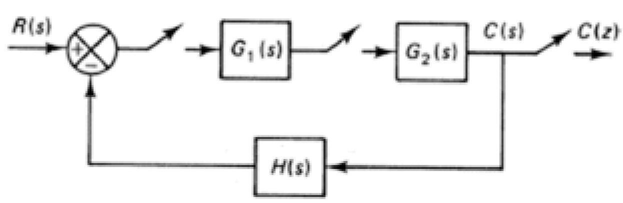
Course Name: DIGITAL CONTROL SYSTEM DESIGN

Max. Marks:60 Duration: 3 hours

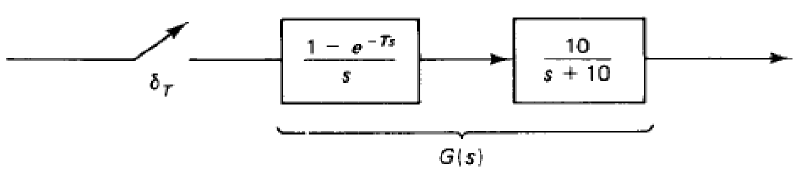
PART A

Answer all questions. Each question carries 4 marks.

1. Given z-transform $X(z) = \frac{(1-e^{-aT})z}{(z-1)(z- e^{-aT})}$ where a is a constant and T is the sampling period, determine the inverse z- transform x(kT)
2. Evaluate $C(z)$ for the given system.



3. Examine magnitude and phase angle condition of a system for root locus.
4. Consider the transfer function system shown below. The sampling period T is assumed to be 0.1 sec. Obtain G(w)



5. Develop controllable canonical form and observable canonical form of the given system.

$$\frac{Y(Z)}{U(Z)} = \frac{Z+1}{Z^2 + 1.3\,Z \;+\; 0.4}$$

PART B

Answer any five questions. Each question carries 8 marks.

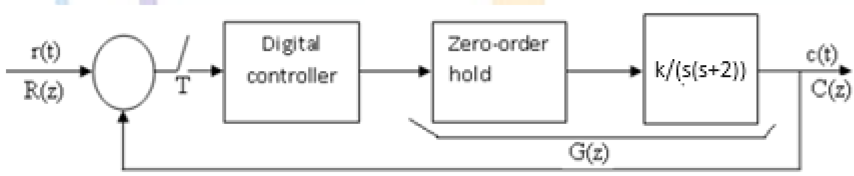
6. Draw and explain the block diagram of a basic digital control system.
7. Obtain the z transform of :

$$x(t) = \begin{cases} \sin\omega t\,, & 0 \le t \\ 0\,, & t < 0 \end{cases}$$

$$f(a) = \begin{cases} a^{k-1}\,, & k = 1, 2, 3 \ldots \\ 0\,, & k \le 0 \end{cases}$$

8. Suppose the characteristic equation of a system is given by
   $P(z) = 2z^4 + 7z^3 + 10z^2 + 4z + 1$
   Examine stability using Jury's Stability theorem

9. For the system shown, design a digital controller, to meet the following specifications:



   i. Velocity error constant Kv =6
   ii. Peak overshoot to step input ≤ 15%
   iii. Settling time ≤ 5 sec

10. Elaborate the steps involved in the design of a lag compensator, based on frequency response method.

11. Consider the system x(k + 1) = Ax(k) + Bu(k), y(k) = Cx(k) where
    A = $\begin{bmatrix} -2 & 1 \\ 1 & -2 \end{bmatrix}$, $B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ and C = [0 1]
    Show if the system is controllable. Find the transfer function $\frac{Y(z)}{U(z)}$. Identify any connection between controllability and the transfer function.

12. Determine the state feedback gain matrix K for the following system

$$x(k+1) = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix} x(k) + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(k),$$

such that the closed loop poles are located at 0.5, 0.6 and 0.7.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E204B	POWER SYSTEM DYNAMICS AND STABILITY	Elective	3	0	0	3	3

Preamble : This course deals with all the power system operational dynamics and stability aspects including case studies. It will equip students to perform small signal stability and transient stability analysis of power system. Also, they will be capable of evaluating various power system stability enhancement methods.

Prerequisite : Basic course on power system

Course Outcomes: After the completion of the course the student will be able to

CO 1	Model the essential elements of power system. (Cognitive knowledge level: Understand, Apply)
CO 2	Perform the small signal stability analysis of power system. (Cognitive knowledge level: Analyse)
CO 3	Perform transient stability analysis of power system. (Cognitive knowledge level: Analyse)
CO 4	Apply different voltage stability criteria in power system. (Cognitive knowledge level: Apply)
CO 5	Evaluate different power system stability enhancement methods. (Cognitive knowledge level: Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	1		1	2	2	
CO 2	1	1	1	2	2	1
CO 3	1	1	1	2	2	1
CO 4	1	1	1	2	2	1
CO 5	1	1	1	3	3	1

Evaluation Pattern

	POWER SYSTEM DYNAMICS AND STABILITY		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	30	30	40
Analyse	30	30	40
Evaluate	20	20	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (8 hours)

Structure of power System and its controls. Concept of Power System Stability-Types of stability. Modelling Power System Components**:** Synchronous machine modelling: Mathematical Description of a Synchronous Machine - Basic equations of a synchronous machine. flux linkage equations, inductance matrix, Stator to stator self-inductance, mutual inductance, stator to rotor inductance, rotor to rotor inductance, Derivation of parks transformation matrix, physical concept, Inductance matrix in dqO frame.

MODULE 2 (7 hours)

Synchronous Machine Modelling (Continuation): voltage equations in stationary and dqO frame, Equivalent circuit for direct and quadrature axis, Per unit representation, Steady state equivalent circuit, Excitation system modelling, static excitation system only.

MODULE 3 (7 hours)

Small Signal Analysis**:** System state space representation, Eigen value and stability, Eigen vectors, state transition matrix, small signal stability of SMIB system, Effect of field flux variation on stability, Effect of exciter with AVR on stability, small signal stability enhancement by PSS.

MODULE 4 **(7 hours)**

Transient Stability: An Elementary View of Transient Stability. Response to a Step Change in Pm, Equal-Area Criterion, Response to a Short-Circuit Fault, Effect of short circuit at midpoint of one of the transmission lines of double circuit line, Effect of short circuit at sending end. Transient stability enhancement techniques.

MODULE 5 (7 hours)

Voltage stability: Concept of reactive power variation at sending end and receiving end of a simple system, Voltage stability analysis of PQ curve, QV curve and PV curve, generator steady state PQ capability curve, generator QV curves, Transmission characteristics on voltage stability, Static and dynamic characteristics of load components, Sensitivity analysis, voltage collapse and its prevention

References

1. Kundur P, *"Power System Stability and Control*", TMH, 3rd edition, 2000
2. Anderson and Fouad, "*Power System Control and Stability*", Galgotia Publications, Compensation 1981
3. Ramanujam R, "*Power System Dynamics- Analysis & Simulation*", PHI learning Private Limited, 2010.
4. Padiyar K R, "Power System Dynamics", 2nd Edition, B.S. Publishers, 2003.
5. Sauer P W & Pai M A," *Power System Dynamics and Stability*", Pearson, 2003.
6. Olle I Elgerd, "*Electric Energy Systems Theory an Introduction*", 2nd Edition, McGraw-Hill, 1983.
7. Kimbark E W, "*Power System Stability",* McGraw-Hill Inc., 1994, Wiley & IEEE Press, 1995.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(8 hours)	
1.1	Structure of power System and its controls	1
1.2	Concept of Power system stability-Types of stability	1
1.3	Synchronous Machine Mathematical Description of a Synchronous Machine. Basic equations of a synchronous machine	2
1.4	Flux linkage equations, inductance matrix, Stator to stator self-inductance, mutual inductance, stator to rotor	2

	inductance, rotor to rotor inductance	
1.5	Derivation of parks transformation matrix, physical concept	1
1.6	Inductance matrix in dqO frame	1
	Module 2(7 hours)	
2.1	voltage equations in stationary and dqO frame	1
2.2	Equivalent circuit for direct and quadrature axis	2
2.3	Per unit representation	1
2.4	Steady state equivalent circuit	1
2.5	Excitation system modelling, static excitation system only	2
	Module 3(7 hours)	
3.1	System state space representation, Eigen value and stability, Eigen vectors, state transition matrix	2
3.2	Small signal stability of SMIB system	1
3.3	Effect of field flux variation on stability, Effect of exciter with AVR on stability	2
3.4	Small signal stability enhancement by PSS	2
	Module 4(7 hours)	
4.1	An Elementary View of Transient Stability	1
4.2	Response to a Step Change in Pm, Equal-Area Criterion	1
4.3	Response to a Short-Circuit Fault	1
4.4	Effect of short circuit at midpoint of one of the transmission lines of double circuit line, Effect of short circuit at sending end.	2
4.5	Transient stability enhancement techniques	2
	Module 5(7 hours)	
5.1	Concept of reactive power variation at sending end and receiving end of a simple system	2
5.2	Voltage stability analysis of PQ curve, QV curve and PV curve	1
5.3	Generator steady state PQ capability curve, generator QV curves	1
5.4	Transmission characteristics on voltage stability, Static and dynamic characteristics of load components	2
5.5	Sensitivity analysis, voltage collapse and its prevention	1

Model Question Paper

QP CODE: Pages: 1

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E204B

Course Name: POWER SYSTEM DYNAMICS AND STABILITY

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Draw and explain power system control hierarchy?
2. Discuss the assumptions made in developing the equations of synchronous machines?
3. Explain rotor angle stability and how does the small disturbances effect on its stability?
4. Explain the Power-Angle relationship of synchronous machines in a power system.
5. Describe the principal factors contributing to voltage collapse.

PART B

Answer any five questions. Each question carries 8 marks.

6. Explain the basic structure of power system with necessary diagram.
7. Synchronous machine inductances are functions of rotor position. Justify?
8. Describe the state space representation and stability of a dynamic system?
9. Draw the small signal stability block diagram representation with constant field voltage and comment about its stability aspects.
10. What is single pole switching and what are the problems that arise in application of this method?
11. Explain static analysis used for voltage stability.
12. Conclude the significance inference from PV curve & QV curve and comment about the stable operating point & collapse region.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E204C	DESIGN OF POWER ELECTRONIC SYSTEMS	Elective	3	0	0	3	3

Preamble: Proper design and selection of power electronic components is crucial for the successful and reliable operation of power electronic products. This course enables the students to design suitable gate drives, power stage and cooling systems for power electronic converters meeting EMC standards

Prerequisite: A basic course on Power Electronics is desirable as prerequisites for the course.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop gate drive schemes for different types of switching devices after understanding pertinent limitations of simple drive schemes (Cognitive knowledge level: Understand, Apply)
CO 2	Analyse different gate drive schemes and design protection circuits and snubbers (Cognitive knowledge level: Analyse, Apply, Evaluate)
CO 3	Do loss calculation and design cooling systems (Cognitive knowledge level: Apply, Analyse)
CO 4	Design of magnetics, filter capacitors and bus bars (Cognitive knowledge level: Apply)
CO 5	Design of power converters for Electromagnetic Compatibility (Cognitive knowledge level: Apply)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	1		3			
CO 2	1		2		3	
CO 3	1		2		3	
CO 4	2	1			3	
CO 5		1		3	2	

Evaluation Pattern

	DESIGN OF POWER ELECTRONIC SYSTEMS		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyse	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

High frequency diodes- reverse recovery issues- fast and soft recoveryschottky diodes- loss computation in diodes- base/gate drive requirements – design of base/gate drive for Power transistors, MOSFET and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping - cascode transistor driver- gate drive considerations for SiC MOSFET- Gate drive power requirements-Protection in drive circuits- dead time requirements- overcurrent and desaturation protection- Noise suppression- ferrite beads- pcb layout considerations for gate drives

MODULE 2 (7 hours)

Snubber circuits- Need for snubber- diode snubbers - Safe Operating Area (SOA) of switching devices-Device loss computation with and without snubber design of turn-off and turn-on snubbers- energy recovery snubbers- snubber for bridge circuit configurations.

MODULE 3 (7 hours)

Cooling and design of heat sinks- heat transfer by conduction, radiation and convection- thermal analogy- control of device temperature- selection of heat sink- thermal resistance due to radiation and convection-natural cooling-Forced air cooling- pulsed power and transient thermal impedance.

