DEPARTMENT OF ELECTRICAL ENGINEERING

SCHOOL OF ENGINEERING AND TECHNOLOGY

Courses of Study
2023 Onwards

Doctor of Philosophy
Electrical Engineering

Courses of Study

(Approved for Batches 2023 and Onwards)

Ph.D Electrical Engineering

Approved in 5th Board of Studies (BoS 2023) held on 24 November, 2023

Department of Electrical Engineering
Islamic University of Science and Technology, Kashmir

Preface

As the academic landscape continues to evolve, the field of electrical engineering stands at the forefront of technological advancement, intertwining deeply with both foundational theories and pioneering innovations. The pursuit of a Doctor of Philosophy (Ph.D.) in Electrical Engineering is more than an academic endeavor; it is a commitment to pushing the boundaries of what is possible, a deep dive into the complexities of electrical and electronic systems that drive our modern world.

This Ph.D. program is designed for those who aspire to lead the charge in innovation, research, and teaching within the realms of academia, industry, and beyond. It fosters a rigorous environment where theoretical knowledge meets practical application, aiming to solve real-world problems through scholarly research and innovative thinking. The journey through this program is one of intellectual rigor, creative challenges, and groundbreaking discoveries.

Our curriculum is structured to provide students not only with the depth of expertise in areas such as signal processing, telecommunications, power systems, and microelectronics but also with the breadth of knowledge that supports interdisciplinary research. Collaboration is key, as the complex problems of today require insights from multiple disciplines. Thus, we emphasize both specialization and versatility, preparing our graduates to excel in diverse settings.

As you embark on this profound journey, remember that a Ph.D. is a testament to your resilience, curiosity, and unwavering pursuit of knowledge. It is both a personal and professional transformation—a period of growth that demands perseverance, creativity, and the willingness to question conventional wisdom.

We are excited to welcome you into a community of scholars dedicated to innovation and excellence. Your research has the potential to lead to significant advancements in electrical engineering and to make a lasting impact on society. We look forward to supporting you through this journey and witnessing the unique contributions you will make to our field.

Welcome to the Ph.D. program in Electrical Engineering. Let your curiosity lead you to undiscovered paths, and may your research contribute profoundly to our understanding and betterment of the world.

About the Department

Vision

The Department of Electrical Engineering, Islamic University of Science and Technology aspires to be a destination for high quality scientific and technological education in electrical sciences and technology, a research and innovation hub with special emphasis on sustainable development in the service of humanity, and a centre where education and research are in full compliance with international standards of quality assurance.

Mission

M1:. Quality education and research: Engage in high quality education and research with an eye on international standards.

M2:. Skills and competence for serving industrial needs: Produce skilled and competent manpower trained in electrical engineering and technology for current and emerging needs of the industry.

M3:. Holistic development: Provide an interdisciplinary learning environment that is student-centric, value-based and promotes holistic student development.

M4:. Societal relevance and sustainable development: Drive research and innovation in electrical sciences and technology to serve societal needs and with emphasis on sustainable development.

The Department of Electrical Engineering at IUST was established in 2012. It currently offers one undergraduate program awarding a Bachelor of Technology (B. Tech) degree in electrical engineering. Ten batches of electrical engineers have graduated since the inception of the department. In 2018, a Ph.D. program was started. The department has state-of-the-art infrastructural facilities to provide its students education and training aligned to its mission. The faculty is well qualified and dedicated, having received training and education at reputed institutions within the country.

Students entering the undergraduate program are provided basic training in analysis and design of electrical energy systems, including, broadly, systems employed for generation, transmission, control and conversion of electrical energy. It is also ensured that students gain sufficient general knowledge in related disciplines of electrical and computer sciences, so that they remain capable of obtaining a specialized degree in their area of interest.

The Department has a well-equipped facility for giving students hands-on training and exposure in all fundamental technologies that are a part of a standard graduate level electrical engineering course, like electromechanical energy conversion, power systems, control systems, computation and simulation etc. All labs are Wi-Fi enabled and have a 24x7 uninterrupted power supply. The department also has a well-equipped departmental library with a good collection of basic and advanced books in electrical engineering and allied subjects.

About the 5th Board of Studies Meeting

The Department of Electrical Engineering (DoEE), IUST, convened its 5th Board of Studies (BoS) meeting on 24th November 2023. The BoS agenda included revision of curriculum for B. Tech Electrical Engineering, introduction of Minor/Honors, postgraduate programmes and Ph.D course work. The meeting was attended by the following:

Board Members Approved by the Competent Authority

1.	Dr. Rumaan Bashir	I/C Dean, SoE&T, IUST	Chairperson
2.	Mr. Rayes Ahmad Lone	I/C Head, EE, IUST	Member/Convener
3.	Prof. Shameem Ahmad Lone	Professor, EE, NIT Srinagar	Member (AC Nominee)
4.	Prof. Mohmmad Rizwan	Professor, EE, DTU, New Delhi	Member (AC Nominee)
5.	Syed Mohammad Ashraf	Manager (Electrical), NHPC Ltd	Member (Industrial Expert)
6.	Dr. Shahkar Ahmad Nahvi	Assistant Professor, EE, IUST	Member
7.	Mr. Zahoor Ahmad Ganie	Assistant Professor, EE, IUST	Member
8.	Mrs. Baziga Youssuf	Assistant Professor, EE, IUST	Co-Opted Member
9.	Dr. Mubashar Yaqoob Zargar	Assistant Professor, EE, IUST	Co-Opted Member
10.	Dr. Ahmed Sharique Anees	Assistant Professor, EE, IUST	Co-Opted Member
11.	Dr. Salman Ahmad	Assistant Professor, EE, IUST	Co-Opted Member
12.	Dr. Viqar Yousuf	Assistant Professor, EE, IUST	Co-Opted Member
13.	Dr. Zahid Farooq	Assistant Professor, EE, IUST	Co-Opted Member
14.	Dr. Danish Rafiq	NPDF Fellow, SERB	Co-Opted Member
15.	Dr. Peer Bilal Ahmad	I/C HOD, Mathematics	Co-Opted Member
16.	Dr. Mohd Junaid Mir	Assistant Professor, ME, IUST	Co-Opted Member
17.	Dr. Imran ul Amin	Assistant Professor, Management, IUST	Co-Opted Member
18.	Dr. Javid Ahmad Khan	Assistant Professor, Economics, IUST	Co-Opted Member
19.	Dr. Shabir Ahmad Kumar	Assistant Professor, Physics, IUST	Co-Opted Member
20.	Mrs. Shaiqa Nasreen	Assistant Professor, ECE, IUST	Co-Opted Member

Contents

Definition of Credit

1 Lecture Hour (L) Per Week	1 Credit
1 Tutorial Hour (T) Per Week	1 Credit
1 Practical Hour (T) Per Week	0.5 Credit
1 Social Hour (S) Per Week	1 Credit

Range of Credits

A range of credits from 173 and above shall be required for a student to be eligible to get an undergraduate degree in Electrical Engineering. A student will be eligible to get an undergraduate degree with Honours or an additional Minor Degree, if he/she completes an additional 18 or more credits during the degree.

Course Code and Definition

All courses (except Open Electives) are denoted by a seven-digit alphanumeric code (XXXXXXX), three alphabets followed by three numerals, followed by one alphabet. The first three alphabets designate the department offering the course, e.g., ELE for Electrical Engineering. The first numeral following the three alphabets indicate the level of the course, 1 to 4 for undergraduate 1st to 4th year, 5 to 6 for postgraduate courses. Open electives have a zero in place of the above level numeral and six digits only. The next two numerals are the unique identification numbers for the course. Courses running in odd semesters are labelled from 01 to 49 and courses running in even semesters are labelled from 50 to 99. The last alphabet indicates the nature of the course. It is one amongst six choices, C (Core Course), E (Discipline Centric Elective), G (Generic Elective), B (Bridge Course), A (Audit Course) and S (Specialization Course/Minor Degree). Since, open electives are identified by a zero in place of the level numeral (at fourth digit), therefore the last digit does not have significance in their course code, and hence will not be used for the definition of the same.

Programme Objective:

The PhD Program in Electrical Engineering aims to provide advanced knowledge and research in both traditional and emerging technologies within the field. The program is designed to equip students with a deep understanding of foundational electrical engineering principles, while also fostering exploration and research in cutting-edge areas such as renewable energy, artificial intelligence, and Internet of Things (IoT). The curriculum emphasizes critical thinking, problem-solving, and the application of advanced methodologies to foster a comprehensive understanding of electrical engineering principles. The main goal is to produce scholars who are capable of making significant contributions to academia, industry, and technology innovation.

Programme Outcomes:

1. Demonstrate advanced expertise in the field of electrical engineering, showcasing a profound understanding of both fundamental and specialized concepts.
2. Showcase the ability to innovate, applying theoretical knowledge to address practical challenges and contribute to technological advancements.
3. Demonstrate the capacity to integrate knowledge from diverse disciplines, fostering a holistic approach to problem-solving and research.
4. Develop essential skills, allowing them to operate and analyze energy systems effectively and apply theoretical knowledge to real-world scenarios.
5. Develop leadership skills within the field, positioning graduates to lead and guide advancements in electrical engineering, whether in academia, industry, or research institutions.

