NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL



RULES AND REGULATIONS

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Program in

POWER ELECTRONICS & DRIVES

(Effective from AY 2021-22)

DEPARTMENT OF ELECTRICAL ENGINEERING

Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society.

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department

Department of Electrical Engineering

VISION

To excel in education, research and technological services in electrical engineering in tune with societal aspirations.

MISSION

- Impart quality education to produce globally competent electrical engineers capable of extending technological services.
- Engage in research & development in cutting edge and sustainable technologies.
- Nurture scientific temperament, professional ethics and industrial collaboration.

Department of Electrical Engineering:

Brief about the Department: The Department of Electrical Engineering was established in the year 1959 in the Regional Engineering College Warangal, which was converted into a National Institute of Technology in the year 2003.

Since the inception of the Institute, the department has been developing state-of-the-art Infrastructure to cater to the needs of technical education and cutting-edge research. In its formative years, the department received considerable financial and logistical support from UNESCO. Later, the Department was funded principally by the MHRD, GOI, which is augmented by aid from various other agencies such as the Institutional Network Scheme (INS) and TEQIP. The development of the department is propelled by well-qualified, well-trained, and dedicated faculty. Consequent to their sustained efforts, the department enjoys a position of eminence in the field of technical education and research.

The Department of Electrical Engineering started offering postgraduate programs since the year 1964. Currently, the Department offers three PG programs in Power Systems Engineering, Power Electronics and Drives, and Smart Electric Grid.

The establishment of postgraduate courses has significantly contributed towards the advancement of research and consultancy activities of the department. To fulfill the objectives stated in the mission and vision of the institute, the department organized several faculty development programs, conferences, and refresher courses, which cater to the needs of industries and utilities (DRDO, BHEL, TATA power companies, VSP to name a few).

The department also organized several continuing education programs in emerging areas for faculty of educational institutions throughout the country. The Department is recognized as a QIP center for M. Tech programs in Electrical Engineering.

The Department of Electrical Engineering has always been a hub of active research. Several research projects, sponsored by MHRD, CSIR, DST, DRDO, SPARC, and other private and governmental organizations have successfully been executed by the faculty of the department. Currently, about 65 doctoral students are pursuing their Ph.D. degrees in various areas of research.

In its sixty-two years of journey, the department had quite a few academic and research accomplishments. A few of them are enumerated below:

- Several funded research projects, to the tune of Rs. 300 Lakhs, are currently under execution, promising high research outcomes.
- A Power System Study Cell was established by the erstwhile APSEB to train their engineers in software pertaining to power systems.
- A sponsored research project was successfully executed, which aims to study the impact of the electrical load of the Vizag Steel Plant on the grid. This project was awarded to the department despite stiff competition from several institutes of higher learning.
- The department has been awarded a center of excellence in power and energy systems, which is in the process of being established.
- All academic programs offered by the department had been accredited by NBA for a full-time period of 5 years in the years 2008 and 2013
- As many as 26 consultancy projects were completed for the vetting of electromechanical designs for lift irrigation projects by the Governments of Telangana and Andhra Pradesh.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Electrical and Electronics Engineering
BTech (Hons.)	Electrical and Electronics Engineering
	Minor in Electrical Engineering
M.Tech.	Power Electronics and Drives
	Power Systems Engineering
	Smart Electric Grid
PG diploma	Power Electronics and Drives
	Power Systems Engineering
	Smart Electric Grid
Ph.D.	Electrical Engineering

Note: Refer to the Rules and Regulations for M.Tech. program (https://oldweb.nitw.ac.in/media/uploads/2022/01/17/m-tech_rules-and-regulations-2021-22.pdf) given in the institute website.

M.Tech. Program in Power Electronics & Drives

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1	Design and develop independently innovative products and services in the field of Power Electronics & Drives
PEO2	Adopt and utilize latest technologies and tools in design of products and systems
PEO3	Communicate effectively to propagate ideas and promote teamwork
PEO4	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment

Program Articulation Matrix

PEO / Mission Statements	PEO1	PEO2	PEO3	PEO4
Impart quality education to produce globally competent electrical engineers capable of extending technological services	3	3	3	2
Engage in research & development in cutting edge and sustainable technologies.	3	3	2	3
Nurture scientific temperament, professional ethics and industrial collaboration	3	3	2	2

1-Slightly; 2-Moderately; 3-Substantially

Program Outcomes (POs)

PO1	Develop scientific temperament and rational thinking abilities to pursue research and tackle complex problems related to power electronics & drive systems.
PO2	Communicate with technical communities on engineering issues while creating awareness for all sections of society.
PO3	Employ the knowledge of power electronics & drives to contribute towards the development of products / technologies which require a team with multidisciplinary expertise.
PO4	Develop eco-friendly and sustainable technologies using the knowledge of power electronics & drive systems.
PO5	Cultivate an attitude of self-learning to cope with ever changing tools and technologies and be productive throughout his / her career.
PO6	Foster a temperament to manage projects, organizations and entrepreneurial ventures maintaining financial integrity and professional ethics.

SCHEME OF INSTRUCTION
M.Tech. Program in Power Electronics & Drives – Course Structure

I – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	EE5101	Analysis of Power Converters	3	0	0	3	PCC
2.	EE5102	Electric Drives	3	0	0	3	PCC
3.	EE5103	Applications of Digital Signal Processors	3	0	0	3	PCC
4.	EE5104	Control and Integration of Renewable Energy Sources	3	0	0	3	PCC
5.		Elective–I	3	0	0	3	PEC
6.		Elective–II	3	0	0	3	PEC
7.	EE5105	Power Electronics Lab	0	1	2	2	PCC
8.	EE5106	Power Electronic Simulation Lab	0	1	2	2	PCC
9.	EE5148	Seminar–I	0	0	2	1	SEM
		TOTAL	18	2	6	23	

I – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	EE5151	Advanced Power Electronics	3	0	0	3	PCC
2.	EE5152	Advanced Electric Drives	3	0	0	3	PCC
3.	EE5153	Digital Control Systems	3	0	0	3	PCC
4.		Elective–III	3	0	0	3	PEC
5.		Elective–IV	3	0	0	3	PEC
6.		Elective–V	3	0	0	3	PEC
7.	EE5154	Electric Drives Lab	0	1	2	2	PCC
8.	EE5155	Digital Signal Processing Lab	0	1	2	2	PCC
9.	EE5198	Seminar–II	0	0	2	1	SEM
		Total	18	2	6	23	

II – Year: I – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1.	EE6147	Comprehensive Viva-voce	2	CVV
2.	EE6149	Dissertation-Part-A	12	DW
		Total	14	

II – Year: II – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
1	EE6199	Dissertation-Part-B	20	DW
		Total	20	

Note: PCC – Professional Core Courses and PEC – Professional Elective Courses

Professional Elective Courses (PEC):

I Year I Semester

S No	Course Code	Course Title
1.	EE5111	Modern Control Theory
2.	EE5112	Power Quality Improvement Techniques
3.	EE5113	Electromagnetic interference and compatibility
4.	EE5114	Electric Vehicles
5.	EE5202	Data Science Applications in Power Engineering
6.	EE5213	HVDC Transmission
7.	EE5214	Instrumentation and Automation
8.	EE5215	Machine Learning and Applications
9.	EE5216	Smart Grid Technologies
10	MA5331	Numerical Optimization Techniques

I Year II Semester

S No.	Course Code	Course Title
1.	EE5161	Applications of Power Converters
2.	EE5162	Design of Power Electronic Converters
3.	EE5163	High Power Inverters
4.	EE5164	Non-linear Control Systems
5.	EE5165	Advanced Control Techniques for Power Converters
6.	EE5166	Power Converters and Control Techniques for Microgrids
7.	EE5167	Predictive Control of Power Converters and Drives
8.	EE5263	Energy Auditing and Management
9.	EE5264	Evolutionary Algorithms Applications in Power Engineering
10.	EE5265	Flexible AC Transmission Systems

Courses offered to Department of Chemical Engineering [M. Tech. (Systems and Control)] :

Semester	Course Code	Course Title
I	EE5111	Modern Control Theory
II	EE5153	Digital Control Systems

Special Notes/Instructions: In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of time-table.