MODULE 4 (8 hours)

Design of inductors -selection of core material and size- core loss and winding losses- reduction of skin effect- leakage inductance- design of high frequency transformers for sine wave and square wave inverters, push-pull, half bridge, full bridge, fly back and forward converters- selection of filter capacitors- bus bars- Case study: design of buck converter, quadratic buck, fly black and single phase PWM rectifier

MODULE 5 (7 hours)

EMI and EMC- Introduction- characteristics of switching processes of power devices- Electromagnetic compatibility (EMC)- conductive and radiative EMI- standards- reduction of EMI- common mode filter-LISN- Shielding of cables and transformers- PCB layout considerations - Case study: buck converter, forward and fly black converters

References

1. Ned Mohan, Tore M. Undeland and William P.Riobbins, " *Power Electronics— Converters, Applications and Design*" Third Edition, John Wiley and Sons. Inc2014
2. L. Umanand, "*Power Electronics-Essentials and Applications*", Wiley, 2014
3. Daniel W. Hart, "*Power Electronics*", Tata McGraw Hill, 2011
4. H.W. Whittington et al., "*Switched Mode Power Supplies- Design and Construction",* University Press, 1997
5. Francois Costa et al., "*Electromagnetic compatibility in Power Electronics*", Wiley Iste, 2014
6. Joseph Vithayathil, "*Power Electronics-Principle and Applications''*, Tata McGraw Hill Education Pvt Ltd, 2010.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(7 hrs)	
1.1	High frequency diodes- reverse recovery issues- fast and soft recovery- schottky diodes- loss computation in diodes	1
1.2	Base drive requirements - design of base drive for Power transistors- dc coupled drive circuits- isolated drive circuits,cascode driver	1
1.3	Gate drive requirements- Design of base gate drive for MOSFETs and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping	1

1.4	Gate drive considerations for SiC MOSFET	1
1.5	Gate drive power requirements	1
1.6	Protection in drive circuits- dead time requirements - overcurrent and desaturation protection	1
1.7	Noise suppression- ferrite beads- pcb layout considerations for gate drives	1
	Module 2(7 hrs)	
2.1	Snubber circuits- Need for snubber- diode snubbers	1
2.2	Safe Operating Area (SOA) of switching devices- device loss computation with and without snubbers	2
2.3	Design of turn-off and turn-on snubbers	2
2.4	Energy recovery snubbers	1
2.5	snubber for bridge circuit configurations	1
	Module 3(7 hrs)	
3.1	Cooling and design of heat sinks- heat transfer by conduction, radiation and convection	2
3.2	Thermal analogy- control of device temperature	1
3.3	Selection of heat sink	1
3.4	Thermal resistance due to radiation and convection- Natural cooling	1
3.5	Forced air cooling of heat sinks	1
3.6	Pulsed power and transient thermal impedance	1
	Module 4(8 hrs)	
4.1	Design of inductors -selection of core material and core size	1
4.2	Core loss and winding losses	1
4.3	Reduction of skin effect and leakage inductance	1
4.4	Design of high frequency transformers for sine wave and square wave inverters	1
4.5	Design of high frequency transformer for push-pull, half bridge, full bridge	1
4.6	Design of high frequency transformers for Fly back and forward converters	1
4.7	Selection of filter capacitors, Design of bus bars	1
4.8	Case study: design of buck converter, quadratic buck, fly black converter and single phase PWM rectifier	1
	Module 5(7 hrs)	
5.1	EMI and EMC- Introduction	1
5.2	Characteristics of switching processes of power devices	1
5.3	Electromagnetic compatibility (EMC)- conductive and radiative EMI- standards	1
5.4	Reduction of EMI- common mode filter- LISN	1
5.5	Shielding of cables and transformers	1
5.6	PCB layout considerations	1
5.7	Case study: buck converter, forward and fly black converters	1

Model Question Paper

QP CODE: Pages: 3

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E204C

Course Name: DESIGN OF POWER ELECTRONIC SYSTEMS

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. List the important drive requirements of a good BJT drive.
2. An RCD snubber is used in a MOSFET based laptop car battery adapter (12 V to 19 V, 2.5 A current output). Calculate the turn-off loss with and without the snubber. The MOSFET is switched at 100kHz and the MOSFET has a turn-off delay time of 90ns and current fall time of 80ns.
3. What do you mean by thermal resistance? Explain how its value can be reduced in a heat sink? Also explain the electrical equivalent model of a typical heat sink arrangement.
4. Calculate the skin depth at 2kHz, and at 200kHz for enamelled copper conductors and hence suggest the conductor(s) size to carry a current of 5A RMS at these frequencies. Justify the selection.
5. Explain the PCB layout considerations in a flyback converter for EMI reduction.

PART B

Answer any five questions. Each question carries 8 marks.

6. A MOSFET needs 250nC of total gate charge to turn ON. Determine the gate current needed if the MOSFET needs to be turned ON in about 350ns. Draw a suitable gate drive scheme. If the MOSFET is used in an application where the switching frequency is 25kHz, what is the minimum duty cycle percentage possible if the device turn-OFF time is 250ns.

7. Explain the need for snubber network for fast recovery diodes and obtain design equations for the snubbers and draw the instantaneous voltage, current and power waveforms across a typical IGBT during turn-off, without and with an RCD snubber
8. (a) A power pulse of 500W with a 10µs duration and a duty cycle of 0.2 occurs in a MOSFET that has transient thermal resistance characteristics as shown in figure below. Determine the maximum junction temperature, if the case temperature is 80°C.

   (b) A student used IRFZ44 MOSFET without any heatsink in a switching regulator application where the switching loss is 1.5W and conduction loss is 0.85W. The thermal resistance RΘj-a of the MOSFET is 62°C/W. What is the typical temperature at the junction at this operating condition? Is the design acceptable? Give your comments.
9. (a) Select suitable airgap length and number of turns for the transformer in a forward converter. Use EE42/21/20 ferrite core. It is given that battery Voltage=12V, Output voltage=200V, Output power=20W, Switching frequency=25kHz. Make suitable assumptions.

   (b) An inductor is constructed with a U-shaped ferrite core.The core has an area of cross section 200mm2 and mean magnetic path length of 12 cm. The relative permeability of the core is 3000. Calculate the inductance when 55 turns are used for the coil. What is the value of inductance when an air-gap of 4mm is introduced in the flux path?
10. (a) Design and select each component of a suitable dc-dc converter with input voltage 100V and output voltage of 10V. Output power = 2000W. Switching frequency 10 kHz, Assume all other required data. Justify your selection of components.
11. (a) Draw the circuit diagram of a forward converter operating at 50kHz, power being drawn from 230V, 50Hz mains. Identify the possible conducted noise emission sources and explain the means to reduce EMI.

    (b) In a flyback converter, the dc input voltage is 320V and output voltage is 20V. The transformer has a turns ratio of 10:1 and a leakage inductance of 400µH as measured on the high voltage side. The transistor which can be considered as an ideal switch, is driven by a 50KHz square wave. The fast recovery diode of the converter has a reverse recovery time of 100ns (i) Draw the circuit diagram and an equivalent circuit suitable for diode snubber design calculations (ii) Determine suitable snubber capacitor and resistance for the diode.
12. A 5V microcontroller PWM port has current sourcing/sinking capability of 10mA only. Hence, a transistor-based gate drive circuit is needed as the gate driver to drive a power MOSFET in a 5V to 19V boost converter application (i) Draw the circuit diagram of the microcontroller interface and the driver (ii) Design a gate driver circuit so that the MOSFET can operate properly at a switching frequency of 100kHz. Make suitable assumptions.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E204D	ELECTRIC VEHICLE SYSTEM DESIGN	Elective	3	0	0	3	3

Preamble : Electric vehicles are currently the dominant technologies in the new generation of automobiles. Electrical vehicles integrate many subsystems and reliable operation of all subsystems is essential for the smooth working of EVs. This course covers the design aspects of EVs including vehicle dynamics, battery pack, battery management system and control of motor drives.

Prerequisite : Basic course in Power Electronics and Electric Drives

Course Outcomes: After the completion of the course the student will be able to

CO 1	Analyse vehicle dynamics with various traction forces in an electric vehicle(Cognitive knowledge level: Analyse)
CO 2	Apply the concepts of battery management systems and design battery pack for EVs (Cognitive knowledge level: Apply)
CO 3	Model and design EV motor drive and control based on PMSM (Cognitive knowledge level: Apply)
CO 4	Model conductive and inductive charging circuits used in EVs (Cognitive knowledge level: Evaluate)
CO 5	Understand basic charging requirements (Cognitive knowledge level: Understand)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	2				
CO 2	3	2	2	2		3
CO 3	3	2	2			
CO 4	3	2	2	2	2	2
CO 5						

Evaluation Pattern

	ELECTRIC VEHICLE SYSTEM DESIGN		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End Semester Examination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	30	30	30
Analyse	40	40	40
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application,analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

Vehicle Dynamics & Load Forces: Power - Energy and Speed Relationship; Calculation of range; Vehicle Load Forces: Aerodynamic Drag – Calculation of aerodynamic drag force and power with no wind and windy conditions; Rolling Resistance - Calculation of rolling resistance force and power - Grading Resistance; Vehicle Acceleration - motive force (road load force) and motive torque - axle torque - traction torque; Calculation of motor power from traction torque - Vehicle acceleration by neglecting the load forces – calculation of acceleration time and acceleration energy.

MODULE 2 (7 hours)

Batteries and Battery Packs: Battery Pack– calculation of cells in pack (series and parallel)-calculation of battery pack weight from single cell weight - units of battery energy storage - capacity

Rate; Battery Parameters- cell voltage - specific energy - cycle life - self-discharge; Lifetime and Sizing Considerations -Time and charge/discharge cycles - Lifetime – Beginning of life (BOL) - End of life (EOL) - DOD - Examples of Battery Sizing; BMS - Battery Charging - Protection and Management Systems; Static battery equivalent circuit model - Series-parallel battery pack equivalent circuits - Efficiency of Battery Pack - Determination of pack Voltage, Range for EV - Determination of Cell/Pack Voltage for a Given Output\Input Power.

MODULE 3 (7 hours)

EV Machine Control: Motoring using a PM DC Machine - DC motor electric drive using dc-dc converter - Generating/Braking using a PM DC Machine - Motoring in Reverse; Review of PMSM dynamic equations - Equivalent circuit of PMSM in dq axis- Torque Equation; PMSM control - Control architecture of PMSM using the coordinate transformation map.

MODULE 4 (7 hours)

Design of EV controller using PMSM**:** Machine sizes under same power rating – Current Voltage and Speed Limits; Torque versus Current Angle - constant power speed range (CPSR) - Torque Speed Profile - constant power speed range; MTPA, MTPV.
EV motor requirements - Method of drawing torque-speed curve - (torque, power, current angle) using any computing tool - PMSM control in practice: Coil resistance measurement -back emf measurement - inductance measurement; Experiment for determining reference current Table - EV control block diagram with current look up table (LUT) and voltage anti-windup.

MODULE 5 (8 hours)

Battery Charging**:** Basic requirements for charging system - Charger architectures for onboard and offboard chargers, Constant Current and Constant Voltage (CC-CV) charging- V2G operation -input power factor correction, IEEE519, Wireless charging schemes; Charging standards-Automotive standard charger, SAE J1772 - Voltage and current levels, VDE-AR-E 2623-2-2, IEC 62196, DC charging technology - CHAdeMo, Combined Charging System (CCS) charger.

References

1. John G. Hayes ,G. Abas Goodarzi, "*Electric Powertrain : Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles*", John Wiley & Sons Ltd, 1st Ed., 2018
2. Kwang Hee Nam, *"AC Motor Control and Electrical Vehicle Applications*",CRC Press , 2nd Edition ,2019
3. John M. Miller, *"Propulsion Systems for Hybrid Vehicles",* Published by The Institution of Engineering and Technology, London, United Kingdom, 2nd Edition, 2010.
4. K. T. Chau, *"Electric Vehicle Machines And Drives Design, Analysis And Application*", John Wiley & Sons Singapore Pte. Ltd,3rd edition 2015.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (7 hours)	
1.1	Power, Energy, and Speed Relationship and calculation of range.	1
1.2	Vehicle Load Forces: Aerodynamic Drag – Calculation of aerodynamic drag force and power with no wind and windy conditions, Rolling Resistance - Calculation of rolling resistance force and power, Grading Resistance	2
1.3	Vehicle Acceleration: motive force (road load force) and motive torque - axle torque - traction torque	2
1.4	Calculation of motor power from traction torque – Vehicle acceleration by neglecting the load forces – calculation of acceleration time and acceleration energy	2
	Module 2 (7 hours)	
2.1	Battery Pack– calculation of cells in pack (series and parallel), Calculation of Battery pack weight from single cell weight, Units of Battery Energy Storage, Capacity Rate, Battery Parameters-cell voltage, specific energy, cycle life, self-discharge	2
2.2	Lifetime and Sizing Considerations -Time and charge/discharge cycles, Lifetime, Beginning of life (BOL), End of life (EOL), DOD - Examples of Battery Sizing	2
2.3	BMS - Battery Charging, Protection, and Management Systems- Static battery equivalent circuit model. Series-parallel battery pack equivalent circuits - Efficiency of Battery Pack - Determination of pack Voltage Range for EV - Determination of Cell/Pack Voltage for a Given Output\Input Power	3
	Module 3 (7 hours)	
3.1	Motoring using a PM DC Machine - DC motor electric drive using dc-dc converter - Generating/Braking using a PM DC Machine - Motoring in Reverse	3
3.2	Review of PMSM dynamic equations - Equivalent circuit of PMSM in dq axis- Torque Equation	2
3.3	PMSM control - Control architecture of PMSM using the coordinate transformation map	2
	Module 4 (7 hours)	
4.1	Machine sizes under same power rating- Current Voltage and Speed Limits	1
4.2	Torque versus Current Angle- constant power speed range (CPSR)- Torque Speed Profile- constant power speed range, MTPA- MTPV	2
4.3	EV motor requirements- Method of Drawing Torque-Speed Curve - (torque, power, current angle) using any computing tool- PMSM control in practice: Coil resistance measurement, back emf	4

	measurement, inductance measurement, Experiment for determining reference current Table - EV control block diagram with current LUT and voltage anti-windup.	
	Module 5 (8 hours)	
5.1	Basic Requirements for Charging System- Architectures for onboard charging	2
5.2	Offboard charger's architecture	1
5.3	Constant Current and Constant Voltage (CC-CV) charging-V2G operation	1
5.4	Input power factor correction, IEEE519, Wireless charging schemes	2
5.5	Automotive standard charger SAE J1772 levels- Voltage and current, VDE-AR-E 2623-2-2-IEC 62196, DC charging technology - CHAdeMo.-Combined Charging System (CCS) charger.	2