List of Courses

S. No	Course Title	Course Code	L	T	S	P	Credits
1.	High Power Converters: Modulation and Control	ELE601E	4	0	0	0	4
2.	Switched Mode Power Conversion and Design	ELE602E	4	0	0	0	4
3.	Modulation Techniques for Voltage Source Converters	ELE603E	4	0	0	0	4
4.	Advanced Electrical Drives and Control	ELE604E	4	0	0	0	4
5.	Power System Control	ELE605E	3	0	0	0	3
6.	Power System Stability	ELE606E	3	0	0	0	3
7.	Advanced Topics in Model Order Reduction	ELE607E	4	0	0	0	4
8.	Nonlinear Dynamical Systems: Analysis and Control	ELE608E	4	0	0	0	4
9.	Grid Integration of Renewable Energy Sources	ELE609E	4	0	0	0	4
10.	Smart Grid and Energy Conservation	ELE610E	4	0	0	0	4
11.	Solar Technologies	ELE501C	3	0	1	0	4
12.	Power System Planning	ELE504C	3	0	0	0	3
13	Distributed Generation and Microgrids	ELE550C	4	0	0	0	4
14	Economics and Planning of Energy Systems	ELE551C	3	0	1	0	4
15	Power Converters for EVs	ELE507C	4	0	0	0	4
16	Embedded System Design	ELE554C	3	0	0	2	4
17	Integrated Energy Systems	ELE501E	3	0	0	0	3
18	Instrumentation and Control in Energy Systems	ELE550E	3	0	0	0	3
19	Renewable Energy Resource Assessment and Forecasting	ELE551G	3	0	0	0	3
20	EV Motor Design	ELE551E	3	0	0	0	3
21	Thermal Management of EV Systems	ELE503E	3	0	0	0	3
22	Control Systems for Electric Vehicles	ELE504E	3	0	0	2	4

Course Contents

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE601E</td><td colspan="5">High Power Converters: Modulation and Control</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="7">Course Objectives: To Analyse different converters topologies and gate drivers. To understand the design aspects and components selection of converters. Design and analyze the PWM schemes for multilevel converters.</td></tr>
<tr><td colspan="7">Course Outcomes: After studying this course, students will be able to:
1. Analyze the operation of basic power converter topologies.
2. Design of gate driver circuit
3. Analyze the operation of pulse width modulation schemes for VSC.
4. Analyze and design of Multilevel converters.
5. Design modulation and control techniques for multilevel converters</td></tr>
</table>

MODULE I

Introduction of Power Semiconductor Devices, converters, PWM, and Drive Circuit

Basic Introduction to Powers Semiconductor Devices, Half Bridge and Full Bridge Circuit Operation, Harmonics in Sinusoidal PWM, Basics of Gate Driver Circuits, Gate Driver Circuits - Turn-on and Turn-off Process, Gate Driver Circuits - Features of Gate Drivers and Basics of Bootstrap Functionality

MODULE II

Pulse Width Modulation in Voltage Source Converters

Carrier-based SPWM, Third harmonic addition in Sine PWM, Introduction to Space Vectors, Space Vector PWM- Timing Calculation, Space Vector PWM- Switching Sequence, Space Vector PWM- Using Carriers

MODULE III

Multilevel Converters, CHB Converter and PWM

Cascaded H-bridge Multilevel Converters, Output Voltage Waveform Synthesis in CHB Converter and Basic of Asymmetrical CHB Converters, Cascaded H-Bridge Converters: Phase-Shifted PWM, Cascaded H-Bridge Converters: Level-Shifted PWM, Fault-Tolerant Operation of Cascaded H-Bridge Converter.

MODULE IV

Modular Multilevel Converter:
Modular Multilevel Converter - Topology and Operation, Arm and Cell Voltage Ratings, Arm Currents, Arm Energy Balancing, Different Circuit Topologies, PWM Technique and Capacitor Voltage Balancing, Fault Tolerant Operation and Commercial Production, Design of Components in MMC

MODULE V

Neutral Point Clamped Converter - Circuit Topology, Neutral Point Clamped Converter- Space Vector Diagram**,** NPC - Sinusoidal PWM and Space Vector PWM using Single Carrier Strategy**,** Mid-point Voltage Fluctuations**,** Neutral Point Clamped Converter - Capacitor Voltage Balancing**,** Other Topologies of NPC Converters - Higher Level NPC, TNPC and Active NPC

Text Books:	
1.	D. Grahame Holmes, Thomas A. Lipo, "Pulse Width Modulation for Power Converters: Principles and Practice", Wiley-IEEE Press; 1st edition, 2003
2.	Bin Wu, "High–Power Converters and AC Drives", Wiley–Blackwell, 2006.
3.	Sergio Alberto González, Santiago Andrés Verne, María Inés Valla, "Multilevel Converters for Industrial Applications", CRC Press; 1st edition, 2013.
Reference Books:	
1.	Sixing Du, Apparao Dekka, Bin Wu, Navid Zargari, "Modular Multilevel Converters: Analysis, Control, and Applications", Wiley-IEEE Press; 1st edition, 2018
2.	B. Jayant Baliga, "Power Semiconductor Devices", 1st Edition, International Thompson Computer Press, 1995.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE602E</td><td colspan="5">Switched Mode Power Conversion and Design</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
</table>

Course Objectives: To understand the fundamentals and essential features of switching converters and their applications. To learn working principles and characteristics of the power semiconductor switches. To learn the modeling concepts of different topologies of switching converters. To learn the closed-loop control design of switching power converters.

Course Outcomes: After studying this course, students will be able to:

1. Understand the fundamentals and essential features of switching converters and their applications.
2. Analyze and implement modeling techniques in switching converters.
3. Model and design of switching power converters topologies.
4. Design the closed-loop control of switching power converters to study the steady-state, dynamic performance.
5. Design the magnetics and practical implementation of the switch mode power converter.

MODULE I

Switched mode power conversion – Overview: Switched-mode power conversion: Overview, Introduction to DC-DC converter, continuous and discontinuous conduction, advantages and disadvantages of isolated converters, Classifications of DC converter, Performance parameters, High gain DC-DC converter topologies, Ratings and applications.

MODULE II

Isolated and Non-isolated Converters: Power semiconductor switches: Diode, Controlled Switches – BJT, MOSFET, IGBT, Ideal and real characteristics, static and switching characteristics, power loss evaluation, turn-on and turn-off snubber design, control, drive and protection

MODULE III

Controller basics: Modeling of converters: Modeling DC-DC converters, State space representation, Circuit Averaging Method, State Space Model of Switching Converters, Modeling, circuit topology, operation, steady-state model, dynamic model of basic switching converters like Buck, Boost, Buck-Boost converters, Transfer function analysis and dynamic performances of switching power converters.

MODULE IV

Common practical control applications: Controller basics: Pulse width modulation, Controller design principles, Common practical control applications, Controllers and Sensing Circuit, Regulation, Voltage and Current Control Method, Closed-loop control of switching power converters.

MODULE V

Magnetic Design and Prototyping

Basics on design of magnetics: Magnetic Design, Selection of magnetic materials for switching converters, Design examples of switching converters, Simple designs and construction of mini projects.

Text Books:	
1.	Middlebrook, R. D.(Robert David), and Slobodan Cuk, Advances in Switched-Mode Power Conversion, Volumes I and II, 2nd Edition, TESLA co, 1983.
2.	Erickson, Robert W., Fundamentals of Power Electronics, Chapman & Hall, 1997.
3.	Mohan, Undeland, Robbins, "Power Electronics Converters, Applications, and Design" Wiley, Indian Edition.
Reference Books:	
1.	Ramanarayanan Course Material on Switched Mode Power Conversion,Department of Electrical Engineering, Indian Institute of Science, Bangalore 560012. http://minchu.ee.iisc.ernet.in/new/people/faculty/vr/book.pdf
2.	B. Jayant Baliga, "Power Semiconductor Devices", 1st Edition, International Thompson Computer Press, 1995.

Course Code	Course Title					Type of Course
ELE603E	Modulation Techniques for Voltage Source Converter					Elective
	L	**T**	**P**	**Contact Hours/Week**	**Credits**	
	4	0	0	4	4	

Course Objectives: To understand the fundamentals and essential features of switching converters and their applications. To learn the working principles and characteristics of power semiconductor switches. To learn the modeling concepts and the closed-loop control design of switching power converters.

Course Outcomes: After studying this course, students will be able to:

1. Identify different types of voltage source converters and their applications.
2. Explain the fundamentals of PWM and its importance in power electronics.
3. Investigate the generation of harmonics in PWM-controlled voltage source converters.
4. Discuss different control strategies for voltage source converters using PWM.
5. Design and evaluate the performance of PWM-controlled VSC systems under different operating conditions.

MODULE I

Fundamentals of Power Electronic switches, Topologies and Applications: Power electronic switches, single-phase and three-phase 2-level VSI, H-bridge, multilevel converters – diode clamp, flying capacitor and cascaded- H-bridge converters; voltage source and current source converters, an overview of applications of voltage source converters.

MODULE II

Pulse Width Modulation (PWM): Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages; undesirable effects of harmonic voltages – line current distortion, increased losses, pulsating torque in motor drives; control of fundamental voltage; mitigation of harmonics and their adverse effects. Square wave operation of voltage source inverter, PWM with a few switching angles per quarter cycle, equal voltage contours, symmetries in waveforms

MODULE III

Optimum PWM Techniques: PWM for 2-level VSI, Triangle-comparison based PWM, Sine-triangle modulation, Third harmonic injection PWM (THIPWM), Bus-clamping PWM, Pulse width modulation (PWM) at low switching frequency, THD optimized PWM, Selective harmonic elimination and Selective harmonic mitigation, Requirement of dead-time, effect of dead-time on line voltages.

MODULE IV

Space Vector-Based PWM: Space vector concept and transformation, per-phase methods from a space vector perspective, space vector-based modulation, conventional space vector PWM, bus-clamping PWM, advanced PWM, triangle comparison approach versus space vector approach to PWM, influence of PWM techniques on switching loss.

MODULE V

PWM for Multilevel Inverter: Extension of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector-based PWM, analysis of line current ripple and torque ripple, Selective harmonic elimination and Selective harmonic mitigation.

Text Books:	
1.	D. Grahame Holmes, Thomas A. Lipo, "Pulse Width Modulation for Power Converters: Principles and Practice", Wiley-IEEE Press, 2003
2.	M.H Rashid, "Power Electronics Handbook", Elsevier, 4th Edition, 2018.
Reference Books:	
1.	Haitham Abu-Rub, AtifIqbal, J. Guzinski, "High Performance Control of AC Drives with Matlab/Simulink", Wiley, 2nd Edition
2.	B. Jayant Baliga, "Power Semiconductor Devices", 1st Edition, International Thompson Computer Press, 1995.