Credits in Each Semester					
	I Sem	**II Sem**	**III Sem**	**IV Sem**	**Total**
Core courses (PCC)	16	13	0	0	**29**
Elective courses (PEC)	6	9	0	0	**15**
Seminar	1	1	0	0	**2**
Comprehensive Viva-voce	0	0	2	0	**2**
Dissertation	0	0	12	20	**32**
Total credits (Sem. wise)	**23**	**23**	**14**	**20**	**80**

DETAILED SYLLABUS

M.Tech. – Power Electronics & Drives

EE5101	Analysis of Power Converters	3 – 0 – 0 : 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Select appropriate switching devices for power converters
CO2	Analyze and design power converter configurations for specific applications
CO3	Select control techniques for low and medium power converters
CO4	Design power electronic converters to improve power quality

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	3	1	2	2
CO2	2	0	3	1	2	2
CO3	2	0	3	1	2	2
CO4	2	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT, MOSFET, IGBT, GTO, Wide band gap devices (GaN, SiC) - Design of driver and snubber circuit

DC-DC Converters: Non-isolated DC-DC converters: buck, boost, buck-boost, CUK converters under continuous and discontinuous conduction operation - Isolated DC-DC converters: forward, fly-back, push-pull, half-bridge and full-bridge converters - Relationship between I/P and O/P voltages - design of filter inductor and capacitors

Inverters: Single-phase and three-phase inverters - PWM techniques: single, multiple and sinusoidal PWM techniques - selective harmonic elimination, space vector modulation, current source inverter- High power inverters: Multi-pulse inverters, multi-level inverters - Diode-clamped, cascaded and Flying capacitor types, Carrier and Vector based multi-level modulation schemes -Concept of active power filters- Introduction to Matrix Converters.

Front-End (AC-DC) Converters: Conventional methods of power factor improvements: Semi- converter, extinction angle control, symmetrical angle control – active front-end converters - Single phase: Boost, voltage doubler and PWM rectifiers –voltage and current controlled three-phase PWM rectifiers

Learning Resources:

Text Books:

1. Power Electronics Handbook, M.H. Rashid, Butterworth-Heinemann, 2017, 4th Edition.
2. Power Electronics: Converters, Applications and Design, N. Mohan, T.M. Undeland, W.P. Robbins, John Wiley & Sons, 2003, 3rd Edition.

References Books:

1. Power Electronics: Essentials and Applications, Umanand, L., John Wiley India, 2009, 1st Edition.
2. Fundamentals of Power Semiconductor Devices, Jayant Baliga B, Springer, 2008, 1st Edition.

3. High Power Converters and AC Drives, Bin Wu, Wiley-Interscience, 2017, 2nd Edition.
4. Power Electronic Converter Harmonics Multipulse Method for Clean Power, Derek A Paice, IEEE Press, 1995.

Online Resources:

1. https://nptel.ac.in/courses/108/102/108102157/

EE5102	Electric Drives	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Understand the significance and role of variable speed drives in the present-day industry and the requirement of four-quadrant operation and stability
CO2	Analyze the basic torque producing mechanisms in electrical machines using the principles of field energy and coenergy
CO3	Analyze and design Separately Excited DC motor drives in steady state and dynamic conditions
CO4	Analyze the steady state behavior of induction motor drives with scalar control and its implementation using slip compensation technique

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	3	1	2	2
CO2	2	0	2	1	2	2
CO3	3	0	3	1	2	2
CO4	3	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Review of Basic Electrical Drives: Need of variable speed drives, Review of speed control methods in DC and AC drives, role of electrical drives in energy conservation, classification of electrical drives, four-quadrant operation of electrical drives, stability of electrical drives.

Basic Principles for Electrical Machine Analysis: Magnetically coupled circuits: review of basic concepts, magnetizing inductance, modelling linear and nonlinear magnetic circuits, Electromechanical energy conversion: principles of energy flow, concept of field energy and coenergy, Derivation of torque expression for various machines using the principles of energy flow and the principle of coenergy.

Separately Excited DC Motor Drives: Review of the theory of DC machine, State-space model of a Separately Excited DC machine, reduced order model & transfer function of the DC machines, Review of controllers, Speed control of a separately excited DC drive with inner current loop and outer speed loop, Design of current and speed loops.

Induction Motor drives: Review of speed control methods of induction motors, Implementation of scalar control with slip compensation scheme, Limitations of the scalar control method.

Learning Resources:

Text Books:

1. Analysis of Electric Machinery & Drive systems, Paul C. Krause, Oleg W, Scott D. Sudhoff, IEEE Press, 2013, 3rd Edition.
2. Electric motor drives: modeling, analysis, and control, Rama Krishnan, Pearson Education India, 2015, 1st Edition.
3. Modern Power Electronics & AC Drives, B.K. Bose, Pearson Education India, 2015, 1st Edition.
4. Simulation of Power Electronic Circuits, M.B. Patil, V. Ramanarayanan, V.T. Ranganathan, Narosa Publications, 2013.

Reference Books:

1. Electric Machinery, A. E. Fitzgerald, C Kingsley, Stephen D. Umans, TMH, 2017, 6th Edition.
2. Advanced Electrical Drives: Analysis, Modeling, Control, Rik De Doncker, Duco W. J. Pulle, André Veltman, Springer, 2011.

Online Resources:

1. https://nptel.ac.in/courses/108/106/108106023/
2. https://nptel.ac.in/courses/108/108/108108077/

EE5103	Applications of Digital Signal Processors	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Develop Assembly Language Programs for the Digital Signal Processors
CO2	Configure and use Digital Input / Output lines and ADCs
CO3	Configure and use Interrupts and Event Managers for PWM generation
CO4	Employ DSPs for the real time control of Power Electronic Converters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

TMSLF2407 DSP Controller: Brief Introduction to Peripherals - Types of Physical Memory - Software Tools.

C2XX DSP CPU and instruction set: Introduction to the C2xx DSP Core and Code Generation - The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory -Memory Addressing Modes -Assembly Programming Using the C2xx DSP Instruction Set.

Parallel and Serial Data Transfer: Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports.

Interrupt system of TMS320LF2407: Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software, real time control with interrupts.

The analog-to-digital converter (ADC): ADC Overview - Operation of the ADC and programming modes.

Event Managers (EVA, EVB): Overview of the Event Manager (EV) - Event Manager Interrupts - General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry - General Event Manager Information - PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSP TMSLF2407A.
Introduction to TMS320F28069 DSP Controller

Learning Resources:

Text Books:

1. DSP based Electromechanical Motion Control, Hamid A. Tolyat, CRC press, 2003, 1st Edition
2. TMS320x2806x Piccolo Technical Reference Manual, Texas Instruments, 2017

Reference Books:

1. TMS320F/C24x DSP Controllers Reference Guide: CPU and Instruction Set - Literature Number: SPRU160C
2. TMS320F/C24x DSP Controllers Reference Guide: System and Peripherals - Literature Number: SPRU357C

Online Resources:

1. https://www.ti.com/lit/ug/spru160c/spru160c.pdf
2. https://www.ti.com/lit/ug/spru357c/spru357c.pdf
3. https://www.youtube.com/playlist?list=PLo9tpaskMTCkEwpvT0q0_m0_RSHstnway

EE5104	Control & Integration of Renewable Energy Sources	3 – 0– 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Understand different renewable energy sources and storage devices
CO2	Model and simulate renewable energy sources
CO3	Analyze and simulate control strategies for grid connected and off-grid systems
CO4	Develop converters to comply with grid standards to obtain grid integration

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Electric grid, Utility ideal features, Supply guarantee, power quality, Stability and cost; Importance & Effects of Renewable Energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns.

Dynamic Energy Conversion Technologies: Introduction, types of conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind-based generation technologies.

Static Energy Conversion Technologies: Introduction, types of conventional and nonconventional static generation technologies; Principle of operation and analysis of fuel cell, photovoltaic systems and wind generation technologies; MPPT techniques and its classifications, principle of operation and partial shading effects; Storage Technologies - batteries, fly wheels, super capacitors and ultra-capacitors.

Control Issues and Challenges: Linear and nonlinear controllers, predictive controllers and adaptive controllers, Load frequency and Voltage Control, PLL, Modulation Techniques, Control of Diesel, PV, wind and fuel cell based generators, Dimensioning of filters, Fault-ride through Capabilities.