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E204D

Course Name: *ELECTRIC VEHICLE SYSTEM DESIGN*

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Estimate the range of an electric vehicle at 120 km/h with battery energy of 90 kWh, efficiency of the powertrain from the battery to the transmission is 85%. Take road-load force constants as A= 177.2, B= 1.445 and C=0.354.
2. Calculate the number of cells required in series and parallel modules of a battery pack used in an EV bike with a motor of rating 480W 48V with a back-up of 10hours. Also, find the weight of the battery pack if a Li-ion battery of 3.6V, 2000mAh cells having weight of 65grams are used.
3. A two pole IPMSM is running at 3600 rpm in the steady state. The stator coil resistance is rs = 0.01 Ω. The operating conditions are:

   phase voltage V^{8}_{abc} = -100 $[\sin\left(377t+\frac{\Pi}{3}\right), \sin\left(377t-\frac{\Pi}{3}\right), \sin(377t-\Pi)]^{T}$

   back emf e^{8}_{abc} = -125 $[\sin(377t), \sin\left(377t-\frac{2\Pi}{3}\right), \sin\left(377t-\frac{4\Pi}{3}\right)]^{T}$

   current i^{8}_{abc} = -50 $[\sin\left(377t+\frac{\Pi}{4}\right), \sin\left(377t-\frac{5\Pi}{12}\right), \sin\left(377t-\frac{13\Pi}{12}\right)]^{T}$

   Determine Ld and Lq.
4. Derive the expression for i_{de} for a PMSM to achieve the maximum torque per ampere (MTPA).
5. Differentiate between conductive dc charging and inductive ac charging related to battery charging.

PART B

Answer any five questions. Each question carries 8 marks.

6. Derive expressions for calculating acceleration time and acceleration energy.
7. Estimate the 0 to 60 mph acceleration time and energy for the 2015 Nissan Leaf as per

the parameters given in the table below. Ignore all road loads and the internal moment of inertia assuming a gear efficiency of 97%.

	Unit	Rated Speed	Max. Speed
Vehicle speed	Km/h	43.6	144
Rotor angular speed	Rad/s	314.96	1040
Rotor frequency	Hz	50.13	165.52
Rotor rpm	rpm	3008	9931

8. Determine the beginning-of-life kilowatt-hour storage required in an EV battery pack based on the following requirements: eight years of operation, an average of 48 km of driving per day sday over the 365 days of the year, daily charging, and an average battery output energy per kilometre, Ekm = 180 Wh/km. Assume L = 1 and N100% =1000. Assume two parallel battery strings with 96 Li-ion cells per string, with a total number of cells Ncell = 192, and a nominal voltage of 3.75 V per cell. Determine the ampere-hours per cell. What are the vehicle ranges at BOL and EOL?
9. Derive the battery voltage, Vb, as a function of Ib and DOD from the static battery equivalent circuit model of battery. Calculate the voltage range for a cell used in a HEV application with a DOD of 25% to 75% and a load ranging from no-load to a full load of 6C. Also, find the battery pack voltage if there are 192 cells arranged with 96 cells in series and two strings in parallel.

10. A PM dc machine is used as the traction motor for an electric vehicle. The basic specifications for the machine are Pr(rated) = 80 kW and Tr(rated) = 280 Nm output at rated speed, a gear ratio ng = 8.19, and a wheel radius r = 0.315 m. Given: back emf Ea is 220 V at rated speed, armature resistance Ra = 50 mΩ, and no-load torque Tnl = 2 Nm. Determine the armature voltage and current output by the dc-dc converter and the machine efficiency when the vehicle is operating under the following conditions:

    a) Motoring up a hill and developing full torque at rated speed

    b) Cruising and developing 70 Nm at the rated speed

    c) Cruising and developing 70 Nm at half the rated speed.
11. An IPMSM has its parameters as shown in the following table.

No. of poles	6	Power(peak)	15kW
DC link voltage (V_m)	300V	Base speed	4550 rpm
Inductance L_d	3.05 mH	Rated current (I_m)	40A
Inductance L_q	6.2 mH	Flux (Ψ_m)	0.0948 wb

    a) Determine the d and q axis current yielding the maximum torque under the voltage constraint at 20000 rpm.

    b) Determine torque, power, and power factor at that point. In calculating the power factor, assume that the motor is lossless.
12. Sketch the circuit diagram of a low power charger and determine the expression for the dc charging current.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1S205	ELECTRIC CHARGING SYSTEMS FOR ELECTRICAL VECHICLES	Industry Course	3	0	0	3	3

Preamble: The course is aimed to provide an overview of the technological concepts and regulatory frameworks related to the charging systems of Electrical Vehicle. It covers various energy storage mechanisms, types of chargers and charging standards used in Electric vehicle. Students will be well equipped with the charging systems of electric vehicle.

Prerequisite: Fundamentals of Power Electronics

Course Outcomes: After the completion of the course the student will be able to

CO 1	Analyse the working of different types of controlled rectifiers (Cognitive knowledge level: Apply, Analyse)
CO 2	Analyse the working of different types of choppers (Cognitive knowledge level: Apply, Analyse)
CO 3	Describe the energy storage mechanisms used for EV's (Cognitive knowledge level: Understand)
CO 4	Explain the various types of chargers used for EV's (Cognitive knowledge level: Understand, Analyse)
CO 5	Explain the various charging standards for EV's (Cognitive knowledge level: Understand, Analyse)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2			1		1
CO 2	2			1		1
CO 3	2			1		1
CO 4	2		1	1		2
CO 5	2		1	1		2

Evaluation Pattern

	ELECTRIC CHARGING SYSTEMS FOR ELECTRICAL VECHICLES		
Bloom's Category	**Continuous Internal Evaluation Tests**		**End SemesterExamination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	50	50	50
Analyse	30	30	30
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation

Seminar : 10 marks

Course based task/Seminar/Data collection and interpretation/Case study : 10marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

End Semester Examination

The examination will be conducted by the College with the question paper provided by the Industry. The examination will be for 3 Hrs and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks. The valuation of the answer scripts shall be done by the expert in the Industry handling the course.

SYLLABUS

MODULE 1 (8 hours)

Controlled Rectifiers (Single Phase) – Half-wave-controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) – Output voltage equation – Controlled Rectifiers (3-Phase) - 3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free) – Output voltage equation-Waveforms for various triggering angles (analysis not required).

MODULE 2 (7 hours)

DC-DC converters – Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper – Pulse width modulation & current limit control in dc-dc converters.
Switching regulators – Buck, Boost & Buck-boost –Operation with continuous conduction mode - Waveforms – Design (switch selection, filter inductance and capacitance).

MODULE 3 (7 hours)

Energy Storage: Introduction to energy storage requirements in Electric Vehicles- Units of Battery Energy Storage - Capacity rate- Battery based energy storage systems, Types of battery- Lifetime and Sizing Considerations - Battery Charging, Protection, and Management Systems - Fuel Cell based energy storage systems- Supercapacitors- Hybridization of different energy storage devices.

MODULE 4 (7 hours)

On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams – Types of charging stations - AC Level 1 & 2, DC - Level 3, Wireless charging. Plug-in Hybrid EV, V2G concept.

MODULE 5 (7 hours)

Charging Standards - SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993, Types of Connectors - CHAdeMo, CCS Type1 and 2, GB/T - pin diagrams and differences, IEC 61851- Electric vehicle conductive charging modes, IEC 61980- Electric vehicle wireless power transfer systems, IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers and IS- 17017 standards for EV charging.

References

1. Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press,4th Ed.,2010.
2. James Larminie, John Lowry, *Electric Vehicle Technology Explained*, Wiley, 2nd Ed., 2003.
3. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 1stEd., 2004.
4. John G. Hayes, *Electric powertrain*, Wiley, 2nd Ed., 2001.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 (8 hrs)	
1.1	Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only	2
1.2	Controlled Rectifiers (Single Phase) Output voltage equation – Controlled Rectifiers, Simple numeric problems	2
1.3	3-phase half-wave-controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free)	2
1.4	Controlled Rectifiers (Three Phase) Output voltage equation- Waveforms for various triggering angles (analysis not required). Simple numeric problems	2
	Module 2 (7 hrs)	
2.1	Step down and Step up choppers – Single-quadrant, Two quadrant and Four quadrant chopper	2
2.2	Pulse width modulation & current limit control in dc-dc converters	1
2.3	Switching regulators – Buck, Boost & Buck-boost	2
2.4	Operations with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).	2
	Module 3 (7 hrs)	
3.1	Introduction to energy storage requirements in Electric Vehicles	1
3.2	Units of Battery Energy Storage - Capacity rate	1
3.3	Battery based energy storage systems, Types of battery	1
3.4	Lifetime and Sizing Considerations	1

3.5	Battery Charging, Protection, and Management Systems	1
3.6	Fuel Cell based energy storage systems- Super capacitors	1
3.7	Hybridization of different energy storage devices	1
	Module 4 (7 hrs)	
4.1	On-board chargers	1
4.2	Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack.	1
4.3	Power flow block schematic diagrams	1
4.4	Types of charging stations - AC Level 1 & 2	1
4.5	Types of charging stations DC - Level 3	1
4.6	Wireless charging	1
4.7	Plug-in Hybrid EV, V2G concept	1
	Module 5 (7 hrs)	
5.1	SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993	1
5.2	Types of Connectors - CHAdeMo, CCS Type1 and 2	1
5.3	GB/T - pin diagrams and differences	1
5.4	IEC 61851 - Electric vehicle conductive charging modes	1
5.5	IEC 61980- Electric vehicle wireless power transfer systems	1
5.6	IEC 62196 -AC Couplers Configuration, Combo AC - DC Couplers	1
5.7	IS-17017 standards for EV charging	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________

Name:________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

FIRST SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: *M24EE1S205*

Course Name: ELECTRIC CHARGING SYSTEMS FOR ELECTRICAL VECHICLES

Max. Marks:60 Duration: 3 hours

Answer any five questions. Each question carries 12 marks.

1. (a) What is inverted mode of operation of the converter? Explain. (5 marks)

   (b) Draw the circuit of 3 phase fully controlled rectifier with RLE load and explain the working for α=600 with necessary waveforms. Derive the expression for average output voltage. (7 marks)

2. (a) What is a two-quadrant chopper? Explain. (5 marks)

   (b) A boost converter has an input voltage of Vd=10V and an average output voltage of 20V and average load current of I0=0.5A.The switching frequency is 25kHz and and L=200µH and C=220µF.Determine (a) duty ratio (b) ripple current of the inductor (c) peak current of inductor and (d) ripple voltage of capacitor. (7 marks)

3. (a) Explain about the battery management systems used in EV. (5 marks)

   (b) Draw the circuit of 3 phase fully controlled rectifier with RL load and explain the working for α=60 degree with necessary waveforms. Derive the expression for output voltage. (7 marks)

4. (a) Draw and explain the configuration of a level-1 charger. (5 marks)

   (b) Explain about Fuel cell-based energy storage systems. (7 marks)

5. (a) Explain the CHAdeMo charging protocol for EV. (5 marks)

   (b) Explain the working of a Buck-Boost regulator, showing relevant waveforms and derive the expression for its output voltage. (7 marks)

6. (a)Illustrate the power flow from Grid to EVSE to On-board chargers to battery with the help of a schematic diagram. (5 marks)

   (b) Explain the operation of level-3 battery charger with a neat circuit diagram. (7 marks)

7. (a) Compare the operation of different types of batteries. (5 marks)

   (b) Describe the various charging standards used for electric vehicles. (7 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1P206	MINI PROJECT	Project	0	0	3	3	2

Preamble: Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem solving skills.

The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Evaluation Committee - Programme Coordinator, One Senior Professor and Guide.

Sl. No	Type of evaluations	Mark	Evaluation criteria
1	Interim evaluation 1	30	
2	Interim evaluation 2	30	
3	Final evaluation by a Committee	25	Will be evaluating the level of completion and demonstration of functionality/ specifications, clarity of presentation, oral examination, work knowledge and involvement
4	Report	10	The committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level(not more than 25%)
5	Supervisor/Guide	5	
Total Marks		100	

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1L207	RENEWABLE ENERGY AND DRIVES LABORATORY	Laboratory	0	0	3	3	2

Preamble : Among the renewable energy options available, solar energy represents a promising and major energy resource. The syllabus imparts practical knowledge about the power electronic circuits with renewable energy and electric drives. It also introduces the application of power electronics in large industrial equipment.