Course Code	Course Title					Type of Course
ELE604E	Advanced Electrical Drives and Control					Elective
	L	**T**	**P**	**Contact Hours/Week**	**Credits**	
	4	0	0	4	4	

Course Objectives: To impart knowledge about fundamentals of Electric drives and control, operational strategies of DC and AC motor drives as per different quadrant operations and to discuss Review of Drive Concept: Review of introductory concepts of drives.

Course Outcomes: After studying this course, students will be able to:

1. Describe the structure of Electric Drive systems and their role in various applications such as flexible production systems, energy conservation, renewable energy, transportation etc., making Electric Drives an enabling technology.
2. Learn speed control of induction motor drives in an energy efficient manner using power electronics.
3. To acquire the knowledge of selection of drives as per practical operational industrial requirements.
4. To apply their knowledge to prepare control schemes as per different types of motors used in industries.
5. To estimate & solve harmonic and power factor related problems in controlling AC and DC drives.

MODULE I

Review of Conventional Drives: speed –torque relation, Steady state stability, methods of speed control, braking for DC motor – Multi quadrant operation, Speed torque relation of AC motors, Methods of speed control and braking for Induction motor, Synchronous motor. Criteria for selection of motor for drives.

MODULE II

Converter Control of DC Drives: Analysis of series and separately excited DC motor with single phase and three phase converters operating in different modes and configurations. Chopper Control of DC Drives: Analysis of series and separately excited DC motors fed from different choppers for both time ratio control and current limit control, four quadrant controls.

MODULE III

Design of DC Drives: Single quadrant variable speed chopper fed DC drives, Four quadrant variable speed chopper fed DC Drives, Single phase/ three phase converter, Dual converter fed

DC Drive, current loop control, Armature current reversal, Field current control, Different controllers and firing circuits, simulation.

MODULE IV

Inverter fed AC Drives: Analysis of different AC motor with single phase and three phase inverters, Operations in different modes and configurations, Problems and strategies. Cyclo-converter fed AC Drives: Analysis of different AC motor with single phase and three phase cyclo-converters, Operations in different modes and configurations, Problems and strategies, Vector Control, and Rotor side Control.

MODULE V

AC Voltage controller fed AC Drives: Speed control and braking, Operations in different modes and configurations, Control and estimation of AC drives: Induction motor: scalar control, FOC control, DTC, adaptive control, Problems, and strategies.

Text Books:	
1.	R. Krishnan, "Electric motor drives: modeling, analysis and control, Pearson.
2.	Haitham Abu-Rub, AtifIqbal, J. Guzinski, "High Performance Control of AC Drives with Matlab/Simulink", Wiley, 2nd Edition
3.	Bimal.K. Bose, "Power Electronics and Variable frequency drives", Standard Publishers Distributors, New Delhi, 2000
Reference Books:	
1.	Haitham Abu-Rub, AtifIqbal, J. Guzinski, "High Performance Control of AC Drives with Matlab/Simulink", Wiley, 2nd Edition
2.	M. H. Rashid, "Power Electronics - Circuits, Devices and Applications", P.H.I Private Ltd. New Delhi, Second Edition, 1994

Course Code	Course Title					Type of Course
ELE605E	Power System Control					Elective
	L	**T**	**P**	**Contact Hours/Week**	**Credits**	
	3	0	0	3	3	
Course Objectives: After finishing this course, students will be able to grasp the fundamental concepts of power system control. Students will also be able to understand the principles behind AGC, AVR, and different control techniques.						
Course Outcomes: After studying this course, students will be able to: 1. Develop solutions for implementing power system control. 2. Assess and evaluate the impact of control loop adjustments on power system performance. 3. Analyze the interaction between different components (Governor, Turbines, Generator, Load, Tie-line) in a power system. 4. Implement AGC and AVR features in a simulated power system. 5. Evaluate the issues related with the integration of renewable energy sources.						

MODULE I

Power System – Introduction

Interconnection, Stability, Operating states, Control loops, AGC, AVR; System modeling – Governor, Turbines, Generator, Load, Tie-line.

MODULE II

Automatic Generation Control (AGC)

AGC implementation, AGC features, Participating factors, Static and Dynamic performance; Modes of control viz. Flat frequency, Tie-line control, and Tie-line Bias control; Static and Dynamic response of the controlled two-area system.

MODULE III

Automatic Voltage Regulator (AVR)

Types of alternator exciters, AVR for generator excitation control, static and dynamic performance of AVR loop; MVAR control, Application of voltage regulator, synchronous condenser, transformer taps, static VAR compensators.

MODULE IV

The Control Techniques

Classical, Optimal, Adaptive, and Intelligent (fuzzy & neural) control techniques; Energy storage devices and their application to power system control.

MODULE V

Renewable Energy Penetration

Effect of incorporating renewable sources in power systems, the importance of power electronics in integrating renewable power sources, effect on frequency and voltage, and their solution.

Text Books:	
1.	Olle I Elgard, "Electric Energy Systems Theory - An Introduction" Tata McGraw Hill, 2nd Edition.
2.	Allen J. Wood and Wollenberg B.F, "Power Generation Operation and control", John Wiley & Sons, 2nd Edition, 1996.

Reference Books:	
1.	Prabha Kundur, "Power System Stability and Control", McGraw Hill, 2006.
2.	Kirchmayer L.K., "Economic Control of Interconnected Systems", John Wiley & Sons, 1959
3.	Abhijit Chakrabarti and Sunita Halder, "Power System Analysis, Operation and Control" PHI.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE606E</td><td colspan="5">Power System Stability</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="7">Course Objectives: After finishing this course, students will understand the basic concepts of power system stability. Students will learn how to use Eigenvalue analysis, power system stabilizers, governors, and energy storage devices to determine and enhance the system stability.</td></tr>
<tr><td colspan="7">Course Outcomes: After studying this course, students will be able to:
1. Develop solutions for improving power system stability and efficiency.
2. Analyze the interaction between different components (Governor, Turbines, Generator, Load, Tie-line) in a power system.
3. Develop the mathematical model of the power system in software for analyzing the system stability.
4. Design a suitable scheme for transient stability enhancement of a power system.
5. Design a suitable storage system for improving the transient stability.</td></tr>
</table>

MODULE I

Power system dynamics, Power system stability and its problems, Types of stability, Synchronous machine modeling, dq0-transformation, Per unit representation, Equivalent circuits for direct and quadrature axes.

MODULE II

Excitation system and its modeling, Excitation system requirements, and the types of excitation systems. Mathematical analysis, Modelling of turbines, governors, and loads.

MODULE III

Fundamental concepts of small signal stability, State-space representation, Linearization, Eigenvalue and eigen properties of the state matrix, small signal stability of single machine infinite bus (SMIB) system.

MODULE IV

Transient instability, Analysis using digital simulation and energy function method, Transient stability controllers. Mitigation using power system stabilizer (PSS) design and supplementary modulation control of FACTS devices.

MODULE V

High-speed fault clearing. Steam turbine fast valving. High-speed excitation systems. Types of power system stabilizers, modeling of different Power System Stabilizers, modeling of fast-acting energy storage systems, Stability improvement using power system stabilizers, energy storage devices, and governor.

Text Books:	
1.	Prabha Kundur, “Power System Stability and Control,” McGraw Hill, 2006.
2.	Anderson and Fouad, “Power System Control and Stability,” Galgotia Publications, Compensation 1981.

Reference Books:	
1.	Sauer P W & Pai M A,” Power System Dynamics and Stability,” Pearson, 2003.
2.	Padiyar K R, “Power System Dynamics,” 2nd Edition, B.S. Publishers, 2003.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE607E</td><td colspan="5">Advanced Topics in Model Order Reduction</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="7">Course Objective: This course aims to equip students with advanced knowledge and practical skills in Model Order Reduction (MOR), covering classical and modern methods, nonlinear systems, and emerging data-driven approaches.</td></tr>
<tr><td colspan="7">Course Outcomes (COs):
1. Develop the ability to identify scenarios necessitating Model Order Reduction.
2. Acquire proficiency in classical MOR techniques for linear systems.
3. Apply modern MOR methods, including balancing-based and Krylov-based approaches.
4. Demonstrate competence in model reduction for nonlinear systems.
5. Understand and apply data-driven model reduction methods.</td></tr>
</table>

MODULE I

Introduction to Model Order Reduction (MOR)
Need for MOR in large-scale systems, Examples and sources of large systems, Mathematical formulation of MOR for Linear Time-Invariant (LTI) systems.

MODULE II

Classical Model Reduction Methods
Modal and Pade Approximation, Routh Approximants, Explicit Moment Matching.

MODULE III

Modern Methods in Model Reduction: Balancing-based methods, Krylov-based methods (Arnoldi and Lanczos Algorithms), Implicit moment matching techniques.

MODULE IV

Model Order Reduction for Nonlinear Systems: Mathematical formulation of MOR for nonlinear systems, Proper Orthogonal Decomposition (POD), Discrete Empirical Interpolation Method (DEIM), Trajectory Piece-wise Linear approximation.

MODULE V

Data-Driven Model Reduction Methods: Need for data-driven model reduction methods, adaptive data-driven model reduction techniques, Introduction to Dynamic Mode Decomposition (DMD), and Sparse Identification of Nonlinear Dynamics (SINDY).