Integration of Energy Conversion Technologies: Introduction & importance, sizing, Optimized integrated systems, Interfacing requirements, Distributed versus Centralized Control, Grid connected Photovoltaic systems –classifications, operation, merits & demerits; Islanding Operations, stability and protection issues, load sharing, operation & control of hybrid energy systems, Solar Photovoltaic applications. IEEE & IEC codes and standards for renewable energy grid integrations.

Learning Resources:

Text Books:

1. Renewable and Efficient Electric Power Systems, G. Masters, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.
2. Microgrids and Active Distribution Networks, S. Chowdhury, S. P. Chowdhury, P. Crossley, IET Power Electronics Series, 2012.
3. Integration and Control of Renewable Energy in Electric Power System, Ali Keyhani Mohammad Marwali and Min Dai, John Wiley publishing company, 2010, 2nd Edition.

Reference Books:

1. Fundamentals, technologies & Applications, Chetan Singh Solanki, Solar Photovoltaic, PHI Publishers, 2019, 3rd Edition.
2. Control of Power Inverters in Renewable Energy and Smart Grid Integration, Quing-Chang Zhong, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 1St Edition.
3. Power Conversion and Control of Wind Energy Systems, Bin Wu, Yongqiang Lang, Navid Zargari, IEEE- John Wiley and Sons Ltd. Publishers, 2011, 1st Edition.
4. Report on "Large Scale Grid Integration of Renewable Energy Sources - Way Forward" Central Electricity Authority, GoI, 2013.

Online Resources:

1. https://nptel.ac.in/courses/108/102/108102145/
2. https://nptel.ac.in/courses/103/103/103103206/

EE5105	Power Electronics Lab	0–1–2: 2

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Determine the characteristics of power devices and converters
CO2	Implement control circuits for power converters
CO3	Determine the performance of power converters
CO4	Determine the performance of Z-source and resonant converters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	3	2
CO2	2	0	2	1	3	2
CO3	3	0	2	1	2	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments

1. Static characteristics of MOSFET and IGBT
2. PV characteristics and Implementation of MPPT
3. Analysis of DC-DC converters (a) Buck converter, (b) Boost converter, and (c) Buck-Boost converter
4. Closed loop control of Buck and Boost converter
5. Quasi-square wave control of a Single phase Full bridge VSI
6. Unipolar and bipolar PWM techniques for single-phase half-bridge and full-bridge inverters.
7. 120˚ and 180 operation of three-phase inverter and selective harmonic elimination for three- phase inverter
8. Sine-PWM techniques for three-phase two-level inverters.
9. Space vector modulation for a three-phase VSI
10. Pulse width modulation control of Single phase AC voltage controller
11. Single phase Five level cascaded H-Bridge inverter
12. Hysteresis current control of a single phase inverter
13. Control of Front-end active rectifiers/Bidirectional Converters
14. Control of Z-source inverter
15. Control of Resonant DC - DC converters

EE5106	Power Electronic Simulation Lab	0 – 1 – 2: 2

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Use simulators as a learning aid and gain insight regarding power electronic converters and drive systems
CO2	Validate the performance of power converters with different PWM schemes
CO3	Explore the behavior of new circuits for power conversion
CO4	Explore the dynamic performance of Induction motor and multi-carrier PWM techniques.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	3	0	3	1	2	2
CO3	3	0	3	1	3	2
CO4	2	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments

1. Study of the dynamics of second order system.
2. Study of the dynamic behaviour of an electromechanical relay.
3. Study of the dynamics of magnetic circuits.
4. (a) Study of instantaneous power in various frames of reference.

   (b) Study of torque produced in an induction machine in '*abc*' and '*qd0*' frames.
5. Implementation of buck and boost dc-dc converters.
   a. Design of various elements such as inductor, capacitor for continuous and discontinuous current operation.
   b. State-space modelling.
   c. Study the dynamic behaviour of the DC-DC converters through numerical integration methods.
6. Study on the design of PI controllers and stability analysis for a DC-DC buck Converter.
7. Sine-PWM techniques for single-phase half-bridge, full-bridge and three-phase inverters.
8. Programming of sine-triangle PWM technique in simulation environment.
9. Space vector modulation (SVM) for three-phase two-level inverters using classical and Kim-Sul methods.
10. Closed-loop implementation single-phase high power factor rectifiers (Boost rectifier and PWM rectifier).
11. Multicarrier PWM techniques for three-phase diode clamped and cascade H-bridge multilevel inverters.
12. Study of the dynamic performance of a V/Hz controlled induction motor drive using the *dq0* model.

EE5148	Seminar–I	0 – 0– 2: 1

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Identify and choose appropriate topic of relevance.
CO2	Assimilate literature on technical articles of specified topic
CO3	Write technical report.
CO4	Present a technical talk on the chosen topic

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	2	1	3	1
CO2	3	0	3	1	3	1
CO3	3	0	3	1	3	1
CO4	3	0	3	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

There is no specific syllabus for this course. Student can choose any topic, of his / her choice, pertaining to Power Electronics and Drives. Topic should be a relevant and currently researched one. Students are advised to refer articles published in current journals in the area of Power Electronics and Drives for choosing their seminar topics. Student should review minimum of 10 to 15 research papers relevant to the topic chosen, in addition to standard textbooks. Students are required to prepare a seminar report, in the standard format and give presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. It is mandatory for all the students to attend the presentations of their classmates.

Learning Resources:

1. Journal papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE5111	Modern Control Theory	3 – 0 – 0 : 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Develop mathematical models of physical systems
CO2	Design optimal controllers for power electronic converters and power systems
CO3	Analyze the issues related to the stability of automatic control systems
CO4	Design complex nonlinear systems with linearization

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	0	2	1	2	2
CO2	2	0	2	1	2	2
CO3	2	0	3	1	2	2
CO4	2	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Introduction to linear control systems

System representation: Introduction to state and state variables - system representation in state variable form - transformations - Phase variable form - Canonical forms – Physical systems - Plant models – Representation using state function - Lagrange linearization

Time response: State transition matrix – Properties and methods of valuation - Time response of linear systems -State diagrams - Resolvant matrix - Resolvant algorithm

Controllability and observability: Definition and concepts - Criteria for controllability and observability - State variable feedback - Pole placement - Luenberg observer design

Stability: Introduction - definition of stability - stability in the sense of Lyapunov - stability of linear systems - transient response - Behavior of estimation - stability of nonlinear systems - generation of Lyapunov functions

Optimal control: Formulation of the optimal control problem - method of calculus of variations - use of Hamiltonian method - Pontryagin's minimum principle - Optimal control problem - Hamilton – Jacobi approach - Continuous time linear state regulator matrix riccati equation - Methods of solution – State variable feedback design.

Introduction to non-linear control systems

Learning Resources:

Text Books:

1. Modern control Engineering, Katsuhiko Ogata, Pearson Education India, 2015, 5th Edition.
2. Modern Control Systems Theory, M. Gopal, New Age International Private Limited, 2014, 3rd Edition.

Reference Books:

1. Modern Control Theory, Z. Bubnicki, Springer, 2010, 1st Edition.
2. State functions & linear control systems, Schultz & Melsa, McGraw Hill Book Co. New York, 1998.

Online Resources:

1. https://nptel.ac.in/courses/108/107/108107115/

EE5112	Power Quality Improvement Techniques	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Identify power quality problems in distribution system
CO2	Evaluate power quality indices in distribution system
CO3	Develop mitigation techniques for compensating devices to improve power quality in distribution system
CO4	Suggest compensating devices to improve power quality in distribution system

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	1	3	2
CO2	1	2	2	1	3	2
CO3	3	2	2	1	3	2
CO4	3	2	2	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Power Quality: Significance of power quality, Power quality terms: Transients, Long- duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage fluctuation, CBEMA and ITI curves. Devices for Overvoltage Protection: Surge arresters and transient voltage surge suppressors, Isolation transformers and Low-impedance power conditioners.

Waveform Distortion: Introduction, Voltage versus current distortion, Harmonics versus transients, Harmonics indices: Total Harmonics Distortion (THD) and Total Demand distortion (TDD); Harmonic standards; Harmonic analysis; Harmonic phase sequence; Triplen harmonics; Interharmonics.