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Prerequisite: Fundamentals of power electronics and electric drives

Course Outcomes: After the completion of the course the student will be able to

CO 1	Design and Demonstrate power electronic circuits, drives, renewable energy circuits using microcontrollers /DSP /FPGA (Cognitive knowledge level: Understand, Analyse)
CO 2	Solve engineering problems applied to power electronic applications (Cognitive knowledge level: Apply)
CO 3	Examine the performance of various power electronic converters and drives through simulation software like MATLAB (Cognitive knowledge level: Evaluate)
CO4	Analyse the experiment efficiently as an individual and as a member in the team to solve various problems (Cognitive knowledge level: Analyse)
CO 5	Build proper reports of experiments that clearly illustrate the concepts, design and simulation & experimental results (Cognitive knowledge level: Create)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	3	3	3	1
CO 2	3	1	3	3	3	1
CO 3	3	1	3	3	3	1
CO 4	2	2	3	2	2	2
CO 5	1	3	2	1	1	2

Mark distribution

Total Marks	CIE Marks
100	100

Continuous Internal Evaluation Pattern:

Lab work and Viva-voce : 60 marks
Final evaluation Test and Viva voce: 40 marks

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final evaluation shall be done by two examiners; one examiner will be a senior faculty from the same department.

SYLLABUS

LIST OF EXPERIMENTS

	SIMULATION EXPERIMENTS
1	Simulation of MPPT tracking of solar modules (Perturb & Observe)
2	Simulation of Direct Torque Control of 3-phase induction motor
3	State Space Modelling and open loop control of PMSM motor using SPWM /SVPWM
4	Design and simulation of closed loop control of chopper fed DC drive
5	State Space Modelling and open loop control of 3-phase induction motor using SPWM /SVPWM
6	Simulation of a separately excited DC motor drive with closed loop control for four quadrant Operation
	HARDWARE EXPERIMENTS
7	Study of solar PV characteristics -effect of tilt.
8	Study of effect of shading on solar panels.
9	Single phase sine-triangle PWM/SVPWM generation using Microcontroller.
10	Single phase sine-triangle PWM generation using DSPACE/FPGA.
11	Three phase VSI feeding R load using sine-triangle PWM.
12	VSI fed three phase induction motor drive using open loop V/f control by Microcontroller

Reference books

1. M.H. Rashid, *Power Electronics: Circuits, Devices and Applications*. PHI/Pearson 4th Ed., 2017
2. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*. Wiley 3rd Ed., 2007.
3. L. Umanand, *Power Electronics: Essentials and Applications.* Wiley India 1st Ed., 2009.
4. Daniel W. Hart, *Power Electronics.* Tata McGraw-Hill 1st Ed., 2011.

SEMESTER 3

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1M301/ M24EE1M305/ M24EE1M306	MOOC	MOOC	0	0	0	0	2

Preamble: A MOOC course of a minimum 8-week duration must be successfully completed before the end of the fourth semester (starting from Semester 1). The MOOC course shall be considered valid only if it is conducted by AICTE, NPTEL, SWAYAM, or NITTTR. The course must have a minimum duration of 8 weeks and should include syllabus content equivalent to at least 40 hours of teaching. Additionally, it must have a proctored/offline end-semester examination. Students may complete the MOOC course at their convenience but must do so before the end of the fourth semester. The Board of Studies (BoS) will provide a list of approved MOOC courses, provided that at least 70% of the course content aligns with the student's area or stream of study. However, a MOOC course will not be considered if more than 50% of its content overlaps with a core/elective course in the respective discipline or with an open elective. A credit of 2 will be awarded to students who successfully complete the MOOC course as per the evaluation criteria of the respective agency conducting the course.

LIST OF MOOC COURSES :

1. Fuzzy Sets, Logic and Systems & Applications

- Duration: 12 weeks
- Provider: NPTEL
- Course Content: The course is designed to give a solid grounding of fundamental concepts of fuzzy logic and its applications
- Relevance: The level of the course is chosen to be such that all students aspiring to be a part of computational intelligence directly or indirectly in near future should get these concepts.

2. Power Quality

- Duration: 12 weeks
- Provider: NPTEL
- Course Content: This course is intended to provide tools to classify, quantify, and analyze the power quality problems and to provide practical engineering solutions to mitigate these problems.
- Relevance: It enables students to understand the concept of power and power factor in single-phase and three-phase systems supplying nonlinear loads. To understand the

conventional compensation techniques used for power factor correction and load voltage regulation.

3. Advance Power Electronics

- Duration: 12 weeks
- Provider: NPTEL
- Course Content: This course includes advanced topics of power electronics such as some of latest devices their control and applications.
- Relevance: It is highly relevant for students, offering thermal design, protection, gating circuits, digital signal processors used in their control.

4. Facts Devices

- Duration: 8 weeks
- Provider: NPTEL
- Course Content: FACTS is the acronym for Flexible AC Transmission Systems and refers to a group of resources used to overcome certain limitations in the static and dynamic transmission capacity of electrical networks.
- Relevance: The main purpose of these systems is to supply the network as quickly as possible with inductive or capacitive reactive power that is adapted to its particular requirements, while also improving transmission quality and the efficiency of the power transmission system.

5. Operation And Planning of Power Distribution Systems

- Duration: 12 weeks
- Provider: NPTEL (via SWAYAM)
- Course Content: This course will provide an overview of modern power distribution systems.
- Relevance: It enables students to design modelling of different types of distributed generation units and storage.

6. Power Quality Improvement Technique

- Duration: 8 weeks
- Provider: NPTEL
- Course Content: The course addresses the power quality of modern power distribution system is vulgarized due to the increased use of distributed sources, adjustable speed drive, nonlinear load and unbalanced load.
- Relevance: It equips students with essential skills to mitigation of the power quality problems produced by load disturbances and supply .

7. Fuzzy logic and neural networks

Duration: 8 weeks

- Provider: NPTEL
- Course Content: Fundamentals of neural networks and various learning methods will be discussed. The principles of multi-layer feed forward neural network, radial basis function network, self-organizing map, counter-propagation neural network, recurrent neural network, deep learning neural network will be explained with appropriate numerical examples
- Relevance: It is highly relevant for students, basic concepts of multi-layer feed forward neural network, radial basis function network, self-organizing map, counter-propagation neural network, recurrent neural network, deep learning neural network.

8. Basics of semiconductor microwave devices

- Duration: 12 weeks
- Provider: NPTEL
- Course Content This course will deal with semiconductor devices including diodes and transistors which are used in microwave and RF applications, especially for power amplifiers.
- Relevance:This course will seek to give a basic background of such devices in addition to conventional silicon LDMOS and bipolar devices. Toward the end, this course will also try to introduce basic microwave concepts from the device point-of-view.

9. Network Security

Duration: 12 weeks

- Provider: NPTEL
- Course Content: The goals of the field of network security are to understand how malicious users can attack networks, and design mechanisms for defending networks against such attacks.
- Relevance: The objective of the proposed course “Network Security” is to provide a detailed exposure to this important field to students. The course will include hands-on demonstration sessions.

10. Digital Electronic Circuits

- Duration: 12 weeks
- Provider: NPTEL

- Course Content: The course focuses on course is aimed at developing a deep understanding of digital electronic circuits. A signal can be discreet by nature whereas, a continuous signal can be discretized for digital processing and then converted back.
- Relevance: It equips students able to analyze and synthesize different kind of combinatorial and sequential digital systems for real-world use.

11. Digital IC Design

- Duration: 12 weeks
- Provider: NPTEL
- Course Content: The course provides a theoretical summary along with examples of real-life engineering applications to a variety of technical problems such as load shedding and frequency relaying, reclosing and synchronizing, protection issues
- Relevance: This course is intended to develop understanding of evaluate power dissipated in a circuit (dynamic and leakage), design a circuit to perform a certain functionality with specified speed identify the critical path of a combinational circuit.

12. Digital Protection of Power Systems

- Duration: 8 weeks
- Provider: NPTEL
- Course Content: This course focuses on the analytical techniques used in digital relays and application of PMUs in easily comprehensible manners so that academicians and particularly new beginners would not find any difficulty.
- Relevance: It provides students with provides a theoretical summary along with examples of real-life engineering applications to a variety of technical problems such as load shedding and frequency relaying, reclosing and synchronizing and protection issues.

13. Transducers for Instrumentation

- Duration: 12 weeks
- Provider: NPTEL
- Course Content: This course is designed with an aim to make students familier with the working principle of different types of sensors and transducers.
- Relevance: The students will have an exposure to basic physics of the sensors and their importance in the real-world applications.

14. Design of power electronics converter

- Duration: 8 weeks
- Provider: NPTEL
- Course Content: In this course, students will learn the important concepts needed to design proper power electronic hardware, simulation tools, proper designing of power PCB, designing magnetics, reducing electromagnetic interference etc
- Relevance: It equips students should be able to design and test any power electronic converter on their own.

15. Applied Linear Algebra

Duration: 12 weeks

- Provider: NPTEL
- Course Content: The course will be directed towards training students in the art of proving and/or disproving assertions and also developing critical thinking abilities in the subject.
- Relevance: The course should be particularly useful to graduate students (masters and PhD students) who endeavor to solve theoretical problems in control theory, machine intelligence, data science, signal processing and related areas.

16.Vehicle dynamics and electric motor drives

- Duration: 12 weeks
- Provider: NPTEL
- Course Content: Students will be able to understand the operation of battery driven electric vehicle.
- Relevance: The course will start covering this focus areas one by one such as vehicle dynamics, Motors, Power Electronics, PWM, Control etc.

17. Biophotonics

- Duration: 12 weeks
- Provider: NPTEL (via SWAYAM)
- Course Content: Biophotonics is a multidisciplinary field where light-based technologies are utilized to reveal biological mechanisms, and diagnose several diseases along with finding their treatments.
- Relevance: This course introduces the basics of biology and photonics, and provides the

most relevant and important application from chemistry, biology, and medicine. For examples, it includes how to detect and identify new viruses (such as the Coronavirus) and how to measure neural activities in live mouse.

18. Industrial Automation and Control

Duration: 12 weeks

- Provider: NPTEL
- Course Content: This course provides an overall exposure to the technology of Industrial Automation and Control as widely seen in factories of all types both for discrete and continuous manufacturing.
- Relevance: The course, discusses a wide range of related topics from the advantage and architecture of automation systems, measurement systems including sensors and signal conditioning, discrete and continuous variable control systems, hydraulic, pneumatic and electric actuators, industrial communication and embedded computing and CNC Machines.

PROGRAM ELECTIVE 5

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E302A	ENERGY EFFICIENCY IN ELECTRICAL ENGINEERING	ELECTIVE	3	0	0	3	3

Preamble: The course aims to understand various forms & elements of energy and evaluate the techno economic feasibility of the energy conservation technique adopted. The course contains various energy scenarios and performance analysis in various industrial and domestic applications. By the end this course students will be able to design and implement sustainable and energy efficient electrical systems.

Prerequisite: Power Systems, Electrical Machines

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the various forms and elements of energy. (Cognitive knowledge level: Understand)
CO 2	Analyze performance of electrical management systems and motors. (Cognitive knowledge level: Apply)
CO 3	Analyze energy Efficiency in Electrical Utilities. (Cognitive knowledge level: Analyze)
CO 4	Identify methods of energy conservation in Lighting, DG systems and transformers. (Cognitive knowledge level: Apply)
CO 5	Evaluate energy efficient technologies in Electrical Systems. (Cognitive knowledge level: Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	2	2	2	2
CO 2	3	1	2	2	2	2
CO 3	3	1	2	2	2	2
CO 4	3	1	2	2	2	2
CO 5	3	1	2	2	2	2

Assessment Pattern

Course Name	**Energy Efficiency in Electrical Engineering**		
Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination (Marks)**
	Test 1 (Marks)	**Test 2 (Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyze	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIA marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (7 hours)

Energy Scenario

Classification of energy, Capacity factor of solar and wind power generators, Global fuel reserve, Energy scenario in India, Impact of energy usage on climate, Salient features of Energy Conservation Act 2001 & The Energy Conservation (Amendment) Act, 2010 and its importance. Prominent organizations at center and state level responsible for its implementation, Standards and Labelling.

MODULE 2 (7 hours)

Energy Efficiency in Electrical Supply System and Motors

Electrical system: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses.

Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors, numerical problems.

MODULE 3 (8 hours)

Energy Efficiency in Electrical Utilities

Pumps: Introduction to pump and its applications, Efficient pumping system operation, Energy efficiency in agriculture pumps, Tips for energy saving in pumps

Compressed Air System: Types of air compressor and its applications, Leakage test, Energy saving opportunities in compressors.

HVAC and Refrigeration System: Introduction, Concept of Energy Efficiency Ratio (EER), Energy saving opportunities in Heating, Ventilation and Air Conditioning (HVAC) and Refrigeration Systems

Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities, numerical problems.

MODULE 4 (7 hours)

Energy Efficiency in Lighting, DG systems and transformers

Lighting Systems: Basic definitions- Lux, lumen and efficacy, Types of different lamps and their features, Energy efficient practices in lighting

DG Systems: Introduction, Energy efficiency opportunities in DG systems, Loading estimation

Transformers: Introduction, Losses in transformer, transformer Loading, Tips for energy savings in transformers, numerical problems

MODULE 5 (7 hours)

Energy Efficient Technologies in Electrical Systems

Maximum demand controllers, automatic power factor controllers, energy efficient motors, soft starters with energy saver, variable speed drives, energy efficient transformers, electronic ballast, occupancy sensors, energy efficient lighting controls, energy saving potential of each technology, numerical problems.