Text Books:	
1.	A. C. Antoulas, "Approximation of Large Scale Dynamical Systems," SIAM, 2005.
2.	S. L. Brunton and J. N. Kutz, "Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control," Cambridge University Press, 2019.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE608E</td><td colspan="5">Nonlinear Dynamical Systems: Analysis and Control</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="7">Course Objective: To develop a profound understanding of nonlinear dynamical systems and the ability to analyze and design control strategies for such systems. Develop an understanding of chaos theory, fractals, and dynamics, as well as advanced control methods such as sliding mode control and adaptive control.</td></tr>
<tr><td colspan="7">Course Outcomes (COs):
1. Understanding: Acquire a deep understanding of nonlinear dynamics, chaos theory, and fractals, along with their historical context in the field of dynamics.
2. Analysis: Develop the skills to analyze nonlinear dynamical systems and understand their peculiar features, like bifurcations, limit cycles etc. Understand and analyze various models for nonlinear systems including using state space models, phase portraits, etc.
3. Analysis: Explore advanced topics in limit cycles and bifurcations, including the Poincaré−Bendixson Theorem, Liénard Systems, Relaxation Oscillations, and various bifurcation types like Saddle-Node and Hopf Bifurcations.
4. Analysis: understand stability notions and analyze for stability using Lyapunov's methods
5. Control Design: Design controllers for nonlinear systems using Lyapunov's methods, sliding mode control, adaptive control etc..</td></tr>
</table>

Module-I

Introduction to Nonlinear dynamical system and controls: History of Dynamics, Peculiarities of nonlinear systems, equilibrium points, limit cycles, Chaos, Fractals, One-dimensional systems and elementary bifurcations. Standard nonlinearities like saturation, backlash etc.. State Space Models, Control Loops, Controller Design, and Examples, The Pendulum on a Cart, Mobile Robots—The Nonholonomic Integrator.

Module-II

Phase Plane Analysis and Linearisation: Concept and construction of phase portraits, Phase plane analysis of linear and nonlinear systems, Existence of limit cycles. Describing Function Method and Applications. Linear Systems and Linearisation: Linear Systems Review, Systems with Inputs, Controllability and Observability, Stabilizability and Detectability, Pole Placement, Fixed Points and Linearization.

Module-III

Limit Cycles and Bifurcations: Poincaré−Bendixson Theorem , Liénard Systems Relaxation Oscillations, Weakly Nonlinear Oscillators, Bifurcations Revisited , Saddle-Node, Transcritical, and Pitchfork Bifurcations, Hopf Bifurcations

Module-IV

Stability: Equilibrium points, Concept of stability of nonlinear systems, Linearization and Local stability, Lyapunov's direct method, Lyapunov's analysis of LTI systems. Stability Notions, Quadratic Lyapunov Functions, Stability by Lyapunov's Second Method, Region of Attraction, Converse Theorems, Invariance Theorems.

Module-V

Nonlinear Control Design: Control design based on Lyapunov's direct method, Feedback Linearization, Sliding Mode Control, Chattering and Chattering Avoidance, Estimating the Disturbance, Output Tracking. Adaptive Control, Motivating Examples and Challenges, Limitations of Static Feedback Laws, Estimation-Based Controller Designs, Model Reference Adaptive Control, Adaptive Control for Nonlinear Systems, Introduction to model predictive control.

Text Books:	
1.	*Applied Nonlinear Control,* J. J. Slotine, Prentice Hall, 1991.
Reference Books:	
1.	*Nonlinear System Analysis,* M. Vidyasagar, Society for Industrial and Applied Mathematics, 2002.
2.	*Nonlinear Systems*, H. K. Khalil, 3rd Edition, Prentice Hall, 2001.
3	*Introduction to Nonlinear Control: Stability, Control Design, and Estimation* Christopher M. Kellett and Philipp Braun, Princeton.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE609E</td><td colspan="5">Grid Integration of Renewable Energy Sources</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="7">Course Objective: The primary objective is to furnish students with insights into the impacts arising from the integration of distributed renewable generation in power systems. Moreover, the course seeks to improve students' skills in utilizing advanced simulation tools to evaluate the efficiency of electric power systems under a substantial penetration of renewable energy.</td></tr>
<tr><td colspan="7">Course Outcomes: After studying this course, students will be able to:
1. Understand the concept of distributed generation, concept of Nano/micro/mini grid, and also issues related to integration of large renewable energy sources
2. Develope strong foundation for power system equipment used for integration.
3. Understand power systems, their operation and control focussed on the issues related to the integration of distributed renewable generation into the network.
4. Have a detailed knowledge of power quality and its management along with approaches for grid stabilization.
5. Develop a deep understanding of protection issues for integration of renewable energy sources for different types of networks.</td></tr>
</table>

MODULE I

Introduction: General introduction to the concept of distributed generation and its technical, economic and social impacts in the electrical system, Various techniques of utilizing power from renewable energy sources, concept of nano/micro/mini grid. Need of integrating large renewable energy sources, issues related to integration of large renewable energy sources, rooftop plants. Concept of VPP.

MODULE II

Power system equipment's for grid integration: Synchronous generator: synchronization/integration to existing grid, load sharing during parallel operation, stability (swing equation and solution), Induction Generator: working principle, classification, stability due to variable speed and counter-measures, Power Electronics: need of power electronic equipment's in grid integration, converter, inverter, chopper, AC regulator and cycloconverters for AC/DC conversion.

MODULE III

Integration of alternate sources of energy: Introduction, principles of power injection: converting technologies, power flow; instantaneous active and reactive power control approach; integrating multiple renewable energy sources; DC link integration; AC link integration; HFAC link integration; islanding and interconnection

MODULE IV

Grid stabilization, Power quality and management: Scheduling and dispatch, Forecasting, reactive power and voltage control, frequency control, operating reserve, storage systems, 6 0 0 electric vehicles Ancillary services in Indian Electricity Market (regulatory aspect), CERC and CEA orders (technical and safety standards) THD, voltage sag, voltage swell, frequency change and its effects, network voltage management, frequency management, system protection, grid codes.

MODULE V

Technical impact of Protection: Description of the different network topologies where distributed renewable generation can be connected. Principles of design, operation and protection Study of protection practice for distributed renewable generators and their impact on the network protection system, both transmission and distribution

Text Books:	
1.	Integration of Alternative sources of Energy, Felix A. Farret and M. Godoy Simoes, IEEE Press – Wiley-Interscience publication, 2006.
2.	Grid integration of solar photovoltaic systems, Majid Jamil, M. Rizwan, D.P.Kothari, CRC Press (Taylor & Francis group), 2017
3.	Renewable Energy Grid Integration, Marco H. Balderas, Nova Science Publishers, New York, 2009.
4.	Wind Power Integration connection and system operational aspects, B. Fox, D. Flynn L. Bryans, N. Jenkins, M. O' Malley, R. Watson and D. Milborrow, IET Power and Energy Series 50 (IET digital library), 2007
Reference Books:	
1.	Advanced grid requirements for the integration of wind farms into the Spanish transmission system, Morales1, X. Robe1, M. Sala, P. Prats, C. Aguerri, E. Torres, IET Renew. Power Generation., Vol. 2, No. 1, pp. 47–59, 2008.
2.	Renewable Energy Engineering and Technology – A Knowledge Compendium, V.V.N. Kishore, TERI Press, 2008.
3.	Comparative analyses of seven technologies to facilitate the integration of fluctuating renewable energy sources, B.V.Mathiesen H. Lund, IET Renew. Power Generation., Vol. 3, NO. 2, pp. 190– 204, 2009.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td rowspan="3">ELE610E</td><td colspan="5">Smart Grid and Energy Conservation</td><td rowspan="3">Elective</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>Contact Hours/Week</td><td>Credits</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="7">Course Objective: The course covers Smart Grid technology, including its introduction, architecture, challenges, and applications. It emphasizes sustainability and efficiency in the energy sector, particularly within the Indian context, with a focus on practical knowledge and problem-solving skills.</td></tr>
<tr><td colspan="7">Course Outcomes: After studying this course, students will be able to:
1. Grasp the fundamental concepts and definition of smart grids, and delve into the policy framework and architecture of smart grids in India.
2. Gain insights into smart meters, IoT technologies, and data management. Comprehend the significance of IoT in power systems, SCADA, demand response, and the application of big data analytics.
3. Explore various renewable energy sources, with a focus on wind energy, and delve into diverse modes of energy storage, including mechanical, electrical, and chemical options.
4. Examine the Energy Conservation Act and its sector-specific applications, evaluate energy-efficient practices in buildings, and delve into the assessment of global and Indian energy policies and regulations.
5. Evaluate international and Indian energy policies, regulations, and their impact on the power sector.</td></tr>
</table>

MODULE I

Smart Grid: Introduction of Indian smart grid policy. Basic concept and definition of smart grid. Smart grid architecture. Smart grid technologies. Properties of smart grid: flexibility, reliability, demand response and other performance parameters. Application of smart grid Challenges being faced during implementation of smart grid. virtual power plants, Smart Utilities (case studies), Smart Grid Maturity Model (SGMM). DC smart micro grids.

MODULE II

Smart meters and IoT: Introduction, technology, data management, energy monitoring, smart energy meter, Phasor Measurement Unit (PMU), smart metering infrastructure, data acquisition, IoT for power systems Internet of things for electricity infrastructure and energy management. SCADA, Demand response, AMI, IoT aided smart grid, big data for power systems and introduction to data analytics.