Harmonic Sources: Introduction; Harmonics generated from electrical machines such as transformers and rotating machines; Arcing devices; Static power conversion: Phase controlled and uncontrolled rectifiers, AC voltage regulators, Cycloconverters, Pulse width modulated inverters; Converter fed ac and dc drives;

Effects of Harmonic Distortion: Introduction; Resonances; Effects of harmonics on rotating machines; Effect of harmonics on static power plant; Power assessment with distorted waveforms; Effect of harmonics on measuring instruments; Harmonic interference with ripple control systems; Harmonic interference with power system protection; Effect of harmonics on consumer equipment; Interference with communication systems.

Harmonic Elimination: Introduction; Passive power filters: Design, A Shunt active power filters: Configurations, State of the art, Design and control strategies. Three-phase four- wire shunt active power filters

Voltage Quality: Introduction; Sources of Sags, Swell, Unbalance and Flicker; Voltage quality standards; Effects of sags, Swell, Unbalance and Flicker; Voltage sag magnitude due to fault; Voltage sag magnitude calculation based on influence of cross section of conductor, transformer and fault levels; Critical distance for a voltage sag magnitude; Causes of phase-angle jumps in voltage; Classification of voltage sags, voltage sag transformation due to transformers.

Methods for improving Voltage Quality: Introduction; Dynamic Voltage Restorer (DVR): Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire DVR.

Unified Power Quality Conditioner (UPQC): Introduction; design and control; Three- phase three-wire UPQC and three-phase four-wire UPQC topologies, Multilevel inverters based UPQC topologies, Mitigation of Flicker

Learning Resources:

Text Books:

1. Power Quality: Problems and Mitigation Techniques, Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Wiley, 2015.
2. Understanding power quality problems, Math H. J. Bollen, Wiley-IEEE Press, 2000, 1st Edition.
3. Power Quality Enhancement Using Custom Power Devices, Ghosh Arindam, Ledwich Gerard, Springer, 2009.

References Books:

1. Instantaneous Power Theory and Applications to Power Conditioning, Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes, Wiley-IEEE Press, 2017.
2. Electrical Power Systems Quality, Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty, McGraw Hill, 2012, 3rd Edition.
3. Power System Harmonics, J. Arrillaga, N.R. Watson, Wiley, 2003, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/107/108107157/
2. https://nptel.ac.in/courses/108/106/108106025/

EE5113	Electromagnetic Interference & Compatibility	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Recognize the sources of Conducted and radiated EMI in Power Electronic Converters and consumer appliances and suggest remedial measures to mitigate the problems
CO2	Assess the insertion loss and design EMI filters to reduce the loss
CO3	Design EMI filters, common-mode chokes and RC-snubber circuits measures to keep the interference within tolerable limits
CO4	Develop suitable techniques to mitigate EMI/EMC issues in power converters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	0	2	1	2	2
CO2	1	0	2	1	2	2
CO3	2	0	2	1	2	2
CO4	2	0	2	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Sources of conducted and radiated EMI, EMC standardization and description, measuring instruments, conducted EMI references, EMI in power electronic equipment: EMI from power semiconductors circuits.

Noise suppression in relay systems: AC switching relays, shielded transformers, capacitor filters, EMI generation and reduction at source, influence of layout and control of parasites.

EMI filter elements: Capacitors, choke coils, resistors, EMI filter circuits. Ferrite breeds, feed through filters, bifilar wound choke filter, EMI filters at source, EMI filter at output

EMI filter design for insertion loss: Worst case insertion loss, design method for mismatched impedance condition and EMI filters with common mode choke-coils, IEC standards on EMI

EMI in Switch Mode Power Supplies: EMI propagation modes, power line conducted-mode inference, safety regulations (ground return currents), Power line filters, suppressing EMI at sources, Line impedance stabilization network (LISN), line filter design, common-mode line filter inductors- design& example, series –mode inductors and problems, EMI measurements.

Faraday Screens for EMI prevention: As applied to switching devices, transformers faraday screen and safety screens, faraday screens on output components, reducing radiated EMI on gapped transformer cores, metal screens, electrostatic screens in transformers

Learning Resources:

Text Books:

1. Electromagnetic Compatibility in Power Electronics, Laszlo Tihanyi, IEEE Press, 1995, 1st Edition.
2. Practical Design for Electromagnetic Compatibility, Ficchi, Rocco F., Hayden Book Co., 1981.

References Books:

1. Handbook on Switch-Mode power supplies, Keith H Billings, Taylor Morey, McGraw-Hill

Publisher, 2011, 3rd Edition.
2. Switching Power Supply Design, Abraham I. Pressman, Keith Billings, Taylor Morey, McGraw Hill International, 2009, 3rd Edition.

Online Resources:
1. https://nptel.ac.in/courses/108/106/108106138/

EE5114	Electric Vehicles	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand the concepts of electric vehicles, hybrid electric vehicles and their impact on environment
CO2	Analyze the drive-train topologies and advanced propulsion techniques
CO3	Analyze hybrid energy storage methodologies
CO4	Select suitable power converter topologies for motor control and hybrid energy storage

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3	3	2
CO2	1	2	2	3	3	2
CO3	1	2	3	3	3	2
CO4	2	2	3	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Conventional vehicle, basics of vehicle performance, History of electric vehicles, social and environmental importance of electric vehicles, impact of modern drive-trains on energy supplies.

Hybrid Electric Vehicles: Micro hybrid vehicles, mild hybrid vehicles, full hybrid vehicles, Parallel hybrid vehicles, series Hybrid Vehicles, Series-Parallel Hybrid vehicles, plug-in hybrid vehicles, power flow diagrams for various operating modes. Plug-in Hybrid Vehicles: Operating principle, architectures: series-parallel-series-parallel, challenges related to grid connection. Range-extended Electric Vehicles: Classification and configurations, Fuel Cell Electric Vehicles, Solar electric Vehicles, Electric Bi-cycles and their propulsion systems, Vehicle-to-grid, vehicle-to-home concepts, Concept of Hybrid Electric Vehicles.

Electric drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis

Electric propulsion unit: Electric components used in electric vehicles, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives, Drive system efficiency.

Energy Storage: Storage requirements for Electric Vehicles, Battery based energy storage, Fuel Cell based energy storage, Super Capacitor based energy storage and their analysis. Power pack management systems, Cell balancing techniques, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices, compressed air storage systems, super conducting magnetic storage systems and Energy management systems.

Converters for Hybrid Energy Storage Systems: Converter configurations for hybrid energy systems based on Battery and Ultra Capacitors-cascaded converter, multiple parallel-connected converter, dual-active-bridge converter, multiple-input converter,- multiple modes single converter, interleaved converter, switched capacitor converter, converters for coupled inductor based hybridization. Fundamentals of Chargers: Charger classifications and standards, selection of AC charging systems, DC charging systems, Converter topologies for charging, wireless chargers.

Learning Resources:

Text books:

1. Advanced Electric Drive Vehicles, Ali Emadi, CRC Press, Taylor & Francis Group 2015.
2. Electric and Hybrid Vehicles: Design Fundamentals, Iqbal Hussein, CRC Press, 2003, 2nd Edition.

References:

1. Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, CRC Press, 2005.
2. Electric Vehicle Technology Explained, James Larminie, John Lowry, Wiley, 2003.

Online Resources:

1. https://nptel.ac.in/courses/108/106/108106170/
2. https://nptel.ac.in/courses/108/102/108102121/

EE5202	Data Science Applications in Power Engineering	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Distinguish between Algorithmic based methods and Knowledge based Methods
CO2	Able to distinguish between Artificial Neural Networks and Fuzzy Logic
CO3	Adopt Soft Computing techniques for solving Power System Problems
CO4	Apply appropriate AI frame work for solving Power System Problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	0	0	3	0	0	0
CO2	3	0	0	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	3	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Artificial Neural Networks (ANN):

Introduction to Artificial Neural Networks - Definition and Fundamental concepts -Biological Neural Network – Modeling of a Neuron -Activation functions – initialization of weights - Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – XOR Problem - ADALINE and MADALINE

ANN Paradigms:
Multi – layer perceptron using Back propagation Algorithm (BPA) -Self – Organizing Map (SOM) -Learning Vector Quantization (LVQ) - Radial Basis Function Network -Functional link network -Hopfield Network -Bidirectional Associate Memory (BAM)

Deep Learning:
Deep Architectures – Convolutional Neural Networks – Convolutional Layer – Pooling Layer – Normalization Layer- Fully Connected Layer – Deep belief Networks

Fuzzy Logic:
Introduction – Classical and Fuzzy sets- Properties, Operations and relations-Fuzzy sets – Membership function – Basic Fuzzy set operations -Properties of Fuzzy sets – Fuzzy cartesion Product - Operations on Fuzzy relations – Fuzzy logic – Fuzzy Cardinalities - Fuzzy Logic Controller (FLC): Fuzzy Logic System Components: Fuzzification - Inference Engine - Defuzzification methods

Applications of ANN and Fuzzy Logic:
Load flow studies - Economic load dispatch - Load frequency control – Single area system and two area systems - Reactive power control - Speed control of DC and AC Motors. Fuzzy control applications in wide area control – ANN in hybrid state estimation – ANN applications for power system protection.