References

1) *General Aspects of Energy Management and Energy Audit*, Bureau of Energy Efficiency, Government of India, 2015.
2) *Energy Efficiency in Electrical Utilities*, Bureau of Energy Efficiency, Government of India, 2015.
3) *Energy Efficiency in Thermal Utilities*, Bureau of Energy Efficiency, Government of India, 2015.
4) Y P Abbi and Shashank Jain, *Handbook on Energy Audit & Environmental Management*, TERI,2006.
5) S. C. Tripathy, *Utilization of Electrical Energy and Conservation*, McGraw Hill, 3rd edition 1991.
6) Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India, www.beeindia.gov.in.
7) Ministry of New and Renewable Energy (MNRE), Government of India, www.mnre.gov.in.
8) Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change, Government of India, www.cpcb.nic.in.
9) Energy Efficiency Services Limited (EESL), www.eeslindia.org.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 **Energy Scenario (7 hours)**	
1.1	Classification of energy- primary and secondary energy, commercial and non-commercial energy, non-renewable and renewable energy with special reference to solar energy, Capacity factor of solar and wind power generators.	2
1.2	Global fuel reserve, Energy scenario in India, Impact of energy usage on climate	1
1.3	Salient features of Energy Conservation Act 2001 & The Energy Conservation (Amendment) Act, 2010 and its importance. Prominent organizations at centre and state level responsible for its implementation.	2
1.4	Standards and Labelling: Concept of star rating and its importance, Types of product available for star rating	1
	Module 2 **Energy Efficiency in Electrical Supply System and Motors (7 hours)**	
2.1	Electrical system: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, numerical problems.	2
2.2	Selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses	2

2.3	Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance.	1
2.4	Rewinding and motor replacement issues, energy saving opportunities with energy efficient motors, numerical problems.	2
	Module 3 **Energy Efficiency in Electrical Utilities (8 hours)**	
3.1	Pumps: Introduction to pump and its applications, Efficient pumping system operation, Energy efficiency in agriculture pumps, Tips for energy saving in pumps, numerical problems.	2
3.2	Compressed Air System: Types of air compressor and its applications, Leakage test, Energy saving opportunities in compressors.	2
3.3	Energy Conservation in HVAC and Refrigeration System: Introduction, Concept of Energy Efficiency Ratio (EER), Energy saving opportunities in Heating, Ventilation and Air Conditioning (HVAC) and Refrigeration Systems	2
3.4	Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.	2
	Module 4 **Energy Efficiency in Lighting, DG systems and transformers (7 hours)**	
4.1	Lighting Systems: Basic definitions- Lux, lumen and efficacy, Types of different lamps and their features, Energy efficient practices in lighting	2
4.2	DG Systems: Introduction, Energy efficiency opportunities in DG systems, Loading estimation	2
4.3	Transformers: Introduction, Losses in transformer, transformer Loading, Tips for energy savings in transformers, numerical problems	2
	Module 5 **Energy Efficient Technologies in Electrical Systems (7 hours)**	
5.1	Maximum demand controllers, automatic power factor controllers, numerical problems	2
5.2	Energy efficient motors, soft starters with energy saver	1
5.3	Variable speed drives, energy efficient transformers	2
5.4	Electronic ballast, occupancy sensors, energy efficient lighting controls	2

Model Question Paper

QP CODE: Pages: 2

Reg No.:_______________________

Name:_________________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

THIRD SEMESTER M. TECH DEGREE EXAMINATION, DECEMBER 2024

Course Code: M24EE1E302A

Course Name: ENERGY EFFICIENCY IN ELECTRICAL ENGINEERING

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. State the meaning and need of Energy Conservation.
2. List any four factors to be considered while selecting motor for any particular application.
3. Explain the concept of Energy Efficiency Ratio (EER)
4. Compare conventional core transformer with amorphous core transformer on the basis of i)Construction ii) Material used iii) Losses and iv) Cost
5. State any four benefits of Variable Frequency Drives (VFDs).

PART B

Answer any five questions. Each question carries 8 marks.

1. Explain the impact of energy usage on climate.
2. (a) State three advantages of improvement of Power Factor at Load side. (4 marks)
   (b) Power Factor at the load side is 0.75 and average minimum load is 100 kW. What is the kVAr rating of capacitor to improve the Power Factor at the load side to 0.95? (4 marks)
3. A 50 kW induction motor with 86% full load efficiency is being considered for replacement by a 89% efficiency motor. What will be the saving in energy if motor works for 6000 hrs. per year and cost of energy is Rs. 4.50 per kwh?
4. What are the factors affecting the performance and savings opportunities in HVAC?
5. What are the energy efficiency opportunities in DG systems?
6. What is energy efficient motors? Explain with technical aspects.
7. Explain different energy efficient lighting control with features.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E302B	DESIGN AND INSTALLATION OF SOLAR PV SYSTEMS	ELECTIVE	3	0	0	3	3

Preamble: This course aims to design and Analyze the performance of solar PV systems. This course provides an introduction to the modelling and Analyzes of MPPT algorithms and converters for PV applications. The students will be able to implement sustainable non-conventional energy sources.

Prerequisite : Power system, Power Electronics and Control Systems

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand various RES, estimate and select solar irradiance models. (Cognitive knowledge level: Understand)
CO 2	Design and implementation of appropriate converters for PV applications. (Cognitive knowledge level: Apply)
CO 3	Analyze various MPPT techniques. (Cognitive knowledge level: Apply)
CO 4	Design and Analyzes of the Standalone SPV System. (Cognitive knowledge level: Analyze)
CO 5	Evaluate the life cycle cost of Grid connected PV system. (Cognitive knowledge level: Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	2	2	2	2
CO 2	3	2	3	2	2	2
CO 3	3	2	3	2	2	2
CO 4	3	2	3	3	2	2
CO 5	3	2	3	3	2	2

Assessment Pattern

Course name	**Design and Installation of Solar PV Systems**		
Bloom's Category	**Continuous Assessment Tests**		**End SemesterExamination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	10	10	10
Apply	40	40	40
Analyze	40	40	40
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIA marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (9 hours)

Introduction to various RES, Measurement and Estimation of Solar Irradiance

Need for Renewable Energy Sources- Potential Renewable Energy Sources (RES) for Power Generation- Solar Energy, Wind Energy, Biomass Energy, Small Hydropower Plants Hydropower Project Classification, Geothermal Energy and Its Potential in India, Wave Energy, Tidal Energy-Government Initiatives for Solar Photovoltaic Systems.

Measurement and Estimation of Solar Irradiance: The Solar Irradiance Spectrum, Solar Constant and Solar Irradiance, Depletion of Solar Radiation by the Atmosphere, Factors Affecting the Availability of Solar Energy on a Collector Surface, Radiation Instruments, Solar Irradiance Components, Instruments Used Detectors for Measuring Radiation, Measuring Diffuse Radiation.

Mathematical Models of Solar Irradiance, Estimation of Global Irradiance, Diffuse Irradiance, Regression Models, Intelligent Modeling, Fuzzy Logic–Based Modeling of Solar Irradiance, Artificial Neural Network for Solar Energy Estimation.

MODULE 2 (6 hours)

Converter Design for SPV System

DC to DC Converters- Classification of DC-to-DC Converters- Buck converter, Boost converter, Buck–boost converter- Uses.

DC to AC Converters (inverters): Classification of Inverters- Classification based on output voltage: Square wave inverters, Modified square wave inverters, Pure sine wave inverters. Voltage source inverter: half bridge and full bridge -Current source inverter Multilevel inverter: Diode clamped, Flying capacitor- Applications Photovoltaic (PV) Inverter-Standalone inverter- Grid Tied inverter-string inverters, solar microinverters, and centralized inverters.

MODULE 3 (9 hours)

Fundamentals of Solar Photovoltaic Cells, MPPT techniques, Modules, and Arrays

Solar PV Fundamentals: The Solar Cell, Material for the Solar Cell, PV cell characteristics and equivalent circuit, Model of PV cell, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature, Temperature effect, Solar PV Modules, Bypass Diodes, Hot Spot Formation, Fill Factor, Solar Cell Efficiency and Losses, Methods to Increase Cell Efficiency. Standard Test Conditions (STC) of the PV Cell, Factors Affecting PV Output-Tilt Angles, Partial Shading, Effect of Light Intensity, PV Module Testing and Standards and Testing for Grid-Connected Rooftop Solar PV Systems/Power Plants.

Maximum Power Point Tracking Techniques and Charge Controllers: MPPT and Its Importance, MPPT Techniques- Curve-Fitting Technique, Fractional Short-Circuit Current (FSCC) Technique, Fractional Open-Circuit Voltage Technique, Direct Method- Perturb and Observe, Incremental Conductance Method .

Comparison of Various MPPT Techniques, Charge Controllers and MPPT Algorithms, Modeling of PV System with Charge Controller.

MODULE 4 (6 hours)

Energy Storage for PV Applications, Design of the Standalone SPV System

Batteries - Capacity, C-rate, Efficiency, Energy and power densities, Battery selection, Other energy storage methods, Battery Storage System, Functions Performed by Storage Batteries in a PV System-Types of Batteries- Lead-Acid Batteries, Nickel Cadmium (Ni-Cd) Batteries, Nickel-Metal Hydride (Ni-

MH) Batteries, Lithium Ion Batteries etc. Installation, Operation, and Maintenance of Batteries, System Design and Selection Criteria for Batteries, Effect of DoD Disposal of Batteries, Super Capacitors, Fuel Cells.

Mounting Structure: Assessment of Wind Loading on PV Array, Types of Module Mounting Systems, PV Array Row Spacing, Standards for Mounting Structures.

Design of the Standalone SPV System: Sizing of the PV Array- Sizing of the Battery Block-Design of the Battery Charge Controller- Design of the Inverter, Sizing PV for applications without batteries, PV system design, Load profile, Days of autonomy and recharge, Battery size, PV array size, Direct PV-battery connection, Charge controller, Simulation using MATLAB.

MODULE 5 (6 hours)

Grid-Connected PV Systems, Life Cycle Cost Analysis

Grid connection principle, PV to grid topologies, (Basic concept of d-q theory) Complete 3phase grid connection, 1phase d-q controlled grid connection (Basic treatment only), SVPWM, Life cycle costing, Growth models, Annual payment and present worth factor, LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill, Payback Period Calculation, Comparison of PV and Conventional Electricity Costs, Case study using MATLAB.

References

1. Jamil, Majid, M Rizwan and D Kothari, *Grid Integration of Solar Photovoltaic Systems*, CRC Press,1st edition, 2017.
2. Godfrey Boyle, *Renewable energy: Power for a sustainable future*, Oxford University press, 3rd edition, 2012.
3. D. Y. Goswami, F. Kreith and J. F. Kreider, *Principles of Solar Engineering*, CRC press, 2nd edition, 2000.
4. Mukherjee and Thakur, *Photovoltaic Systems Analysis and Design*, PHI, Eastern Economy 1st Edition, 2011.
5. Solanki, *Solar Photovoltaics- Fundamentals, Technologies and Applications*, PHI, 3rd Edition, 2015
6. B. H. Khan, *Non-Conventional Energy Resources*, McGraw Hill Education India Private Limited, 3rd Edition, 2017.
7. O'Hayre, R.P., S. Cha, W. Colella and F.B.Prinz, *Fuel Cell Fundamentals*, Wiley, 3rd edition, 2016.
8. D. P. Kothari, K.C. Singal and Rakesh Ranjan, *Renewable Energy Sources and Emerging Technologies*, PHI, 2nd edition, 2011.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(9 hours)	
1.1	Introduction to various RES-Solar Energy, Wind Energy, Biomass Energy, Small Hydropower Plants Hydropower Project Classification, Geothermal Energy and Its Potential in India.	2
1.2	The Solar Irradiance Spectrum, Solar Constant and Solar Irradiance, Depletion of Solar Radiation by the Atmosphere, Factors Affecting the Availability of Solar Energy on a Collector Surface,	2
1.3	Radiation Instruments, Solar Irradiance Components, Instruments Used Detectors for Measuring Radiation, Measuring Diffuse Radiation	2
1.4	Mathematical Models of Solar Irradiance, Estimation of Global Irradiance, Diffuse Irradiance, Regression Models, Intelligent Modelling	1
1.5	Fuzzy Logic–Based Modelling of Solar Irradiance	1
1.6	Artificial Neural Network for Solar Energy Estimation	1
	Module 2(6 hours)	
2.1	Classification of DC-to-DC Converters- Buck converter, Boost converter, Buck–boost converter- Uses	1
2.2	Classification Inverters based on output voltage: Square wave inverters, Modified square wave inverters, Pure sine wave inverters	1
2.3	Voltage source inverter: half bridge and full bridge -Current source inverter	1
2.4	Multilevel inverter: Diode clamped, Flying capacitor- Applications	1
2.5	Photovoltaic (PV) Inverter-Standalone inverter- Grid Tied inverter-string inverters, solar microinverters, and centralized inverters	2
	Module 3(9 hours)	
3.1	The Solar Cell, Material for the Solar Cell, PV cell characteristics and equivalent circuit, Model of PV cell, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Effect of temperature	1
3.2	Temperature effect, Solar PV Modules, Bypass Diodes, Hot Spot Formation, Fill Factor, Solar Cell Efficiency and Losses, Methods to Increase Cell Efficiency.	1
3.3	Standard Test Conditions (STC) of the PV Cell, Factors Affecting PV Output-Tilt Angles, Partial Shading, Effect of Light Intensity	1
3.4	PV Module Testing and Standards and Testing for Grid-Connected Rooftop Solar PV Systems/Power Plants	1
3.5	MPPT and its Importance, MPPT Techniques- Curve-Fitting Technique, Fractional Short-Circuit Current (FSCC) Technique	1