MODULE III

Renewable Energy and Energy Storage Systems: Solar Energy: solar photovoltaic and thermal systems, Wind: current status, types, measuring instruments, potential assessment, Biomass: gasification, anaerobic and aerobic decomposition, fermentation and incineration and Energy from waste, Different modes of energy storage, Technology Types– Mechanical energy storage: flywheels, compressed air, and pumped hydro; Electrical and Magnetic Energy storage: Batteries, Capacitors, electromagnets, Chemical energy storage

MODULE IV

Energy Conservation in Buildings: Energy conservation Act; Energy Conservation: Basic concept, energy conservation in Household, Transportation, Agricultural, service and Industrial sectors, Lighting, Heating Ventilation & Air Conditioning. Tariffs and Power factor improvement in power system, Demand Side management concept, Energy Efficient Practices and Technologies. Role of building design and building services to evaluate the energy performance in buildings. Study of Climate and its influence in building design for energy requirement, Principles of energy conscious design of buildings, Building Envelope, Orientation, Building Configuration, Passive Cooling, Basic Principles of Day-lighting

MODULE V

Energy Policy and Regulation: Assessment of International Energy Policy & Regulatory Aspects; Indian Power Sector – Generation, Transmission and Distribution, Energy Markets & Power Exchange; Indian Electricity Regulations and Acts, Electricity Act 2003, Rural Electrification Policies; CERC – Regulations, Orders, Tariff Guidelines

Text Books:	
1.	James Momoh, "Smart Grid: Fundamentals of design and analysis", John Wiley & sons Inc, IEEE press 2012.
2.	Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", John Wiley & sons inc, 2015.
3.	Fereidoon P. Sioshansi, "Smart Grid: Integrating Renewable, Distributed & Efficient Energy", Academic Press, 2012. Clark W.Gellings, "The smart grid: Enabling energy efficiency and demand response", Fairmont Press Inc, 2009.
Reference Books:	
1.	Renewable Energy Engineering and Technology – A Knowledge Compendium, ed. VVN Kishore (TERI Press, 2008).
2.	Sumper Andreas and Baggini Angelo: Electrical Energy Efficiency: Technologies and Applications (John Wiley 2012)

Course Code	Course Title						Type of Course
ELE501C	Solar Technologies						Core
Semester	**L**	**T**	**S**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
I	3	0	1	0	4	4	Professional Core

Course Objective: The objective of the course is to develop a comprehensive technological understanding in solar technologies, solar thermal, PV parameters, and system components and also provide in-depth understanding of design parameters to help in designing the different applications based solar thermal and PV power plant.

Course Outcomes (COs): After successfully finishing the course, students should be able to:

1. Understand the solar resource assessment and solar energy collector for energy application. Understand the working of solar thermal based system for thermal application.
2. Understand the working of solar cell along with the impact of different parameters on the output power.
3. Design the MPPT controllers for Solar PV systems.
4. Understand the different components of the solar power plants along with different solar configuration of solar plant
5. Design the solar thermal and photovoltaic power generation with the software.

MODULE I

Solar Resource Assessment and Thermal Energy: Basics of solar radiation, solar angles, measurements and estimation of solar radiation, Measurement and recording of solar irradiance with Pyranometer and irradiance meter. Classifications of solar collectors, flat plate and evacuated tube solar collector, Concentrating solar collectors, design considerations, design of receivers for heat collection, Tracking systems for solar concentrators, Heat transfer fluids for solar collectors, Emerging technologies in solar concentrators.

MODULE II

Solar Photovoltaic: Design of solar photovoltaic cell and its working principle, types of solar cell, characteristics of solar cell, data sheet and parameter understanding, Efficiency of Solar Cell, Factor affects the performance of solar cell, solar photovoltaic module/panel and array, Connection of PV module/panel in Series and Parallel, Estimation and Measurement of PV Module Power, Selection of PV Module. Overview and selection criteria for different types of photovoltaic system, solar inverters, battery and charge controller, AC Cables, AC Distribution Boards, AC Isolator, Array Junction Boxes(AJB), Connectors, DC Cables, DC Distribution Boards, Disconnects/switches, Earthling Kit, Fuses, Lightning Protection.

MODULE III

Solar PV Application Design and Calculation: Design and calculation of Street light, Solar water pump, EV charging station and cold storage, Introduction to MPPT and its types, Introduction to power tracker, Types of Solar PV System, Off Grid, On-Grid, Hybrid System, Design methodology for SPV system. Payback period of solar thermal energy systems and PV System. Solar PV Software: Homer, PVsyst, MATLAB & SIMULINK.

MODULE IV

Design of Solar Thermal Technologies: Design considerations, challenges and possible solutions in integrating solar thermal energy systems for various applications, Solar thermal power generation: Stand-alone and Grid-connected.

MODULE V

Solar Thermal Application: Solar thermal energy systems for various industrial process heating, water heating, water distillation, drying, Solar cooker, solar building heating and cooling, and solar Refrigeration, Application of solar energy in building heating and ventilation (Trombe wall, Phase change material etc.), Thermal energy storage systems: Sensible, Latent and Thermochemical energy storage system, materials for energy storage.

Books Recommended:

Text Books:	
1.	Solar Photovoltaics – Fundamentals, Technologies and Applications, C. S. Solanki, 2nd ed. (PHI Learning, 2011)
2.	Non-Conventional Energy Resources, B.H Khan, 3rd Edition, McGraw Hill Education India Private Limited, 1 July 2017
Reference Books:	
1.	Handbook of photovoltaic science and engineering, ed. A. Luque and S. Hegedus (John Wiley and Sons,2010)
2.	Renewable Energy Engineering and Technology – A Knowledge Compendium, ed. V.V.N. Kishore(TERI Press, 2008).
3.	Photovoltaic system engineering, R. A. Messenger and A. Abtahi, 3rd ed. (CRC Press, 2010)
4.	Grid connected PV systems design and installation, GSES (GSES India Sustainable Energy, 2013)

Course Code	Course Title					Type of Course
ELE504C	Power System Planning					Core
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
I	3	0	0	3	3	Professional Core

Course Objectives: The objective is to equip students with the knowledge and skills required for effective power planning, generation planning, system reliability analysis, and load forecasting in the power sector. Students should be able to apply these concepts and techniques to real-world power system planning and decision-making.

Course Outcomes: After studying this course, students will be able to:

1. Understand the fundamentals and importance of power planning and to analyze the needs, uses, and current status of different forecasting techniques used in the power sector.
2. Explore the concept of integrated power generation, its relevance in power planning and examine the role of private participation in the power sector and its impact on planning.
3. Learn about generation system models, state load models, methods for assessing reliability, including frequency and duration methods.
4. Understand the applications of load forecasting in the power sector and analyze the factors affecting load patterns and their significance in forecasting
5. Learn about various STLF methods, such as the similar day approach, regression methods, time series, artificial neural networks (ANN), expert systems, and fuzzy logic-based approaches

MODULE I

Introduction of Power Planning

National and regional planning, Structure of power system, Planning tools, Electricity regulation, Needs uses and current status of forecasting, Fundamentals of quantitative forecasting, Load forecasting, forecasting techniques, modeling, Explanatory and time serious forecasting, least square estimates, Peak load forecasting, Accuracy of forecasting methods, Regression methods, Box Jenkins time serious methods.

MODULE II

Generation Planning

Integrated power generation, co-generation/captive power, power pooling and power trading, transmission & distribution planning, power system economics, power sector finance, financial planning, private participation, rural electrification investment, concept of rational tariffs.

MODULE III

Generator System Reliability Analysis

Generation system model, State load model, Capacity outage probability tables, Recursive relation for capacitive model building, Evaluation of reliability indices, Frequency and duration methods.

MODULE IV

Load Forecasting

Load Forecasting Categories-Long term, Medium term, short term, very short term Applications of Load Forecasting, Factors Affecting Load Patterns, Medium and long term load forecasting methods- end use models, econometric models, statistical model based learning.

MODULE V

Intelligent Techniques for Load Forecasting

Applications of Load Forecasting, methods- similar day approach, regression methods, time series, ANN, Expert systems, Fuzzy logic based method, support vector machines ANN architecture for STLF, Seasonal ANN, Adaptive Weight, Multiple-Day Forecast, Training and Test Data, Stopping Criteria for Training Process, sensitivity analysis.

Books Recommended:

Text Books:	
1.	Electric Power System Planning, S. Dasari, IBT Publishers (1999)
2.	Electric Power Distribution, A.S,Pabla, McGraw Hill Book Co
3.	Reliability Modeling in Electrical Power Systems, J. Endrenyi, John Willey, New York
4.	Electrical Power System Design, M. V. Deshpande, TMH publication
Reference Books:	
1.	Power System Restructuring and Deregulation, L. L. Lie, John Willey & Sons UK
2.	Modern Power System Planning, X. Wang, J. R. Mc Donald, MGH

Course Code	Course Title						Type of Course
ELE503C	Distributed Generation and Microgrids						Core
Semester	**L**	**T**	**S**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
I	3	0	1	0	3	4	Professional Core

Course Objectives: Understand the concept of Distributed Generation (DG) and Microgrids, and examine the impact of grid integration with non-conventional energy (NCE) sources on existing power systems, focusing on reliability, stability, and power quality issues.

Course Outcomes: After successfully finishing the course, students should possess the capability to:

1. Distinguish between distributed and central power generation, and list various sources and regulatory standards for DG installation.
2. Apply knowledge to identify and address operational parameters and issues related to grid integration, including voltage, frequency, THD, and response to grid abnormalities.
3. Create an understanding of the power electronics interfaces used in both DC and AC microgrids.
4. Apply knowledge to describe the modes of operation, control, and protection strategies in microgrids, including grid-connected and islanded modes, active and reactive power control, and anti-islanding schemes.
5. Evaluate the impact of microgrid operation on power quality, assess regulatory standards, and analyze microgrid economics.

Module I

Distributed Generations (DG): Concept of distributed generations, Distributed Vs Central power generation, topologies, selection of sources, regulatory standards/framework, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. DG installation classes, security issues in DG implementations.

Module II

Impact of Grid Integration: Requirements for grid interconnection, limits on operational parameters: voltage, frequency, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability. Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants.

Module III

Basics of a Microgrid: Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids.

Module IV

Control and Operation of Microgrid: Modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, regulatory standards, Microgrid economics, Introduction to Smart microgrids, Nano and Pico Grids.

Module V

Power Quality issues in Microgrids: Power quality issues in microgrids- Modelling and Stability analysis of Microgrid, THD, regulatory standards, Microgrid economics, Introduction to smart microgrids.