Learning Resources:

Text Books:

1. Neural Networks, Fuzzy Logic & Genetic Algorithms, S. Rajasekaran and G.A.V. Pai, PHI, New Delhi, 2008.
2. Fuzzy Logic with Fuzzy applications, T.J. Ross, Mc Graw Hill Inc, 1997.

Reference Books:

1. Neural Networks: A Comprehensive Foundations Simon Haykin, Pearson Edition, 2003.
2. Fuzzy sets, Uncertainty and Information, G.J.Klir and T.A.Folger, PHI, Pvt.Ltd,1994.
3. Neural Network & Fuzzy System, Bart Kosko, Prentice Hall, 1992.
4. Neural Computing Theory & Practice, P. D .Wasserman, Van Nostrand Reinhold, New York, 1989.

Online Resources:

1. https://smartgridcenter.tamu.edu/index.php/data-science-and-machine-learning-for-modern-power-systems/

EE5213	HVDC Transmission	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Distinguish HVDC Transmission and EHVAC transmission system.
CO2	Analyze HVDC transmission with Current Source Converters and Voltage Source Converters.
CO3	Evaluate performance metrics for HVDC converter configuration.
CO4	Synthesize controllers for Voltage Source Converters based HVDC under DC fault conditions.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

DC POWER TRANSMISSION TECHNOLOGY: Introduction, Comparison of AC&DC Transmission, Applications of DC Transmission, Description of DC Transmission System, Modern Trends in DC Transmission.

HVDC WITH CURRENT SOURCE CONVERTERS

ANALYSIS OF HVDC CONVERTERS: Choice of converter configuration, Simplified analysis of Graetz circuit: without overlap, with overlap, Converter Bridge characteristics. Equivalent circuit of HVDC link, power factor and reactive power of converters.

CONVERTER AND HVDC SYSTEM CONTROL: Principles of DC link control, Converter control characteristics, power reversal in DC link, voltage dependent current order limit(VDCOL), System control hierarchy, Firing angle control , constant current control and Extinction angle control, Power control.

LCC HVDC System Harmonics: Harmonic Performance Criteria, Harmonic Limits, Harmonic Filters, Non-characteristic Harmonic Reduction Using HVDC Controls.

HVDC WITH VOLTAGE SOURCE CONVERTERS

VSC HVDC Applications and Topologies, Performance and Cost Comparison with LCC HVDC: Voltage Source Converters (VSC), Comparison with Line-Commutated Converter (LCC) HVDC, Overhead and Subsea/Underground VSC HVDC Transmission, DC Cable Types with VSC HVDC, Monopolar and Bipolar VSC HVDC Systems, VSC HVDC Converter Topologies, VSC HVDC Station Components, AC Reactors, DC Reactors.

Two-Level PWM VSC HVDC Modelling, Control and Interaction with AC Systems: Various Two- Level Converter Models, VSC Converter Control Principles, Complete VSC Converter Controller. Power Exchange between Two AC Voltage Sources , Converter Phasor Model and Power Exchange with an AC System and Operation with Very Weak AC Systems.

VSC HVDC under AC and DC Fault Conditions and applications: Introduction, DC Faults with Two-Level VSC, Influence of DC Capacitors, VSC Converter Modelling under DC Faults conditions. VSC HVDC High-Level Controls and AC Grid Support, HVDC Embedded AC Grid, HVDC Connecting Two Separate AC Grids, HVDC in Parallel with a Passive AC System and

VSC HVDC Operation with Offshore Wind Farms.

Learning Resources:

Text Books:

1. HVDC Power Transmission System, K.R. Padiyar, New Age Intl. Co, 2015.
2. High Voltage Direct Current Transmission: Converters, Systems and DC Grids, Dragan Jovcic, Khaled Ahmed, Wiley Publishers, 2015.

Reference Books:

1. Direct Current Transmission, Edward Wilson Kimbark, John Wiley & Sons,1971, Vol-1.
2. Self-Commutating Converters for High Power Applications, Jos Arrillaga, Yonghe H. Liu, Neville R. Watson, Nicholas J. Murray, Wiley Publishers, 2009.
3. HVDC Transmission: Power Conversion Applications in Power Systems, Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, Wiley Publishers 2009.

Online Resources:

1. https://www.youtube.com/playlist?list=PL4B78E9972172086A

EE5214	Instrumentation and Automation	3-0-0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Analyze the performance of physical systems for measurement of physical quantities
CO2	Understand Signal Conditioning operations and design systems for measurement and instrumentation.
CO3	Synthesize Industrial Automation and Control technologies
CO4	Implement PLCs for Industrial Automation.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Static and Dynamic characteristics of Instrument, measurement of translational and rotational displacement, resistive potentiometers, strain gauges, Linear Variable Differential Transformer (LVDT), Synchros, induction potentiometers, piezoelectric transducers, electro optical devices, digital displacement transducers (translational and rotary encoders), magnetic and photoelectric pulse counting for speed, transducers for torque, voltage, current, power, frequency, power factor and phase angle measurement and microprocessor based measurement.

Signal Conditioning: Instrumentation amplifiers: Basic characteristics. Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers. Noise Reduction Techniques in Signal Conditioning- Fundamentals of 4-20 mA current loops, Regulators and power supplies for industrial instrumentation. Estimation of errors and Calibration, Bus standard for communication between instruments - GPIB (IEEE-488 bus), RS 232 and RS 485 interface, Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters. Interrupt-based Data Acquisition. Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques.

Impact of Automation on Manufacturing and Process Industries; Architecture of Industrial Automation Systems. Data Acquisition systems and PC based automation.

Automatic Control, P-I-D Control, Controller Tuning, Special Control Structures: Feed forward and Ratio Control, Predictive Control, Control of Systems with Inverse Response, Cascade Control. Process and Instrumentation Diagrams.

Sequence Control: PLCs and Relay Ladder Logic, Scan Cycle, RLL Syntax, Structured Design Approach, Advanced RLL Programming, Hardware environment, Timers and counters: Types of timers, programming timers, ON and OFF- delay timers, pulse timers, forms of counter, programming, up and down counters, timers with counters and sequencer.

Learning Resources:

Text Books:

1. Industrial Instrumentation, Control and Automation, S. Mukhopadhyay, S. Sen and A. K. Deb, Jaico Publishing House, 2013

2. Measurement Systems, Applications and Design, Doebelin, Tata McGraw Hill, 2008.
3. Programmable Logic controllers, W Bolton, Elsevier- newness, 2009, 5th Edition.

Reference Books:

1. Fundamentals of Industrial Instrumentation, Alok Barua, Wiley India Pvt. Ltd., 2011.
2. Measurement & Instrumentation: Trends & Applications, M.K. Ghosh, S. Sen and S. Mukhopadhyay, Ane Books, 2010.
3. Chemical Process Control, An Introduction to Theory and Practice, George Stephanopoulos, Prentice Hall India, 2012.
4. Programmable Logic Controllers, Frank. D, Petruzella, Tata McGraw Hill, 2010, 3rd Edition.