3.6	Fractional Open-Circuit Voltage Technique, Direct Method -Perturb and Observe, Incremental Conductance Method	2
3.7	Comparison of Various MPPT Techniques, Charge Controllers and MPPT Algorithms, Modelling of PV System with Charge Controller	2
	Module 4(6 hours)	
4.1	Batteries - Capacity, C-rate, Efficiency, Energy and power densities, Battery selection, Other energy storage methods	1
4.2	Battery Storage System, Functions Performed by Storage Batteries in a PV System-Types of Batteries- Lead-Acid Batteries, Nickel Cadmium (Ni-Cd) Batteries, Nickel-Metal Hydride (Ni-MH) Batteries, Lithium Ion Batteries etc	1
4.3	Installation, Operation, and Maintenance of Batteries, System Design and Selection Criteria for Batteries, Effect of DoD Disposal of Batteries, Super Capacitors, Fuel Cells	1
4.4	Assessment of Wind Loading on PV Array, Types of Module Mounting Systems, PV Array Row Spacing, Standards for Mounting Structures	1
4.5	Sizing of the PV Array- Sizing of the Battery Block-Design of the Battery Charge Controller- Design of the Inverter, Sizing PV for applications without batteries, PV system design, Load profile, Days of autonomy and recharge, Battery size, PV array size, Direct PV-battery connection, Charge controller, Simulation using MATLAB.	2
	Module 5(6 hours)	
5.1	Grid connection principle, PV to grid topologies, Complete 3phase grid connection, 1phase d-q controlled grid connection, SVPWM	2
5.2	Life cycle costing, Growth models, Annual payment and present worth factor	2
5.3	LCC with examples- Life Cycle Cost Analysis- Case Study based on Difference in Power Consumption Bill, Case study using MATLAB.	1
5.4	Payback Period Calculation, Comparison of PV and Conventional Electricity Costs	1

Model Question Paper

QP CODE: Pages: 2

Reg No.:______________________

Name:________________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

THIRD SEMESTER M. TECH DEGREE EXAMINATION, DECEMBER 2025

Course Code: *M24EE1E302B*

Course Name: DESIGN AND INSTALLATION OF SOLAR PV SYSTEMS

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Discuss the importance of intelligent techniques for the estimation of solar irradiance.
2. Sketch and explain the P-V curve for two solar cells in parallel with nonidentical V-I Characteristic.
3. Enlist the advantages and disadvantages of string inverter as a grid tide inverter.
4. A PV Cell is to be emulated with a 24V battery with a 10ohm series resistance. Calculate the Fill Factor in this case.
5. Consider a situation where one enters into an annual maintenance contract (AMC) for a particular item. The annual maintenance amount is Rs.5000 for a 5-year period. If the rate of interest is 8% and the rate of inflation is 5%, what is the present worth of the AMC?

PART B

Answer any five questions. Each question carries 8 marks.

6. (a). Write the applications for the following solar radiation–measuring instruments:

   (i) Pyrheliometer

   (ii) Sunshine recorder (4 marks)

   (b) Draw the flowchart for an ANN model for estimation of solar irradiance using Backpropagation algorithm. (4 marks)
7. A PV panel having an area of 1.5m^{2}gives the following readings under standard test conditions. The short circuit current is 8A, the open circuit voltage is 40V, the voltage at peak power is36.5V and the current at peak power is 7A. The fill factor of the PV panel is found to be 0.72. Calculate the efficiency of the panel.

8. Derive the expression for impedance seen by the solar cell utilizing the volt sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation.
9. (a) The present cost of a solar panel is Rs 2000. If the interest rate is 8% and the inflation rate is 5% then how much must one save today in order to purchase the solar panel 5 years from now? (4 marks)

   (b) Explain the steps involved in design of standalone solar PV system. (4 marks)
10. Draw the functional block diagram of a 3-phase grid connected Solar P V system under d-q frame control. Explain each section in details.
11. Derive the expression for impedance seen by the solar cell utilizing the volt-sec and amp-sec balance concept, when a Buck Converter is used for MPPT operation. Sketch the operating region with Load line concept in I-V curve of Solar cell, while using Buck Converter for MPPT operation.
12. (a) What are the advantages of supercapacitors and fuel cells compared to conventional battery energy storage system? (4 marks)

(b) Explain Depth of Discharge, life cycle of battery and round-trip efficiency. (4 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E302C	INDUSTRIAL AUTOMATION	ELECTIVE	3	0	0	3	3

Preamble: This course aims to develop and implement various automated systems in industry. This course deals in detail with the various aspects of automation such as sensors, actuators, controllers, mechanical and electrical elements and their integration for automating new and existing manufacturing and process industries and applications. This course will be beneficial to students in designing automation schemes for industries and to design automated systems.

Prerequisite: Instrumentation, Control Systems and Electrical Machines

Course Outcomes: After the completion of the course the student will be able to

CO 1	Apply a suitable sensor system for the given application based on the evaluation of the constraints. (Cognitive knowledge level: Apply)
CO 2	Design and implement a suitable signal conditioning scheme for applications in electrical systems. (Cognitive knowledge level: Apply)
CO 3	Understand the characteristics of various actuator systems and Identify the right type of actuator for the given application. (Cognitive knowledge level: Apply)
CO 4	Apply and Analyze the fundamentals of numerical control in Industrial robotic automation. (Cognitive knowledge level: Analyze)
CO 5	Design and Analyze discrete control systems using PLCs, DCS, and SCADA by understanding their architecture, programming, and communication protocols for industrial automation. (Cognitive knowledge level: Evaluate)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	2	1	2	2
CO 2	3	1	2	1	2	2
CO 3	3	1	2	1	2	2
CO 4	3	1	2	1	2	2
CO 5	3	1	2	1	2	2

Assessment Pattern

Course name	**Industrial Automation**		
Bloom's Category	**Continuous Assessment Tests**		**End SemesterExamination (%Marks)**
	Test 1 (%Marks)	**Test 2 (%Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyze	30	30	30
Evaluate	10	10	10
Create	-	-	-

Mark distribution

Total Marks	CIA marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answerquestions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (6 hours)

Introduction to Industrial Automation

Basic Elements of an Automated System, Levels of Automation, Hardware components for Automation: Sensors, classification, Static and dynamic behavior of sensors, Working principle of different sensors: Proximity sensors, Temperature sensors, flow sensors, Pressure sensors, Force sensors, Position sensors.

MODULE 2 (7 hours)

Signal conditioning

Need for signal conditioning, Types of signal conditioning, Signal conditioning using operational amplifier-Amplifier (Inverting and Non-inverting) and Filter circuits (Basic concepts). Design of first order low pass filter, Signal conditioning for data acquisition systems, anti-aliasing filters, Analog–Digital Conversions, Analog-to-Digital Converters (ADC)- Steps in analog-to-digital conversion, Successive Approximation Method, Digital-to-Analog Converters (DAC)- Steps in digital to analog conversion, Zero-order and first order data hold circuits.

MODULE 3 (6 hours)

Actuators

Types of actuators- Working of mechanical, electrical, pneumatic and hydraulic actuators. Mechanical systems for motion conversion, transmission systems, Solenoids, Electric and stepper motors control.

MODULE 4 (7 hours)

Robotics and Automated Manufacturing Systems

Robot Anatomy and Related Attributes: Joints and Links, Common Robot Configurations, Joint Drive Systems, Sensors in Robotics, Robot Control Systems, Applications of Industrial Robots- Material handling, Fundamentals of Numerical control (NC) Technology.

MODULE 5 (10 hours)

Digital Control and Programmable Logic Controllers

Digital Process Control: Logic and Sequence control, Ladder Logic Diagrams, Programmable Logic Controllers: Components of the PLC, PLC Operating Cycle, Programming the PLC.

Introduction to Distributed control system (DCS) -Process Automation Network-Communication Modes-Protocols in Process Automation-Fieldbus communication Protocol-Topology, Benefits, Types-Foundation Field Bus, PROFIBUS, HART.

Introduction to Supervisory Control and Data Acquisition Systems (SCADA)-SCADA Communication Protocols, Case study.

References

1. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson, 5th Edition, 2020.
2. Yoram Koren, *Computer Control of Manufacturing Systems*, Tata McGraw Hill, 1st Edition, 2017.
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8. Salivahanan, S., and V S Kanchana Bhaaskaran, Linear integrated circuits, McGraw-Hill Education, 2021.
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COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1 **Introduction to Industrial Automation (6 hours)**	
1.1	Basic Elements of an Automated System, Levels of Automation.	1
1.2	Hardware components for Automation: Sensors, classification, Static and dynamic behavior of sensors.	2
1.3	Working principle of different sensors: Proximity sensors, Temperature sensors, flow sensors	2
1.4	Working principle of different sensors: Pressure sensors, Force sensors, Position sensors	1
	Module 2 **Signal conditioning (7 hours)**	
2.1	Need for signal conditioning, Types of signal conditioning.	1
2.2	Signal conditioning using operational amplifier-Amplifier (Inverting and Non-inverting) and Filter circuits (Basic concepts). Design of first order low pass filter.	2
2.3	Signal conditioning for data acquisition systems, anti-aliasing filters, Analog–Digital Conversions, Analog-to-Digital Converters (ADC)- Steps in analog-to-digital conversion.	2
2.4	Successive Approximation Method, Digital-to-Analog Converters (DAC)- Steps in digital to analog conversion, Zero-order and first order data hold circuits.	2

	Module 3 **Actuators (6 hours)**	
3.1	Types of actuators- mechanical, electrical, pneumatic and hydraulic actuators-Working principle.	2
3.2	Mechanical systems for motion conversion, transmission systems.	2
3.3	Solenoids, Electric and stepper motors control.	2
	Module 4 **Robotics and Automated Manufacturing Systems (7 hours)**	
4.1	Robot Anatomy and Related Attributes: Joints and Links, Common Robot Configurations.	2
4.2	Robot Anatomy and Related Attributes: Joint Drive Systems, Sensors in Robotics	2
4.3	Robot Control Systems, Applications of Industrial Robots- Material handling.	1
4.4	Fundamentals of Numerical control (NC) Technology.	2
	Module 5 **Digital Control and Programmable Logic Controllers (10 hours)**	
5.1	Digital Process Control: Logic and Sequence control.	2
5.2	Ladder Logic Diagrams, Programmable Logic Controllers: Components of the PLC, PLC Operating Cycle.	1
5.3	Programming the PLC.	2
5.4	Introduction to Distributed control system (DCS) -Process Automation Network-Communication Modes	1
5.5	Protocols in Process Automation-Fieldbus communication Protocol-Topology, Benefits, Types-Foundation Field Bus, PROFIBUS, HART.	2
5.6	Introduction to Supervisory Control and Data Acquisition Systems (SCADA)-SCADA Communication Protocols, Case study.	2

Model Question Paper

QP CODE: Pages: 2

Reg No.:_______________________

Name:_________________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

THIRD SEMESTER M. TECH DEGREE EXAMINATION, DECEMBER 2025

Course Code: M24EE1E302C

Course Name: INDUSTRIAL AUTOMATION

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. Explain the working of a strain-gauge.
2. Explain why anti-aliasing filters are used in analog to digital converters.
3. What are the factors to consider while deciding choosing between hydraulic, pneumatic or electrical actuation systems for an automation scheme?
4. Explain the principle of the Touch sensor and also mention how they are used in robots.
5. Explain the use of an up-down counter in PLC with a suitable example.

PART B

Answer any five questions. Each question carries 8 marks.

6. Differentiate the static and dynamic characteristics of a temperature sensor and explain how it affects the selection of a suitable temperature sensor.
7. Design a first order low pass filter with a cutoff frequency of 2 kHz.
8. Explain the basic terminologies in robotic system and also explain the components of robotic system.
9. (a) Explain the working of a three-way pressure reducing valve. (4 marks)

   (b) Explain the working of solenoids. In what applications would you use a Solenoid valve. (4 marks)
10. Construct a ladder logic for controlling a process tank as per the logic given below;
    i. The tank should be filled by a valve V1 when low level float switch L1 is ON and an external input S1 is received.
    ii. V1 should be closed when the liquid level reaches a high-level float switch L2.
    iii. An agitator motor should be turned on after a delay of 5sec after L2 is triggered.

iv. After agitating for 30mins, contents of the tank should be emptied by opening another valve V2.

v. The temperature should be maintained at 70°C using a thermostat T1 and Heater H.

11. (a) Explain the levels of Automation. (4 marks)

    (b) Explain the working of Flow sensor. (4 marks)

12. . (a)With neat schematic explain the architecture of the PLC. (5 marks)

    (b)Differentiate between PLC and SCADA. (3 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1E302D	ELECTRICAL SYSTEM MODELING	ELECTIVE	3	0	0	3	3

Preamble: This course aims to impart the knowledge on mathematical design, modeling and analysis of controllers for electrical systems. The course includes modeling and Simulation of Switching Converters with State Space Averaging. By the end of this course students will be able to design and model various controllers and converters in various electrical system applications.