<u>Books Recommended:</u>

Text Books:	
1.	A. Keyhani, "Design of Smart power grid renewable energy systems", Wiley IEEE.
2.	W.G. Clark, "The Smart Grid: Enabling Energy Efficiency and Demand Response",
Reference Books:	
1.	J.N. Green, R.G. Wilson "Control and Automation of Electric Power DistributionSystems (Power Engineering)", CRC Press.
2.	R.C. Dugan, M.F. McGranghan, S. Santoso, H.W. Beaty, "Electrical Power System
3.	Quality", 2nd Edition, McGraw Hill Publication.

Course Code	Course Title						Type of Course
ELE551C	Economics and Planning of Energy Systems						Core
Semester	**L**	**T**	**S**	P	**Contact Hours/Week**	**Credits**	**Course Category**
II	3	0	1	0	4	4	Professional Core

Course Objective: The course objectives include understanding the fundamental concepts of energy economics, analyzing energy data, evaluating energy costs, and comprehending the economic aspects of energy demand and production. Additionally, the course aims to explore renewable energy economics, energy policy evaluation, environmental considerations, and project planning, with a focus on achieving energy security and sustainability at regional, national, and global levels, involving various stakeholders.

Course Outcomes (COs): After successfully finishing the course, students should be able to:

1. Understand energy economics, including concepts, data analysis, cost assessment, and energy policy perspectives, with a specific focus on India's national energy landscape and subsidies.
2. Develop the ability to analyse and assess the economic aspects of renewable energy, calculate power generation costs, employ econometric methods, optimize inputs and outputs, and apply various energy planning and forecasting techniques.
3. Assess and analyse national and regional energy policies, oil import strategies, energy conservation, rural energy economics, and integrated energy planning.
4. Apply, assess and address the conflict between energy consumption and environmental impact using economic approaches, energy efficiency, and risk analysis
5. Equip students with the skills and knowledge to plan and implement energy projects, address energy security, promote renewable energy innovations, and understand the roles of governments, societies, and NGOs in meeting regional, national, and global energy goals.

MODULE I

Basic concepts, energy data, energy cost, energy balance, Energy accounting framework, Economic theory of demand, production and cost market structure, National energy map of India, Energy subsidy: National and international perspectives

MODULE II

Concepts of economic attributes involving renewable energy, Calculation of unit cost of power generation from different sources with examples, different models and methods, Application of econometrics, input and output optimization, energy planning and forecasting different methods

MODULE III

Evaluation of National and Regional energy policies, oil import, energy conservation, rural energy economics, integrated energy planning.

MODULE IV

Conflict between energy consumption and environmental pollution, Economic approach to environmental protection and management, Energy-Environment interactions at different levels, energy efficiency, cost-benefit risk analysis.

MODULE V

Project planning and implementation, Planning for energy security and renewable energy innovations, Regional, National and Global aspirations and requirements, Role of Governments, Societies and NGOs.

Books Recommended:

Text Books:	
1.	Bhattacharyya S. C.; Energy Ecosnomics, Springer
2.	Ferdinand E. B.; Energy Economics: A Modern Introduction, First Edition, Kluwer
3.	Kandpal T. C. and Garg H. P.; Financial Evaluation of Renewable Energy Technology, Macmilan
4.	Stoft S.; Power Systems Economics, Willey-Inter Science
Reference Books:	
1.	Munasinghe M. and Meier P.; Energy Policy Analysis and Modeling, CambridgeUniversity Press
2.	Samuelson P. A. and William D. N.; Economics, 14th edition, McGraw Hill
3.	Thuesen G. J. and Fabrycky W. J.; Engineering Economy, Ninth Edition, Prentice Hall India

Course Code	Course Title					Type of Course
ELE507C	Power Converters for EVs					Core
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
I	4	0	0	4	4	Professional Core
Course Objectives: Analysis of the theoretical aspects of different converters and inverters. To understand the design aspects and components selection of a converters and the Control aspects of the converters for EVs						
Course Outcomes: After studying this course, students will be able to: 1. Analyze the operation of different power converters. 2. Design of non-isolated and isolated converters used in electric vehicles. 3. Design of thermal and magnetic components. 4. Analyze the operation of practical inverters. 5. Analyze the Bidirectional converter topologies used in Electric Vehicles.						

MODULE I

Power Semiconductor Devices and Design of Drive Circuit

Ideal and Typical Power Switching Waveforms, Ideal and Typical Power Device Characteristics, Turn-on and Turn-off Characteristics of semiconductor switches, Drive circuits for different power semiconductor switches, Design of snubber circuit, intelligent power modules (IPM).

MODULE II

DC to DC Switch Mode Power Converters and their Design:

Introduction, steady state analysis of non-isolated and isolated DC-DC Converter under continuous and discontinuous mode of operation, components selection for the design of DC-DC converter and filters, Design of PWM techniques.

MODULE III

Design of Switch Mode DC-AC Inverters:

Single-Phase Voltage Inverters - Pulse-Controlled Output Voltage, Pulse-Width Modulated Inverters - Unipolar PWM, Three-Phase Inverters- PWM, Space Vector Modulation - Space Vector Modulation: Basic Principles, Application of Space Vector Modulation Technique, Selection of components for the design of single-phase and three-phase inverter components.

MODULE IV

Design of Thermal and Magnetic Components:

Introduction, modes of heat transfer, thermal model of power devices, Selection of heat sinks. Magnetic materials, hysteresis and eddy current losses in core, selection of parameters for the design of a magnetic components for Power Electronic Applications, thermal consideration, design steps of inductor.

MODULE V

Bidirectional Converter Topologies for Plug-In Electric Vehicles

Introduction, Literature Survey, Bidirectional Converters, Bidirectional AC/DC Converters for

Plug-In EV with Reduced Conduction Losses, Boost Operation, Buck Operation, Regenerative Braking Operation.

Books Recommended:

Text Books:	
1.	L. Ashok Kumar, S. Albert Alexander, "Power Converters for Electric Vehicles", CRC Press, Taylor & Francis Group, 2021
2.	Mohan N. Undeland. T & Robbins, "Power Electronics Converters, Application and Design" Wiley, 3rd edition, 2002.
3.	Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
Reference Books:	
1.	Christophe Basso, "Switch Mode Power Supplies: SPICE Simulations and Practical Designs", McGrawHill,2008.
2.	DC-DC Switching Regulator Analysis by Daniel M. Mitchell
3.	B. Jayant Baliga, "Power Semiconductor Devices", 1st Edition, International Thompson Computer Press, 1995.

Course Code	Course Title					Type of Course
ELE554C	Embedded System Design					Core
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
II	3	0	2	5	4	Professional Core

Course Objectives: Gain comprehension of microcontrollers and microprocessors frequently employed in embedded systems. Enhance proficiency in writing and debugging software for embedded systems, utilizing programming languages like C, C++, or assembly language. Develop the capability to design and prototype hardware components for embedded systems, along with interfacing with sensors and actuators. Acquire the expertise to seamlessly integrate hardware and software components, culminating in the creation of a fully operational embedded system.

Course Outcomes: After studying this course, students will be able to:

1. Analyze various processing element in an embedded system to develop optimum design.
2. Understand interfacing techniques for popular input devices, including sensors, as well as output devices and communication protocols.
3. Understand the serial communication, Evaluate the use of Interrupts and Event Managers for PWM generation.
4. Select, configure and design power supplies for embedded applications.
5. Apply effective embedded programming techniques in the C-Programming language.

MODULE I

Introduction to Embedded Systems

Modular approach to Embedded System Design, Microcontroller Based Embedded System Design. Salient Features of Modern Microcontrollers. Elements of Microcontroller Ecosystem and their significance. Design of Power Supply for Embedded Systems, Supply Design Considerations for Embedded Systems.

MODULE II

Introduction to MSP430 Microcontroller.

MSP430 CPU Architecture. Programming Methods for MSP430, Fundamentals of Physical Interfacing. Connecting Input Devices: Switches, Keyboard and Output devices: LEDs, Seven Segment Displays (SSD), Shaft encoder.

MODULE III

Programming the MSP430.

Installing and using Code Composer Studio (CCS). Introduction to Embedded C. Interfacing LEDs and Switches with MSP430 using Digital Input and Output. MSP430 Clock and Reset System. MSP430 Clock sources and distribution. Handling Interrupts in MSP430.

MODULE IV

Interfacings and PWM

Interfacing Seven Segment Displays and Liquid Crystal Displays with MSP430. Low Power Modes in MSP430. Introduction to MSP430 Timer Module and it's Modes of

Operation. Generating Pulse Width Modulation (PWM) using Timer Capture Mode. ADC operation in MSP430. Interfacing analog inputs. Adding DAC to MSP430.

MODULE V

Serial Communication Protocols:
UART, SPI, I2C. Interfacing Universal Serial Communication Interface (USCI) Module of the MSP430 for UART Communication. Advanced Coding Exercises based on Interrupt driven Programming. Building an Electronics Project. Circuit Prototyping techniques.

List of Experiments

1. Introduction to MSP430 launch pad and Programming Environment.
2. Read input from switch and Automatic control/flash LED (soft-ware delay).
3. Interrupts programming example using GPIO.
4. Configure watchdog timer in watchdog & interval mode.
5. Configure timer block for signal generation (with given frequency).
6. Read Temperature of MSP430 with the help of ADC.
7. Test various Power Down modes in MSP430.
8. Pulse Width Modulation (PWM) Generator.
9. Use Comparator to compare the signal threshold level.
10. Speed Control of DC Motor

Books Recommended:

Text Books:	
1.	Santanu Chattopadhyay, Embedded system Design, PHI Learning Pvt. Ltd., 2010
2.	John H Davies, MSP430 Microcontrollers Basics, Newnes Publishers, 1st edition, 2008.
3.	C P Ravikumar, MSP430 Microcontrollers in Embedded System Projects, Elite Publishing House , 1stedition, 2012
Reference Books:	
1.	Embedded System 2nd Edition by Raj Kamal , Tata McGraw-Hill Education.
2.	Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Morgan Kaufman Publishers.
3.	MSP430 Microcontroller Basics. John H. Davies. Elsevier. ISBN-10: 9789380501857.