Online Resources:

1. https://paktechpoint.com/free-courses-of-instrumentation-control-automation-scada-electrical/

EE5215	Machine Learning and Applications	3– 0 –0: 3

Course Outcomes (COs):

At the end of the course, the student will be able to

CO1	Understand basic concepts of Machine Learning Techniques
CO2	Distinguish between supervised learning, unsupervised learning and reinforced learning
CO3	Develop the skills in using machine learning software for solving practical problems
CO4	Apply Machine Learning Algorithms for Electrical Engineering problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	3	2	0
CO4	3	0	3	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

NEURAL NETWORKS:

Introduction to Neural Networks, Models of Neuron Network, Architectures – Knowledge representation, Artificial Intelligence and Neural Networks – Learning Process, Error Correction Learning, Multi-layer perceptron using Back Propagation Algorithm (BPA)

LEARNING THEORY:

Introduction to Machine Learning: What is Learning – Learning Objectives – Data needed – Bayesian inference and Learning – Bayes theorem – inference – naïve Bayes – Regularization – Bias-Variance Decomposition and Trade-off – Concentration Inequalities – Generalization and Uniform Convergence – VC –dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning

SUPERVISED LEARNING:

Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis, Naïve Bayes – Kernal Method: Support Vector Machine (SVM) – Kernal function – Kernal SVM - Gaussian Process – Tree Ensembles: Decision Trees- Random Forests – Boosting and Gradient Boosting

UNSUPERVISED LEARNING (CLUSTERING):

K –means Clustering Algorithm – Gaussian Mixture Model (GMM) – Expectation Maximization (EM) – Variational Auto Encoder (VAE) – Factor Analysis – Principle Components Analysis (PCA) – Independent Component Analysis (ICA)

REINFORCEMENT LEARNING:

Markov Decision Processes (MDP) – Bellman's Equations- Value Iteration and Policy Iteration - Value Function Approximation – Q – Learning

Applications of ML:

Load Forecasting – Energy Market forecasting – Fault identification and localization – Renewable Uncertainty estimation

Learning Resources:

Text Books:

1. Pattern Recognition and Machine Learning, Christopher Bishop, Springer, 2011

2. Machine Learning, E. Alpaydin, MIT Press, 2010

Reference Books:

1. Machine Learning, Tom M. Mitchell, McGraw Hill International Edition, 1997

Online Resources:

1. https://www.learndatasci.com/best-machine-learning-courses/

EE5216	Smart Grid Technologies	3– 0 –0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand the features of Smart Grid.
CO2	Assess the role of automation in Transmission and Distribution
CO3	Apply Evolutionary Algorithms for the Smart Grid and Distribution Generation.
CO4	Understand operation and importance of PMUs, PDCs, WAMS, Voltage and Frequency control in Micro Grids.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO-1	3	0	3	0	0	0
CO-2	3	0	3	0	0	0
CO-3	3	0	3	0	2	0
CO-4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Smart Grid: Introduction to Smart Grid - Working definitions of Smart Grid and Associated Concepts – Smart Grid Functions – Traditional Power Grid and Smart Grid – New Technologies for Smart Grid – Advantages – Indian Smart Grid – Key Challenges for Smart Grid.

Smart Grid Architecture: Components and Architecture of Smart Grid Design – Review of the proposed architectures for Smart Grid. The fundamental components of Smart Grid designs – Transmission Automation – Distribution Automation – Renewable Integration

Tools and Techniques for Smart Grid: Computational Techniques – Static and Dynamic Optimization Techniques – Computational Intelligence Techniques – Evolutionary Algorithms – Artificial Intelligence techniques.

Distribution Generation Technologies: Introduction to Renewable Energy Technologies – Micro grids – Storage Technologies –Electric Vehicles and plug – in hybrids – Environmental impact and Climate Change – Economic Issues.

Communication Technologies and Smart Grid: Introduction to Communication Technology – Synchro-Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS)- Introduction to Internet of things (IOT)- Applications of IOT in Smart Grid

Control of Smart Power Grid System: Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids.

Learning Resources:

Text Books:

1. Smart Grids, Infrastructure, Technology and Solutions, Stuart Borlase, CRC Press, 2013, 1st Edition.
2. Renewable and Efficient Electric Power System, Gil Masters, Wiley–IEEE Press, 2013, 2nd Edition.

Reference Books:

1. Synchronized Phasor Measurements and their Applications, A.G. Phadke and J.S. Thorp, Springer Edition, 2017, 2nd Edition.
2. Wind Power in Power Systems, T. Ackermann, Hoboken, NJ, USA, John Wiley, 2012, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/107/108107113/

MA5331	Numerical Optimization Techniques	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Understand fundamentals of linear and non-linear optimization.
CO2	Analyse and solve single and multi-dimensional optimization problems
CO3	Apply the Simplex method to the linear programming
CO4	Apply the KKT conditions for non-linear optimization
CO5	Apply the distributed and stochastic optimization tools to real world problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	2	2
CO2	2	0	3	1	2	2
CO3	2	0	2	1	2	2
CO4	2	0	3	1	2	2
CO5	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Basic Concepts: Formulating an Optimization Problem, review of Linear Algebra and Analysis, one dimensional optimality conditions, Convex Sets and Convex Functions.

Unconstrained Optimization: Multi-dimensional optimality conditions and conceptual algorithm, Line Search Methods, Steepest Descent method, Conjugate gradient method, Classical Newton Method, Trust-region and quasi-Newton methods, Nonlinear Least Squares Problem and Algorithms.

Linear Programming: Geometric Solution, Basic feasible solution, The Simplex Method, Dual problem and duality theorems, Karmarkar's Algorithm.

Constrained non-linear optimization: Local and global solutions, Feasible and descent directions; First Order KKT Conditions, Constraint Qualification, Second Order KKT Conditions; Quadratic Programming; Penalty, Barrier and Augmented Lagrangian Methods; Sequential Quadratic Programming; Interior-Point Methods; Distributed optimization; Stochastic programming.

Power System Optimization

Unit commitment, Economic load dispatch, Optimal power flow, Security constrained optimal power flow, State estimation problems.

Learning Resources:

Text Books:

1. Numerical Optimization, J. Nocedal, & S. Wright, Springer Science & Business Media, 2006, Second Edition.
2. Linear and Nonlinear Programming, D. G. Luenberger & Y. Ye, 2016, Springer, Fourth Edition.

Reference Books:

1. Nonlinear programming: Theory and Algorithms, M. S. Bazaraa, H. D. Sherali, & C. M. Shetty, John Wiley & Sons, 2013, Third Edition.
2. Numerical Optimization with Applications, Suresh Chandra, Jayadeva, & Aparna Mehra, 2013, Alpha Science International Ltd, First Edition.
3. Engineering optimization: Theory and Practice, S. S. Rao, John Wiley & Sons, 2019, Fifth Edition.

EE5151	Advanced Power Electronics	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Analyze and design resonant converters
CO2	Develop power converter models under steady-state and small-signal conditions
CO3	Design feedback control systems for power converters
CO4	Synthesize and design magnetic components for power converter

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	2	0	3	1	3	2
CO3	2	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Resonant Converters: Introduction, Basic resonant circuit concepts, Classification - Load resonant converters, Resonant switch converters, Zero voltage switching clamped voltage converters, Resonant DC link inverters High frequency link integral half cycle converters, Phase modulated resonant converters, Dual active bridge converters, High gain converters.

Modeling of DC-DC Converters: Basic ac modeling approach, State space averaging, Circuit averaging and averaged switch modeling, Canonical circuit modeling, Converter transfer functions for buck, boost and buck-boost topologies.

Current Mode Control: Introduction, types, advantages and disadvantages, Slope compensation, Determination of duty cycle and transfer functions for buck, boost and buck-boost converters.

Design of Closed Loop Control: Controller Design: Introduction, mechanism of loop stabilization, Shaping E/A gains vs frequency characteristics, Conditional stability in feed-back loop, Stabilizing a continuous mode forward and fly-back converter, Feed- back loop stabilization with current mode control, right plane zero.

Design of Power Converters Components: Design of magnetic components - design of transformer, design of inductor and current transformer - Selection of filter capacitors, Selection of ratings for devices, input filter design, Thermal design

Learning Resources:

Text Books:

1. Power Electronics-Circuits, Devices & Applications, M.H. Rashid, Pearson, 2013, 4th Edition.
2. Power Electronics: Converters, Applications & Design, N. Mohan, T.M. Undeland, W.P. Robbins, J.Wiley & Sons, 2003, 3rd Edition.

References Books:

1. Switching Power Supply Design, Abraham I. Pressman, Keith Billings &Taylor Morey, McGraw Hill International, 2009, 3rd Edition.
2. Fundamentals of Power Electronics, R.W. Erickson and Dragan Maksimonic, Springer, 2001, 2nd Edition.