Prerequisite : Power Electronics, Advanced Control Systems.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Model the various Mechanical, Electrical and Control Systems. (Cognitive knowledge level: Apply)
CO 2	Modelling and Realisation of compensators and controllers. (Cognitive knowledge level: Analyze)
CO 3	Design and construct control systems with observers. (Cognitive knowledge level: Apply)
CO 4	Understand the techniques of AC equivalent circuit modelling. (Cognitive knowledge level: Understanding)
CO 5	Apply the concepts of state space averaging in switching converters. (Cognitive knowledge level: Apply)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	1	2	2	2
CO 2	3	1	1	2	2	2
CO 3	3	1	1	2	2	2
CO 4	3	1	2	3	2	2
CO 5	3	1	2	3	2	2

Assessment Pattern

Course name	**Electrical System Modeling**		
Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination (% Marks)**
	Test 1 (% Marks)	**Test 2 (% Marks)**	
Remember	-	-	-
Understand	20	20	20
Apply	40	40	40
Analyze	30	30	40
Evaluate	10	10	-
Create	-	-	-

Mark distribution

Total Marks	CIA marks	ESE marks	ESE Duration
100	40	60	3 Hours

Continuous Internal Evaluation Pattern:

Seminar* : 10 marks

Course based task/Micro Project//Data collection and interpretation/Case study : 10 marks

Test paper 1 (Module 1 and Module 2) : 10 marks

Test paper 2 (Module 3 and Module 4) : 10 marks

*Seminar should be conducted in addition to the theory hours. Topics for the seminar should be from recent technologies in the respective course

End Semester Examination Pattern: The end semester examination will be conducted by the college. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 4 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of whichstudent shall answer any five. Each question can carry 8 marks. Total duration of theexamination will be 3 Hrs.

SYLLABUS

MODULE 1 (6 hours)

Mathematical Modelling

Mathematical Modelling of Control Systems: Transfer Function and Impulse-Response Function, Automatic control systems, Modelling in State Space, State-Space Representation of Scalar Differential Equation Systems, Transformation of Mathematical Models with MATLAB

Mathematical Modelling of Mechanical Systems and Electrical Systems: Mathematical Modelling of Mechanical Systems and Electrical Systems.

MODULE 2 (8 hours)

Control System Design

Control System Design by frequency response-Lead compensation, Lag compensation, Lag-Lead compensation, Realization of compensators.

PID Controllers-Tuning Rules, Computational approach to obtain optimal sets of parameter values, Modifications of PID control schemes, Two Degrees of Freedom control, Zero placement approach, Case study.

MODULE 3 (8 hours)

Control Systems Analysis in State Space: State-Space Representations of Transfer-Function Systems, Transformation of System Models with MATLAB/PSPICE, Solving the Time-Invariant State Equation, Controllability and Observability.

Control Systems Design in State Space: Pole Placement, Solving Pole-Placement Problems with MATLAB, State Observers, Design of Regulator Systems with Observers, Design of Control Systems with Observers.

MODULE 4 (7 hours)

AC equivalent circuit modelling: Basic AC modelling approach- Averaging the Inductor and Capacitor Waveform- Small Signal Equivalent Circuit Model- Modelling examples of basic switched mode converters - Modelling the PWM- The Canonical Circuit Model.

MODULE 5 (7 hours)

Modelling and Simulation of Switching Converters with State Space Averaging:

State Space Averaging Technique -, State Equations of a Network, Basic State-Space Averaged Model, State-Space Averaging Result, Simulation and Design of power electronic converters using State-space averaged models- State-Space Averaging of a Nonideal Buck-Boost Converter- State-Space Averaging of a Boost Converter with ESR, Simulation using MATLAB/PSPICE.

References

1. Katsuhiko Ogata, *Modern Control Engineering*, Pearson Education India., 5th Edition, 2015.
2. I. J. Nagrath and M. Gopal, *Control Systems Engineering*, New Age International (P) Limited, 7th Edition, 2021.
3. A.Nagoor Kani, *Advanced Control Theory*, CBS publications, 3rd Edition,2020
4. Robert W. Erickson, and Dragan Maksimovic, *Fundamentals of Power Electronics*, Springer, 3rd edition, 2020.

5. C Rashid M.H., *Power Electronics Circuits, Devices and Applications*, Pearson Education,4th Edition, 2017.
6. Ned Mohan and Robbins Undeland, *Power Electronics: Converters, Applications and Design*, John Wiley, 3rd Edition, 2007.

COURSE CONTENTS AND LECTURE SCHEDULE

No	Topic	No. of Lecture/ Tutorial hours
	Module 1(8 hours)	
1.1	Transfer Function and Impulse-Response Function	1
1.2	Automatic control systems	1
1.3	Modelling in State Space	1
1.4	State-Space Representation of Scalar Differential Equation Systems, Transformation of Mathematical Models with MATLAB	1
1.5	Mathematical Modelling of Mechanical Systems	2
1.6	Mathematical Modelling of Electrical Systems	2
	Module 2(7 hours)	
2.1	State-Space Representations of Transfer-Function Systems	2
2.2	Transformation of System Models with MATLAB	1
2.3	Solving the Time-Invariant State Equation	1
2.4	Controllability	2
2.5	Observability	1
	Module 3(7 hours)	
3.1	Pole Placement, Solving Pole-Placement Problems with MATLAB	2
3.2	State Observers	2
3.3	Design of Regulator Systems with Observers	2
3.4	Design of Control Systems with Observers	1
	Module 4(7 hours)	
4.1	Basic AC modelling approach	1
4.2	Averaging the Inductor and Capacitor Waveform	1
4.3	Small Signal Equivalent Circuit Model	1
4.4	Modelling examples of basic switched mode converters	2
4.5	Modelling the PWM	1
4.6	The Canonical Circuit Model	1
	Module 5(7 hours)	
5.1	State Equations of a Network	2
5.2	Basic State-Space Averaged Model, State-Space Averaging Result	1
5.3	State-Space Averaging of a Nonideal Buck-Boost Converter	2
5.4	State-Space Averaging of a Boost Converter with ESR	2

Model Question Paper

QP CODE: Pages: 1

Reg No.:________________________

Name:__________________________

MAR ATHANASIUS COLLEGE OF ENGINEERING (AUTONOMOUS), KOTHAMANGALAM

THIRD SEMESTER M. TECH DEGREE EXAMINATION, DECEMBER 2025

Course Code: M24EE1E302D

Course Name: ELECTRICAL SYSTEM MODELING

Max. Marks:60 Duration: 3 hours

PART A

Answer all questions. Each question carries 4 marks.

1. With neat block diagram explain automatic control system?
2. Describe briefly the dynamic characteristics of the PI controller, PD controller and PID controller?
3. Discuss about controllability and observability in linear control system.
4. Explain canonical circuit model method for deriving ac equivalent circuit model of switching converters.
5. Define state space averaging modelling technique for ac converters.

PART B

Answer any five questions. Each question carries 8 marks.

6. Obtain a state space equation and output equation for the system defined by

$$\frac{Y(s)}{U(s)} = \frac{2s^3 + s^2 + s + 2}{s^3 + 4s^2 + 5s + 2}$$

7. Discuss about the mathematical modelling of electrical systems.
8. Compare lag compensation, lead compensation and lag-lead compensation.
9. Consider the transfer function system $\frac{Y(s)}{U(s)} = \frac{25.04s+5.008}{s^3+5.03247s^2+25.1026s+5.008}$

   Obtain a state space representation of this system with MATLAB.
10. Consider the transfer function system $\frac{Y(s)}{U(s)} = \frac{s+6}{s^2+5s+6}$

    Obtain a state space representation of this system in (a) controllable canonical form and (b) observable canonical form.

11. With neat circuit diagrams illustrate the averaged small signal ac model technique for buck, boost and buck-boost converters.
12. Apply state space averaging method to derive the model of non-ideal boost converter with ESR.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1I303/ M24EE1I307	INTERNSHIP	INTERNSHIP	0	0	0	0	3

Summary:

Internship is a structured, short-term, supervised placement designed to provide M.Tech students with practical experience in their field of specialization. Conducted after the second semester for a minimum of 6–8 weeks, the internship can be undertaken at industries, research organizations, or reputed academic institutes. It aims to bridge theoretical knowledge with real-world applications, enhancing students' technical, managerial, and communication skills while offering exposure to industrial environments and professional ethics. Students independently select their internship organization with approval from their faculty advisor, PG Programme Coordinator, or guide, and are assigned a supervisor to oversee their progress.

The internship's objectives include exposing students to industrial settings, sharpening technical and managerial skills, understanding current technological advancements, and appreciating socio-economic and environmental factors in professional contexts. It benefits students by providing hands-on experience, improving employability, and building professional networks. For the institute, it strengthens industry-academia ties and enhances credibility, while industries gain access to motivated pre-professionals and fresh perspectives.

Course Outcomes

CO 1	Students will demonstrate an understanding of industrial practices and real-world applications by integrating theoretical knowledge gained during their M.Tech program into practical settings.
CO 2	Students will develop technical and managerial skills through hands-on experience in industry, research, or academic environments during a 6–8 week supervised internship.
CO 3	Students will apply problem-solving techniques and current technological advancements to address challenges encountered in their chosen internship organization.
CO 4	Students will evaluate socio-economic, environmental, and ethical factors influencing professional engineering practices based on observations recorded during their internship.
CO 5	Students will create a comprehensive internship report and effectively communicate their findings and experiences through a viva voce, showcasing enhanced communication and professional skills.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	1	2	2	1	1
CO 2	2	1	3	2	2	1
CO 3	3	1	2	3	2	0
CO 4	2	1	2	1	1	3
CO 5	1	3	2	1	1	1

Internship types include industry placements (with/without stipend), government/PSU internships (e.g., BARC, ISRO), academic/research institute internships, and opportunities with incubation centers or startups. Students must adhere to organizational rules, maintain a daily diary/logbook, and submit a report, internship certificate, employer feedback, and stipend proof (if applicable) upon completion. The program mandates weekly progress updates to the college guide and compliance with ethical practices and safety protocols.

Evaluation totals 100 marks, split into

1. Continuous Internal Evaluation **(50 marks)**
2. End Semester Evaluation **(50 marks)**

Internal evaluation comprises 25 marks for the student's diary (assessing regularity, quality, and organization of recorded observations) and 25 marks from industry evaluation.

The end semester evaluation includes 25 marks for the internship report (judged on originality, structure, and relevance) and 25 marks for a viva voce conducted by a committee of faculty and an external expert.

Full details of the evaluation process, including formats and criteria, are available in the M.Tech Curriculum 2024, Section: Evaluation Pattern, Subsection IV.

This internship serves as a critical stepping stone for students, offering practical exposure, skill development, and potential career opportunities while fostering collaboration between academia and industry.

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1P304 Track 1	DISSERTATION PHASE 1	PROJECT/DISSERTATION	0	0	16	16	11
M24EE1P308 Track 2			0	0	0	0	11

Overview

Dissertation Phase 1 is a critical component of the M.Tech program conducted during the third semester. It marks the initial stage of the dissertation work, where students begin their research or project under two distinct tracks: Track 1 (conventional M.Tech program) and Track 2 (industry-oriented long-term internship program). The course is designed to enable students to apply their theoretical knowledge and technical skills to address real-world problems in their specialization, fostering research, innovation, and industry readiness.

Structure and Credits

Course Codes:

Track 1: M24EC1P304 (Dissertation Phase 1, conducted in college)

Track 2: M24EC1P308 (Dissertation Phase 1, conducted in industry)

Credits: 11 credits for both tracks

Hours:

Track 1: 16 hours/week

Track 2: Not explicitly specified but aligned with industry work (minimum 16 weeks of prior internship required)

Total Marks: 100 (Continuous Internal Evaluation only)

Objectives

The primary objectives of Dissertation Phase 1 are:

1. Topic Identification and Selection: To identify a relevant, feasible, and innovative research topic aligned with the student's area of interest and the field's current trends or challenges.
2. Literature Review: To conduct a preliminary review of existing research and literature to understand the state of the art, identify gaps, and establish the context for the proposed work.
3. Problem Definition: To clearly define the research problem or question that the dissertation aims to address, ensuring it is specific, measurable, and researchable.
4. Objective Formulation: To establish clear and achievable objectives for the overall dissertation, outlining what the research intends to accomplish.

5. Feasibility Assessment: To evaluate the practicality of the proposed research in terms of available resources, time constraints, and technical requirements.
6. Methodology Outline: To develop a preliminary plan for the research methodology, including the tools, techniques, or approaches that will be used to investigate the problem.
7. Synopsis Preparation: To prepare and submit a concise synopsis or proposal summarizing the research topic, objectives, significance, and planned approach for approval by the academic supervisor or committee.
8. Background Knowledge Building: To deepen the student's understanding of the chosen domain and related concepts, ensuring a solid theoretical foundation for the research.

These objectives are designed to set the stage for Phase 2 and beyond, where the focus typically shifts to implementation, experimentation, and analysis. Phase 1 is critical for ensuring that the research is well-planned and directed toward a meaningful contribution to the field.