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td>ELE501E</td><td colspan="5">Integrated Energy Systems</td><td>Elective</td></tr>
<tr><th>Semester</th><th>L</th><th>T</th><th>P</th><th>Contact Hours/Week</th><th>Credits</th><th>Course Category</th></tr>
<tr><td>-</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td><td>Discipline Centric</td></tr>
<tr><td colspan="7">Course Objectives: Students will understand the fundamental concepts of integrated energy systems, including patterns of fuel consumption, energy needs in various sectors, and the potential of alternative energy sources. They will gain insight into government policies and regulations related to integrated energy systems, as well as environmental and sustainability considerations.</td></tr>
<tr><td colspan="7">Course Outcomes: After successfully finishing the course, students will be able to:
1. Understand fuel consumption patterns and energy needs in various sectors, projecting demands and analyzing renewable and non-renewable energy sources
2. Interpret voltage and thermal effects in integrated energy systems, analyzing fault levels and considerations for islanding and standalone operation through real-world case studies.
3. Design hybrid energy systems like wind-diesel, wind-solar, and solar PV–biogas along with reliability analysis.
4. Create a comprehensive understanding of hybrid energy systems and apply energy modeling techniques to optimize different energy systems for increased efficiency.
5. Evaluating environmental and sustainability aspects, analyzing energy storage and grid management, and assessing future trends.</td></tr>
</table>

Module I

Introduction to Energy Systems: Pattern of fuel consumption, Energy needs in agriculture, domestic, industrial, and community sectors, Projection of energy demands, Substitution of conventional sources by alternative sources, more efficient modern technologies, Potential, availability as well as capacity of renewable and non-renewable energy sources, Energy flow diagram, Total energy concept and waste heat utilization.

Module II

System Aspects of Integration: Voltage and Thermal effects in integrated energy systems, Fault levels in integrated energy systems, Islanding and standalone system operation, Network voltage and system efficiency considerations, Case studies of standalone systems in real-world applications: domestic, commercial and industrial.

Module III

Hybrid Energy Systems: Types, applications and advantages, Mathematical modeling of hybrid energy systems: wind-diesel, wind-solar, Solar PV–Biogas, etc., Reliability analysis of hybrid energy systems.

Module IV

Economic Evaluation: Energy system economic modeling: system components costs (Yearly capital cost, Yearly replacement cost, Yearly DG fuel cost, Operation and maintenance cost), Estimation of the environmental and economic factors used for system optimization.

Module V

Energy Policy and Sustainability: Government policies and regulations related to integrated energy systems in India, Environmental and sustainability considerations in energy system integration, Energy storage and grid management in integrated systems, Emerging trends and future prospects in the field of integrated energy systems.

Books Recommended:

Text Books:	
1.	Renewable Energy Sources for fuels and Electricity by L Barrtom, IslandPress.
2.	Energy Technology by Tohta, PergamonPress.
Reference Books:	
1.	Renewable Energy Resources by J Twidell and T Weir, E&FNSpon.
2.	Integrated Energy systems for Multigeneration by I. Dincer and Y. Bicer, ElsevierScience

Course Code	Course Title					Type of Course
ELE550E	Instrumentation and Control in Energy Systems					Elective
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
-	3	0	0	3	3	Discipline Centric

Course Objectives: Develop a comprehensive understanding of sensors, transducers, and digital interfaces for electrical and process parameter measurements along with PLCs and data loggers for computer-based monitoring and communication systems for energy management and fault detection. Expertise in the control of solar and wind energy systems along with microgrids.

Course Outcomes: After successfully finishing the course, students should possess the capability to:

1. Understand the fundamental operating principles of sensors, transducers, and digital interfaces for measuring electrical and process parameters, facilitating remote monitoring.
2. Grasp the concepts of data loggers and programmable logic controllers, adeptly implementing configurations to measure electrical quantities through the use of microprocessors.
3. Analyze and design computer-based systems for monitoring and communication in energy management.
4. Apply control principles in solar and wind energy systems, showcasing expertise in grid-connected photovoltaic and wind systems, grid synchronization, and control of converters and inverters
5. Demonstrate control mastery in microgrids, implementing primary, secondary, and tertiary control for efficient operation, load frequency control, and management of hybrid ac/dc grids.

Module I

Sensors and Transducers: Sensors for electrical parameter measurement, sensors for process parameter measurement of temperature, pressure and flow Gas analyzers measurement of humidity, smoke, dust and moisture, pH-gas Chromatography-Spectrometry Smart sensors generalised operating principles-interfacing-applications, Digital Transducers, Interface system and Standards, SCADA: Computer automated measurements and controls – Remote monitoring and control.

Module II

Data loggers and PLC's: Introduction to programmable Logic Controllers, Microprocessor and computer in measurement, Data loggers, type of loggers, configuring and checking data-logger, Measurement of electrical quantifies, current, voltage, power, power factor, stability, transient analysis of power generating systems

Module III

PC-based Instrumentation: DATA acquisition systems: Functional block diagram and components; signal conditioning concepts and ground loops, common instrument interfaces, instrument buses, introduction to virtual instrumentation (VI), software based instruments. Computer Based Monitoring and Communication System, Data acquisition systems, expert based systems for energy management, Fault detection system, PC based and GSM communication systems.

Module IV

Control in Solar and Wind Energy System: Operation and Control of Grid-Connected PV System: Control of Single-Phase PV System, Control of PV-Side DC/DC Converter, Control of Grid-Side Inverter, Inner Current Loop. Grid Synchronization, Control of Three-Phase Grid-Connected PV system. Operation and Control of Grid-Connected Wind Energy System: Grid Integration of Wind Turbine System, Power Electronics in Wind Energy System, Control of Doubly Fed Induction Generator–Based Wind Turbine Systems.

Module V

Control in Microgrids: Control of AC Microgrid in Grid-Connected Mode: Primary Control, Secondary Control, Tertiary Control. Autonomous Operation of Microgrid, Load Frequency Control in Microgrid, Operation and Control of Hybrid AC/DC Grid.

Books Recommended:

Text Books:	
1.	D Patranabis, Sensors and Transducers, PHI
2.	M.H. Rashid, Power Electronics, PHI/ Pearson Education
3.	M.Mitra and S.Sengupta, Programmable Logic Controllers And Industrial Automation An Introduction, Penram International Publishing (India)
Reference Books:	
1.	E. A. Doebelin, Measurement Systems: Application and Design, McGraw Hill, New York
2.	B.K.Bose, Modern Power Electronics, JAICO
3.	John. W. Webb Ronald A Reis, Programmable Logic Controllers -Principles and Applications, Prentice Hall Inc.

Course Code	Course Title					Type of Course
ELE551G	Renewable Energy Resource Assessment and Forecasting					Elective
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
-	3	0	0	3	3	Generic

Course Objectives: The course will provide the students an understanding of assessment of various non-conventional energy resources such as solar energy, wind energy, biomass, geothermal, waves, tides and ocean thermal energy and its forecasting methods.

Course Outcomes: After studying this course, students will be able to:

1. Assess different energy resources, understand energy and principles of meteorology and numerical weather prediction.
2. Analyse the concepts of uncertainty in the assessment of solar energy and evaluation of solar forecasting skills.
3. Learn and implement the concept of wind energy assessment and forecasting.
4. Evaluate the Biomass, Geothermal, Ocean Thermal, Tidal, Wave energy assessment and forecasting.
5. Learn and evaluate characterization of forecast errors and bench-marking of renewable energy forecasting.

MODULE I

Introduction to Renewable Sources of Energy: Solar energy, Wind energy, Biomass energy, Geothermal energy, Ocean thermal energy, wave and tidal energy.

Principles of Meteorology and Numerical Weather Prediction: Introduction to meteorology for renewable energy forecasting, Observational data and assimilation into numerical weather prediction (NWP) model, Probabilistic of forecasting, Statistical models, such as Auto-regressive Moving Average (ARMA) and Auto-regressive Integrated Moving Average (ARIMA), and data-driven models, such as Artificial Intelligence (AI) algorithms.

MODULE II

Solar Energy Assessment and Forecasting: Uncertainty in the assessment, means of resource assessment: satellite based, land station based, software based (Meteonorm, Solar GIS) Meteorological consideration Solar forecasting for different timescales. Forecasting and uncertainty in the forecasting, Clear sky models, Persistence forecast, Evaluation of solar forecasting skills. Solar radiation forecasting using machine learning and AI for solar prediction methods and other energy prediction models such as time series models, unit root test and co-integration models and ANN models.

MODULE III

Wind Energy Assessment and Forecasting: Wind resource and origins, Measurement and distribution, Site selection for wind monitoring station, Assessment techniques, Wind forecasting using statistical and numerical methods, short term prediction models, upscale models, spatio-temporal forecasting, ramp forecasting variability forecasting and uncertainty of wind power predictions.

MODULE IV

Small Hydro, Biomass and Geothermal Energy Assessment and Forecasting: Statistical analysis of data, Sources and generation of small hydro and biomass. Forecasting based on statistical data, Measurement of productivity, Geological survey for geothermal regions, Distribution of geothermal energy, Types of geothermal resources, Thermal gradient measurements and monitoring micro seismic activity, Reflection seismic, deep exploration drilling and testing with estimation.

MODULE V

Ocean thermal energy, Waves and Tidal Energy Assessment and Forecasting: Measurement and statistical analysis for assessment and forecasting of Ocean thermal, Waves and Tidal energy, statistical and time series model, wave energy converters, Characterization of forecast errors and bench-marking of renewable energy forecasting: ANEMOS benchmark, WIRE benchmark.

Books Recommended:

Text Books:	
1.	Kariniotakis G. (Ed.), Renewable Energy Forecasting: From Models to applications. Woodhead Publishing (2017).
2.	Jan K., Solar Energy Forecasting and Resource Assessment, Academic Press, (2013).