3. Power Electronics: Essentials and Applications, Umanand, L, John Wiley India, 2009, 1st Edition.

Online Resources:

1. http://nptel.ac.in
2. http://freevideolectures.com
3. http://onlinecourses.nptel.ac.in
4. http://engineeringvideolectures.com

EE5152	Advanced Electric Drives	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Apply the theory of transformations to derive the dynamic (dq0) model of an induction motor
CO2	Implement Vector control for induction motor and the PMSM drives and the Direct Torque Control for Induction Motor Drives
CO3	Implement slip power recovery schemes for induction motor drives and analyse 5-Ph IM drives
CO4	Analyze BLDC and the SRM drives

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	2	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Theory of Transformations: Concept of space vector, direct and quadrature axis variables, various types of Krause transformation, condition for power invariance, Expression for power with various types of transformation, Transformations between reference frames, Clarke and Park's Transformations, Variables observed from various frames

Dynamic Model of an induction motor: Inductance matrices of induction motor, Voltage and torque in machine variables, Derivation of *dq0* model for a symmetrical induction machine, Voltage and torque equation in arbitrary reference frame variables

Induction Motor drives: Principle of vector control of IM, Indirect vector control with feedback, Indirect vector control with feed-forward, Indirect vector control in various frames of reference, Decoupling of vector control with feed forward compensation, Direct Torque Control of IM, control of wound rotor induction machine, introduction to five-phase induction motor drives

Permanent Magnet Drives: Expression for torque, Model of PMSM, Implementation of vector control for PMSM, BLDC drives

Switched Reluctance Motor Drives: Torque expression, converters for SRM drives, Control of SRM drives

Learning Resources:

Text Books:

1. Analysis of Electric Machinery & Drive systems, Paul C. Krause, Oleg W, Scott D. Sudhoff, IEEE Press, 2013, 3rd Edition.
2. Modern Power Electronics & AC Drives, B.K. Bose, Pearson Education India, 2015, 1st Edition.

3. Electric Motor Drives: Modeling, Analysis and Control, R. Krishnan, Pearson Education India, 2015, 1st Edition.

Reference Books:

1. High-power Converters and AC Drives, Bin-Wu, Wiley-Blackwell, 2017, 2nd Edition.
2. Simulation of Power Electronic Circuits, M.B. Patil, V. Ramanarayanan, V.T. Ranganathan, Narosa Publications, 2013.

Online Resources:

1. nptel.ac.in/courses/108/104/108104140/
2. nptel.ac.in/courses/108/104/108104011/

EE5153	Digital Control Systems	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Evaluate the output of a digital system for a given input.
CO2	Describe the dynamics of a Linear, Time Invariant and Causal digital systems through difference equations.
CO3	Analyze digital systems using the Z-transformation.
CO4	Design digital controllers for Power Electronic Systems.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	2	2
CO2	2	0	2	1	3	2
CO3	2	0	3	1	3	2
CO4	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Digital control systems - Quantizing and quantization error, Data acquisition, Conversion and distribution system

Z-Transform: Z-transform - Z-transforms of elementary functions, important properties and theorems, Inverse Z-transform, Z-transform method of solving difference equations

Z-Plane Analysis of Discrete-Time Control Systems: Impulse sampling and data hold, Pulse transfer function, Realization of digital controllers and digital filters, Mapping between s-plane and z-plane, Stability analysis of closed loop systems in z-plane, Transient and steady state analyses

State Space Analysis: State space representation of digital control systems - Solution of discrete time state space equations, Pulse transfer function matrix, Discritisation of continuous time state space equations, Lyapunov stability analysis

Pole Placement & Observer Design: Controllability, Observability

Quadratic Optimal Control Systems: Design via pole placement, State observers, Quadratic optimal control, Steady state quadratic optimal control, Quadratic optimal control of a servo system

Learning Resources:

Text Books:

1. Digital control engineering, M. Gopal, New Age Int. Ltd., 2014, 2nd Edition.
2. Discrete time control systems, K. Ogata, Pearson Education, 2006, 2nd Edition.

Reference Books:

1. Modern control Engineering, Katsuhiko Ogata, Pearson Education India, 2015, 5th Edition.
2. Digital Control Systems, B.C. Kuo, Oxford University Press, 2012, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/103/108103008/

EE5154	Electric Drives Lab	0 – 1 – 2: 2

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Implement speed control schemes for separately exited DC motor, induction motor
CO2	Develop control schemes for permanent magnet synchronous motor and Brushless DC motor drives
CO3	Develop control schemes using analog circuitry and digital control platform
CO4	Evaluate the Closed performance of different electrical drives under different control schemes

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	2	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Open-loop control of separately excited DC motor using four-quadrant DC chopper.
2. Speed control of separately excited DC motor using single-phase dual converter.
3. Torque-speed characteristics of a 6-pulse fully controlled rectifier fed Separately Excited DC motor Drive.
4. Symmetrical angle and pulse width modulation control of 1-phase & 3-phase AC motor connected to AC voltage controller.
5. Open-loop speed control of three-phase induction motor using V/f control technique with analog controller.
6. Closed-loop speed control of three-phase induction motor using the slip- compensation technique.
7. Torque-Speed characteristics of a three-phase induction motor using IM-IM drive
8. Speed control of three-phase induction motor drive using three-level Neutral Point Clamped inverter.
9. Torque-Speed characteristics of a three-phase Permanent Magnet Synchronous Motor drive.
10. Implementation of space vector modulation with DSP TMS320LF2407A for V/Hz control of induction motor drive.
11. Speed control of Brushless DC motor drive.
12. Speed control of switched reluctance motor (SRM).

EE5198	Seminar–II	0 – 0– 2: 1

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Identify and chose appropriate topic of relevance.
CO2	Assimilate literature on technical articles of specified topic
CO3	Write technical report.
CO4	Present a technical talk on the chosen topic

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	2	1	3	1
CO2	3	0	3	1	3	1
CO3	3	0	3	1	3	1
CO4	3	0	3	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no specific syllabus for this course. Student can choose any topic, of his / her choice, pertaining to Power Electronics and Drives. Topic should be a relevant and currently researched one. Students are advised to refer articles published in current journals in the area of Power Electronics and Drives for choosing their seminar topics. Student should review minimum of 10 to 15 research papers relevant to the topic chosen, in addition to standard textbooks. Students are required to prepare a seminar report, in the standard format and give presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. It is mandatory for all the students to attend the presentations of their classmates.

Learning Resources:

1. Journal papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE5155	Digital Signal Processors Lab	0 – 1 – 2: 2

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Configure the on-chip peripherals such as ADC, Digital I/O and QEP to suit the control requirements of Power Converters
CO2	Configure Interrupts and Event manager to implement Pulse Width Modulation
CO3	Develop Assembly AND C-programming Languages for DSP to achieve the real time control of Power Electronic Converters
CO4	Implement control schemes for different electrical drives

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments **on TMS320LF2407A Processor (using Assembly Language)**

1. General Programs to get familiarity with addressing modes, instruction set, arithmetic and logical operations such as:
   a. Arithmetic and logical operations
   b. Direct & Indirect Data Transfer
   c. Sorting of Data in Ascending order and Descending order
   d. Square root of positive integer
   e. Maximum and minimum of given set of numbers
2. Study of the phenomenon of Aliasing
3. Study of the on-chip ADC of TMS320LF2407 processor.
4. Study of the GPIO functionality.
5. Waveform generation with on board DAC of EVM TMS320LF2407
6. PWM signal generation using event manager with dead time
7. Study of the interrupts of TMS320LF2407 processor.
8. Space Vector Modulation of a 3-Phase VSI

List of Experiments **on TMS320F2812 Processor (using C Programming Language)**

9. General Programs to get familiarity with syntax, arithmetic and logical operations (the list is similar to expt.1)
10. Solution of Difference equation
11. Study of interrupts & GPIO
12. Generation of Basic PWM signals
13. Study of Quadrature Encoder Pulse (QEP) Unit
14. Implementation of sine-triangle PWM scheme
15. Implementation of Sine-triangle PWM with Launch XL-F28069M
16. Implementation of SVPWM with Launch XL-F28377S
17. Control of BLDC motor with DRV8301

EE5161	Applications of Power Converters	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Identify power converter configurations and improvise the existing control techniques to suit the application
CO2	Analyze and design inverters for Induction Heating applications
CO3	Develop improved power converters for Low voltage High current applications
CO4	Analyze and design converters for lighting, HV systems and Bi-directional converters for charge/discharge applications

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Inverters for Induction Heating: Inverters for induction cooking, induction hardening, melting, and welding applications.