Course Outcome

After completing dissertation phase 1 student should be able to

CO 1	Demonstrate Research Topic Selection Skills: Students will be able to identify and select a research topic that is innovative, relevant, and feasible within the scope of their M.Tech program.
CO 2	Conduct Effective Literature Analysis: Students will develop the ability to critically review and synthesize existing literature to identify research gaps and establish the context for their study.
CO 3	Define a Clear Research Problem: Students will acquire the skill to articulate a well-defined research problem or question, ensuring it is specific, measurable, and aligned with their dissertation goals.
CO 4	Formulate Research Objectives and Methodology: Students will be able to formulate clear research objectives and outline a preliminary methodology, demonstrating an understanding of the tools and approaches required for their study.
CO 5	Prepare a Comprehensive Research Proposal: Students will gain the capability to create a structured synopsis or proposal, effectively communicating the significance, objectives, and planned approach of their research for evaluation.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	1	2	2	2	1
CO 2	3	2	3	2	2	1
CO 3	3	1	3	2	2	1
CO 4	3	1	3	3	3	1
CO 5	2	3	3	2	2	2

Tracks and Eligibility

Track 1 (Conventional M.Tech Program):

- Dissertation Phase 1 is conducted within the college.
- Suitable for students focusing on academic research or projects not requiring extensive industry immersion.

Track 2 (Industry-Oriented Program):

- Designed for students who have completed a long-term internship (minimum 16 weeks) in industry.
- Dissertation Phase 1 is conducted in the industry where the internship was completed.
- Eligibility:
  - Qualified in GATE or achieved an SGPA above 8.0 in the first semester.
  - Successful completion of an interview by an expert committee at the end of the second semester.

Location:

- Track 1: Conducted in college
- Track 2: Conducted in industry, requiring prior approval from the Department Level Advisory Committee (DLAC) and College Level Advisory Committee (CLAC).

Supervision:

- Track 1: Supervised by an internal faculty member.
- Track 2: Co-supervised by an internal faculty member and an external supervisor (scientist/engineer with a minimum postgraduate degree) from the industry.
- Progress Reporting: Students must submit monthly progress and attendance reports, signed by the external guide (for Track 2), to the internal supervisor.
- Prerequisites: Successful completion of coursework up to the second semester is mandatory.

Continuous Internal Evaluation

The evaluation committee consists of the following members:

1. Project Coordinator
2. A Senior Faculty Member
3. Project Supervisor

Dissertation Phase 1 is evaluated through Continuous Internal Evaluation (CIE) only, with a total of 100 marks. The evaluation process is detailed in the M.Tech Curriculum 2024, Section:

Evaluation Pattern, Subsection IX (Dissertation):

Mark Allocation

Course Outcome (CO)	Marks Allocated	Justification
CO1: Demonstrate Research Topic Selection Skills	15	Topic selection is foundational but less intensive than later stages; it requires creativity and initial research.
CO2: Conduct Effective Literature Analysis	25	Literature review is critical, time-intensive, and requires critical thinking to identify gaps.
CO3: Define a Clear Research Problem	20	Defining the problem is a pivotal step, requiring clarity and alignment with research goals.
CO4: Formulate Research Objectives and Methodology	25	Formulating objectives and methodology demands detailed planning and technical understanding.
CO5: Prepare a Comprehensive Research Proposal	15	Proposal preparation integrates all prior work into a concise document, focusing on communication.
Total	**100**	

Detailed Breakdown and Rationale:

CO1: Demonstrate Research Topic Selection Skills (15 marks)

- This involves identifying a feasible and innovative topic. It’s an essential starting point but less complex than subsequent analytical tasks.
- Assessment: Relevance, originality, and feasibility of the topic.

CO2: Conduct Effective Literature Analysis (25 marks)

- A thorough literature review is a cornerstone of Phase 1, requiring significant effort to survey existing work, analyze gaps, and establish context.
- Assessment: Depth, breadth, and critical evaluation of sources.

CO3: Define a Clear Research Problem (20 marks)

- Defining a specific, measurable research problem is crucial and builds on the literature review. It’s moderately weighted as it sets the direction for the dissertation.
- Assessment: Clarity, specificity, and significance of the problem statement.

CO4: Formulate Research Objectives and Methodology (25 marks)

- This requires outlining clear objectives and a preliminary methodology, which involves technical knowledge and planning. It’s a high-effort task, justifying equal weight to the literature review.
- Assessment: Achievability of objectives and appropriateness of the methodology.

CO5: Prepare a Comprehensive Research Proposal (15 marks)

- The proposal synthesizes all prior work into a structured document. While important for communication, it's less intensive than analysis or planning, hence a slightly lower weight.
- Assessment: Structure, clarity, and completeness of the proposal.

Evaluation Scheme for Track 2 (Industry-Based)

Overview

Target Students: Those who have completed a long-term internship (16 weeks) and aim to conduct their dissertation in industry.

Focus: In-depth research, industry-relevant problem-solving, and collaboration with industrial mentors.

Total Marks: 100 (for Phase 1).

Eligibility:

Qualified in GATE OR SGPA > 8.0 in the first semester.

Successful qualification in an interview by an expert committee at the end of the second semester.

Evaluation Process

Industry Mentor Involvement: The industry mentor (from the internship or dissertation site) provides feedback and assesses feasibility (e.g., 30% weightage).

Academic Supervisor: Ensures academic rigor and alignment with M.Tech standards (e.g., 50% weightage).

Expert Committee Review: Evaluates the final proposal for originality and industry relevance (e.g., 20% weightage, possibly tied to synopsis approval).

Deliverables:

Interim report (literature review, problem statement) – Mid-Phase 1.

Final proposal (synopsis) – End of Phase 1.

Significance

Dissertation Phase 1 serves as a bridge between coursework and full-fledged research or industry application. For Track 1 students, it fosters academic rigor, while for Track 2 students, it enhances industry-academia collaboration, aligning with the college's mission of producing technically competent professionals with real-world exposure.

For full details, refer to the M.Tech Curriculum 2024, Section: Evaluation Pattern, Subsection IX (Dissertation).

SEMESTER IV

CODE	COURSE NAME	CATEGORY	L	T	P	S	CREDIT
M24EE1P401 Track 1	DISSERTATION PHASE 2	PROJECT/DISSERTATION	0	0	27	24	18
M24EE1P402 Track 2			0	0	0	0	18

Overview

Dissertation Phase 2 is the culminating stage of the M.Tech program, conducted during the fourth semester. It builds upon the foundational work completed in Dissertation Phase 1, requiring students to finalize their research or project, present their findings, and demonstrate mastery in their specialization. This phase is offered under two tracks: Track 1(conventional M.Tech program) and Track 2(industry-oriented program), with distinct course codes and execution contexts.

Structure and Credits

- Track 1: M24EC1P401 (Dissertation Phase II, typically conducted in college)
- Track 2: M24EC1P402 (Dissertation Phase II, conducted in industry)
- Credits: 18 credits for both tracks

Hours:

- Track 1: 27 hours/week
- Track 2: Not explicitly specified but aligned with industry work (full-time commitment assumed)

Total Marks: 200 (Continuous Internal Evaluation: 100 marks; End Semester Evaluation: 100 marks)

Objectives

The primary objectives of Dissertation Phase 2 are:

- To complete an in-depth research project or industry-relevant solution in Power Electronics
- To synthesize and apply knowledge gained throughout the M.Tech program to solve complex problems.
- To produce tangible outcomes, such as prototypes, simulations, or publishable research, demonstrating technical expertise and innovation.
- To prepare students for professional careers or advanced academic pursuits by enhancing their research, analytical, and communication skills.

Outcomes

Upon completion of Dissertation Phase 2, students are expected to:

- Deliver a comprehensive solution or research contribution in Power Electronics.
- Demonstrate advanced technical proficiency, critical thinking, and the ability to address real-world challenges.
- Produce a high-quality dissertation report and defend their work effectively.
- For Track 2, align outcomes with industry needs, potentially leading to employment opportunities or patents.

Significance

Dissertation Phase 2 is the capstone of the M.Tech program, reflecting the college's vision of "Excellence in education through resource integration" and mission to produce "technically competent professionals with moral integrity." It bridges academic learning with practical application, preparing students for careers in industry, research, or entrepreneurship. The dual-track approach ensures flexibility, catering to both academic and industry-oriented aspirations.

Scheme for Track 1: Dissertation Phase 2 (College-Based)

Course Outcomes (COs) for Track 1

CO 1	Implement the research methodology proposed in Phase 1 using appropriate tools and techniques (Technical Skills, Problem-Solving Skills).
CO 2	Conduct experiments or simulations to generate data or validate the approach (Research Skills, Critical Thinking Skills).
CO 3	Analyze results and interpret findings to address the research problem (Critical Thinking Skills, Research Skills).
CO 4	Compile a detailed dissertation report documenting the research process and outcomes (Communication Skills).
CO 5	Present and defend the research work effectively to an academic audience (Communication Skills, Technical Skills).

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
CO 1	3	1	3	3	3	1
CO 2	3	1	3	2	3	1
CO 3	3	1	3	2	3	1
CO 4	2	3	2	1	2	1
CO 5	2	3	3	1	2	1

Evaluation Scheme

1. **Continuous Internal Evaluation (CIE) – 100 Marks**

   Assessed by the project coordinator throughout the semester.

   Focus: Progress, effort, and intermediate deliverables.

Component	Marks	CO Assessed	Justification
Methodology Implementation Progress	25	CO1	Monitors execution of the proposed plan in a college lab or simulation setup.
Experimental/Simulation Work	25	CO2	Assesses data collection or validation efforts in a controlled academic setting.
Interim Result Analysis	20	CO3	Evaluates preliminary analysis and critical thinking during the semester.
Draft Report Submission	20	CO4	Checks documentation quality and adherence to academic standards.
Regular Interaction/Presentation	10	CO5	Assesses communication and ability to discuss progress with the supervisor.
Total	**100**		

2. **End Semester Evaluation (ESE) – 100 Marks**

   Assessed by a panel (Project coordinator+ supervisor + external examiner) at the semester’s end.

   Focus: Final output, rigor, and presentation.

Component	Marks	CO Assessed	Justification
Final Methodology Implementation	20	CO1	Evaluates completeness and technical accuracy of the implemented solution.
Quality of Results/Data	25	CO2	Assesses the robustness and validity of experimental or simulation outcomes.
Depth of Analysis and Conclusions	25	CO3	Examines the interpretation and significance of findings.
Final Dissertation Report	20	CO4	Judges the quality, structure, and clarity of the written report.
Viva Voce/Presentation	10	CO5	Tests ability to defend work and communicate findings to an academic panel.
Total	**100**		

Scheme for Track 2: Dissertation Phase 2 (Industry-Based)

Course Outcomes (COs) for Track 2

CO 1	Implement the industry-oriented methodology proposed in Phase 1 using industry tools/resources (Technical Skills, Problem-Solving Skills).
CO 2	Perform industry-relevant experiments, validations, or prototypes (Research Skills, Critical Thinking Skills).
CO 3	Analyze results and draw conclusions applicable to the industry problem (Critical Thinking Skills, Research Skills).
CO 4	Compile a dissertation report integrating academic and industry perspectives (Communication Skills).
CO 5	Present findings effectively to both academic and industry stakeholders (Communication Skills, Technical Skills).

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
CO 1	3	1	3	3	3	1
CO 2	3	1	3	2	3	1
CO 3	3	1	3	2	3	1
CO 4	2	3	2	1	2	1
CO 5	2	3	3	1	2	1

Evaluation Scheme

1. **Continuous Internal Evaluation (CIE) – 100 Marks**

   Assessed jointly by the Project coordinator, supervisor and industry mentor during the semester.

   Focus: Industry collaboration, progress, and practical application.

   For full details, refer to the M.Tech Curriculum 2024, Section: Evaluation Pattern, Subsection IX (Dissertation).

Component	**Marks**	**CO Assessed**	**Justification**
Methodology Implementation Progress	25	CO1	Tracks execution of the plan in an industry environment using real-world tools.
Industry Validation/Prototype Work	25	CO2	Evaluates practical outputs (e.g., prototypes, tests) relevant to industry needs.

Interim Result Analysis	20	CO3	Assesses industry-applicable insights derived during the process.
Draft Report Submission	20	CO4	Ensures documentation meets both academic and industry standards.
Industry Feedback/Interaction	10	CO5	Gauges communication with industry mentor and progress updates.
Total	**100**		

2. End Semester Evaluation (ESE) – 100 Marks

Assessed by a panel (Project coordinator, supervisor, industry mentor, external examiner).

Focus: Final deliverables, industry relevance, and dual-audience presentation.

Component	Marks	CO Assessed	Justification
Final Methodology Implementation	20	CO1	Evaluates the technical success of the industry-implemented solution.
Quality of Industry Outputs/Results	25	CO2	Assesses the practical utility and quality of industry-specific deliverables.
Depth of Analysis and Industry Impact	25	CO3	Examines conclusions and their relevance to industry challenges.
Final Dissertation Report	20	CO4	Judges the report's ability to address academic rigor and industry needs.
Viva Voce/Presentation (Dual Audience)	10	CO5	Tests communication to both academic and industry evaluators.
Total	**100**		