Course Code	Course Title					Type of Course
ELE551E	EV Motor Design					Elective
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
-	3	0	0	3	3	Discipline Centric

Course Objectives: Upon completion of the course, students will have a solid foundation in electrical machine design, capable of analyzing, selecting dimensions, and designing various components for induction motors, Switched Reluctance Machines (SRM), BLDC (Brushless DC) motors, and PMMC (Permanent Magnet DC) motors. Students will apply their knowledge to design different motors for Electric Vehicle applications, considering efficiency, performance and specific requirements of EVs.

Course Outcomes: After studying this course, students will be able to:

1. Understand the foundational electromagnetic laws and behaviour of magnetic materials, including BH curves, and their application in automotive technologies.
2. Design and analysis of electromagnetic systems, including the principles governing electromechanical energy conversion.
3. Design of electrical machine windings, focusing on direct current (DC) and alternating current (AC) machines.
4. Explore the design parameters and calculations involved in the design of induction motors with a particular focus on Electric Vehicles (EVs).
5. Design of SRM motors, BLDC motors and PMMC motors for Electric Vehicles (EVs).

MODULE I

Introduction to Electromagnetic Laws and Magnetic Circuits

Electric Fields, Magnetic Fields, Review of Electromagnetic laws (Ohms Law, Amperes Law, Faraday's Laws, Thumb rule, Fleming's Left-hand and Right-hand rules, Lorentz Force Law), Magnetic Materials and Concepts of BH Curves, Magnetic Circuits with and without Air gaps, Multiple Winding Magnetic Circuits

MODULE II

Basic Concepts of Electromechanical Energy Conversion

Electromechanical Energy Conversion and Force in Electromagnetic Systems, Design and Analysis of the Electromagnetic System with an Example, Realization of Electrical Machines with the Principles of Electromagnets, Working Principles of the Rotating Machines

MODULE III

Design of Electrical Machine Winding

Design of Electrical Windings and MMF distribution, DC Machine Windings, AC Machine Windings, AC Machine Windings Examples with Laboratory Prototype, Winding Design for Variable Speed Machines, Importance, Design Factors and Standards of the Electrical Machines, Electric and Magnetic Loadings, Sizing Equations with D2L (Volume) Product, Sizing Equations with D3L (Volume) Product-I, Sizing Equations with D3L (Volume) Product-II, Volume, Power Density,

MODULE IV

Design of Induction Motor (IM)

Induction Motor (IM) Design, Main dimensions,Stator Core Design of IM, Rotor Core Design of IM, Volume and Density of IM, IM Parameters Calculation like Leakage and Magnetizing Inductances-I, IM Parameters Calculation like Leakage and Magnetizing Inductances-II, Efficiency Calculations, Design of the Induction Motor for an Electric Vehicle Application.

MODULE V

Design of Special Machines for EVs

Design of Special Machines, Switched Reluctance Machine (SRM) Sizing Equations, Stator and Rotor Design of SRM, Machine Parameters of SRM, Calculations of SRM, Design of BLDC and PMMC motors. Thermal Issues, Limits and Heat Transfer Technique, Cooling Methods and Design, Thermal Equivalent Circuits, Thermal Design of Electrical Machines.

Books Recommended:

Text Books:	
1.	Electric Machine Design by A.K. Sawhney
2.	Electrical machine Design by R.K. Agarwal
3.	Thomas A. Lipo, Introduction to AC Machine Design, IEEE Press, John Wiley & Sons, Inc., NJ, USA.
4.	Alexander Gray, Electrical Machine Design - The Design And Specification Of Direct And Alternating Current Machinery, Mc Graw Hill, NY, USA
5.	Krishnan, R., Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and Applications, CRC Press, USA
Reference Books:	
1.	Electrical Machine Design by M. G. Sen
2.	Electrical Machine Design by Rajiv Nagaranjan.
3.	Design of Electrical Machines by Mittle and Mittla.
Online Resources:	
1.	Design of Electric Motors By Prof. PrathapReddy IISc Bangalore https://onlinecourses.nptel.ac.in/noc23_ee140/preview

<table>
<tr><th>Course Code</th><th colspan="5">Course Title</th><th>Type of Course</th></tr>
<tr><td>ELE503E</td><td colspan="5">Thermal Management of EV Systems</td><td>Elective</td></tr>
<tr><th>Semester</th><th>L</th><th>T</th><th>P</th><th>Contact Hours/Week</th><th>Credits</th><th>Course Category</th></tr>
<tr><td>-</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td><td>Discipline Centric</td></tr>
<tr><td colspan="7">Course Objectives: To understand thermal management of electronics and the importance of thermal resistance network. To understand thermal management of microelectronic packages and to comprehend the concepts of cooling techniques. To explain thermal management systems.</td></tr>
<tr><td colspan="7">Course Outcomes: After studying this course, students will be able to:
1. Describe different types of temperature dependent failures in electronics systems.
2. Describe series and parallel thermal layers and thermal resistance in PCB.
3. Use suitable fins and heat sinks for a given electronic application
4. Compare different advanced cooling technologies.
5. Analyze thermal specifications of microelectronic package and parameters affecting thermal characteristics of a package.</td></tr>
</table>

MODULE I

Introduction to Thermal Management of Electronics

Semiconductor Technology Trends, Temperature-Dependent Electrical Failures, Importance of Heat Transfer in Electronics, Thermal Design Process.

MODULE II

Thermal Resistance Network

Thermal Resistance Concept, Series Thermal Layers, Parallel Thermal Layers General Resistance Network, Thermal Contact Resistance, Interface Materials, Spreading Thermal Resistance, Thermal Resistance of Printed Circuit Boards (PCBs).

MODULE III

Fins and Heat Sinks

Fin Equation, Infinitely Long Fin, Adiabatic Fin Tip Convection and Radiation from Fin Tip, Constant Temperature Fin Tip Fin Thermal Resistance, Effectiveness, and Efficiency with Variable Cross Sections. Heat Sink Thermal Resistance, Effectiveness, and Efficiency, Heat Sink Manufacturing Processes.

MODULE IV

Advanced Cooling Technologies

Pipes, Capillary Limit, Boiling Limit. Sonic Limit, Entrainment Limit, Other Heat Pipe Performance Limits, Heat Pipe Applications in Electronic Cooling, Thermosyphons, Liquid Cooling

MODULE V

Thermal Specification of Microelectronic Packages

Importance of Packaging, Packaging Types, Specifications of Microelectronic Packages, Junction-to-Air Thermal Resistance, Junction-to-Case and Junction-to-Board, Thermal Resistances, Package Thermal Characterization Parameters, Parameters Affecting Thermal Characteristics of a Package

Books Recommended:

Text Books:	
1.	Younes Shabany,” Heat Transfer: Thermal Management of Electronics” 2010 , CRC Press.
2.	T. Yomi Obidi, “Thermal Management in Automotive applications”, 2015, SAE International.
Reference Books:	
1.	Jerry Sergent, Al Krum, “Thermal Management Handbook: For Electronic Assemblies Hardcover”, 1998, Mc Graw- Hill.

Course Code	Course Title					Type of Course
ELE504E	Control Systems for Electric Vehicle					Elective
Semester	**L**	**T**	**P**	**Contact Hours/Week**	**Credits**	**Course Category**
-	2	0	2	4	3	Discipline Centric

Course Objective: To introduce advanced linear and state space methods for the control of electrified vehicles.

Course Outcomes: After studying this course, students will be able to:

1. Describe the principles of linear control systems and their application in the context of electrified vehicles.
2. Analyze the behavior of linear systems using transfer functions and state-space representations.
3. Apply state-space methods to analyze and design control strategies for electrified vehicle systems.
4. Design controllers for electrified vehicle systems using advanced linear control techniques.
5. Optimize control strategies to improve the performance, efficiency, and stability of electrified vehicle systems.

MODULE I

Introduction to System modelling:
Importance of control system in Electrical vehicle, Study of control architecture in Electric vehicle, Systems models and their classifications, principles used in modelling of systems, Fundamental studies of Modelling of vehicle dynamics and control.

MODULE II

Model based control approach for Electric Vehicle:
Introduction to P, PI & PID Controller, and Internal Model Control (IMC) Design, Introduction to Model based control system design for Electric Vehicle.

MODULE III

State Space Representation:
Introduction to State Space, State Space Representation, State Space Representation: Companion Form (Controllable Canonical Form), Extended Controllable Canonical Form Observable Canonical Form, Concept of Diagonalization, State transition matrix, Solution of state Equation, Steady State Error for State Space System. Controllability and Observability.

MODULE IV

Stability aspects of control systems:
Stability concept, Stability definition in the sense of Lyapunov, Stability of continuous time Linear systems, Lyapunov stability theorem, Vehicle stability analysis.

MODULE V

Applications: Applications of control techniques in Traction control, Vehicle Control, Electric power steering control.

List of Experiments:

1. Familiarization of Electric Vehicle Control Modules
2. Modelling Studies of Electric Vehicles
3. Model Identification techniques for Electric Vehicle
4. Tuning Techniques for PI/PID Controller
5. PI/PID controller for Electric Vehicle
6. IMC based control techniques
7. Model based control techniques for Electric Vehicle
8. Modelling, Control in State space for Electric Vehicle
9. Study of Observer design for Electric Vehicle

Books Recommended:

Text Books:	
1.	R. T. Stefani, B. Shahian, C. J. Savant, Jr., and G. H. Hostetter, Design of Feedback Control Systems, Oxford University Press, Fourth Edition
2.	Hui Zhang and Dongpu Cao and Haiping Du, Modelling, Dynamics and Control of Electrified Vehicles, WP Publishing, Elsevier
3.	Wuwei Chen, Hansong Xiao, Qidong Wang, Linfeng Zhao and Maofei Zhu, Integrated Vehicle Dynamics and Control,Wiley, First Edition
Reference Books:	
1.	Ashish Tewari, Modern Control Design: with MATLAB and SIMULINK, Wiley, First Edition
2.	Rajesh Rajamani, Vehicle Dynamics and Control, Springer, Second Edition

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