Power Converters for Lighting, pumping and refrigeration Systems: Electronic ballast, LED power drivers for indoor and outdoor applications. PFC based grid fed LED drivers, PV / battery fed LED drivers. PV fed power supplies for pumping/refrigeration Applications.

High Voltage Power Supplies - Power supplies for X-ray applications - power supplies for radar applications - power supplies for space applications.

Low Voltage High Current Power Supplies: Power converters for modern microprocessor and computer loads .

Bi-directional DC-DC (BDC) converters: Electric traction, Automotive Electronics, Battery charging converters, UPS and its applications, Line Conditioners and Solar Charge Controllers, Solar PV tracking.

Learning Resources:

Text Books:

1. Switching Power Supply Design, Abraham I. Pressman, Keith Billings &Taylor Morey, McGraw Hill International, 2009, 3rd Edition.
2. Uninterruptible Power Supplies and Active Filters, Ali Emadi, A. Nasiri, and S. B. Bekiarov, CRC Press, 2005, 1st Edition.

References Books:

1. Hand book of Induction Heating, Valery Rudnev, Don Loveless, Raymond L. Cook, CRC Press, 2017, 2nd Edition.
2. Power Supplies for LED Driving, Steve Winder, Newnes, 2016, 2nd Edition.

3. Understanding Automotive Electronics: An Engineering Perspective, William Ribbens, Butterworth-Heinemann, 2017, 8th Edition.
4. Modern Electric, Hybrid Electric and Fuel Cell Vehicles, M. Ehsani, Yimin Gao, Stefano Longo, K Ebrahimi, CRC Press, 2018, 3rd Edition.

Online Resources:

1. https://www.youtube.com/c/LeonardoENERGY/videos

EE5162	Design of Power Electronic Converters	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Apply numerical methods to develop simulation software for power electronic systems
CO2	Carry out transient simulation for power electronic systems
CO3	Apply switching functions to describe switching states of power converters
CO4	Develop effective models for power electronic converters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	3	1	3	2
CO2	2	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Computation challenges - Simulation process - mechanics of simulation, Solution techniques for time domain analysis -Equation solvers, circuit-oriented simulators.

Simulation of power electronic converters: MNA and ST Approaches- Nodal Analysis, Modified Nodal Analysis, Spare Tableau Approach, Nonlinear Circuits - Newton-Raphson Method, Computation Time, Convergence Issues, Nonlinear Circuit Equations.

Transient Simulation - Introduction, Discretization of Time, Transient Analysis, Accuracy and Stability, Explicit and Implicit Schemes, Methods for Transient Simulation - FE, BE and TRZ, Transient Analysis in Circuit Simulation, Equivalent Circuit Approach: RC Circuit, Buck Converter; Some Practical Aspects: Undamped Oscillations, Ringing, Global Error in Switching Circuits, Round-off Error, Assessment of Accuracy, Singular Matrix Problem, Trapezoidal integration, M & N method for simulating power electronic converters (with buck converter as a representative example).

Switching function: Introduction, Application of the switching function technique, Properties of the switching function, Voltage-Current relations in switched circuits - Single Switch, Parallel Switch. Pulse Width Modulation Modeling- Unipolar, PWM Signal of a composite function, bipolar square wave modulation, Mathematical Modeling of Buck Converter, Modeling using switching function-buck converter, Rectifier, 3-phase VSI inverter, matrix converter, m-phase rectifier. PWM rectifier topologies

Modeling of power electronic converters - PWM rectifier in different frames- abc, alpha-beta and d-q using switching function, Inverters.

Learning Resources:

Text Books:

1. Simulation of Power Electronic Converters, M. B. Patil, V. Ramnarayanan, V.T. Ranganathan, Narosa Publishers, 2010, 1st Edition.
2. State Variables For Engineers, De Russo, P. M., Roy, R. J., Close, C. M., Desrochers, A, John Wiley, New York, 1998, 2nd Edition.

Reference Books:

1. Power Electronics: Converters, Applications, N. Mohan, T.M. Undeland, W.P. Robbins, John Wiley & Sons, 2009, 3rd Edition.
2. Mathematical modeling and digital simulation for engineers and scientists, Smith, J. M, John Wiley, New York, 1987, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/108/108108034/

EE5163	High Power Inverters	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Analyze the Weighted THD and implement SVM based on instantaneous phase reference voltages
CO2	Implement level-shifted, phase-shifted, hybrid and Space Vector PWM schemes for Cascaded H-Bridge Multilevel Inverters
CO3	Develop PWM schemes to balance the neutral point, eliminate common mode voltage and reduce the switching power loss in diode clamped multilevel inverter
CO4	Develop reduced switch count MLIs and PWM current source inverters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Review of two-level inverters and their PWM schemes. Effect of dead-time and compensation in two-level inverters. Limitations of two-level inverters and introduction to multilevel inverters. Convectional multilevel inverter typologies.

Diode clamped multilevel inverter (DCMLI): 3, 4 and 5 level DCMLIs, level-shifted PWM, Neutral point voltage balance, SVM and discontinuous SVM, Elimination of common mode voltage, Active Neutral Point Clamped Inverter (ANPCI).

Cascade H-bridge (CHB) multilevel inverter (MLI): Symmetrical and asymmetrical topologies, level-shifted PWM, phase-shifted PWM, hybrid PWM and SVM. Concept of coupling transformer-less grid connected applications, Topologies of modular multilevel inverters (MMI).

Reduced switch count MLIs: Introduction, classification, operation of T-type, multilevel dc link, switched series parallel source and other topologies.

PWM current source inverters: Trapezoidal modulation, selective harmonic elimination and SVM, Load-commutated inverters (LCI).

Learning Resources:

Text Books:

1. High Power Converters and AC Drives, Bin Wu, Wiley-Inter science, 2017, 2nd Edition.
2. Pulse Width Modulation for Power Converters: Principles and Practice, D. Grahame Holmes and Thomas A. Lipo, IEEE Press, 2003.

References Books:

1. Research publications.

Online Resources:

1. https://nptel.ac.in/courses/108/102/108102157/

EE5164	Nonlinear Control Systems	3– 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand the behavioral properties of nonlinear controlled systems
CO2	Analyze stability analysis of nonlinear systems, feedback linearization control method, Lyapunov design and sliding mode control method.
CO3	Formulate and solve basic robust and nonlinear controller design problems.
CO4	Develop methods of synthesis for nonlinear systems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	3	2
CO2	2	0	2	1	3	2
CO3	2	0	2	1	3	2
CO4	2	0	2	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and classical techniques: Characteristics of nonlinear systems, classification of equilibrium points, limit cycles, analysis of systems with piecewise constant inputs using phase plane analysis, perturbation techniques, periodic orbits, stability of periodic solutions, singular perturbation model, slow and fast manifolds.

Lyapunov Stability and Design: Stability of Nonlinear Systems - Lyapunov stability, local stability, local linearization and stability in the small, Direct method of Lyapunov, generation of Lyapunov function for linear and nonlinear systems, variable gradient method, Centre manifold theorem, region of attraction, Invariance theorems - Input output stability, L stability, L stability of state models, L2 stability, Lyapunov based design, Lyapunonv redesign, Robust stabilization, Nonlinear Damping, back stepping, sliding mode control, adaptive control, Model controller, model reference adaptive control.

Harmonic Linearization and Describing Function Method: Harmonic linearization, filter hypothesis, describing function of standard nonlinearities, study of limit cycles (amplitude and frequency) using SIDF, Dual Input Describing function, study of sub- harmonic oscillations, correction on describing functions.

Feedback Control and Feedback Stabilization: Analysis of feedback systems, Circle Criterion, Popov Criterion, simultaneous Lyapunov functions, Feedback linearization, stabilization, regulation via integral control, gain scheduling, input stat linearization, input output linearization, state feedback control, stabilization, tracking, integral control.

Learning Resources:

Text Books:

1. Nonlinear Control systems, A Isidori, Springer verlag, 2013, 3rd Edition.
2. Nonlinear Systems, Hassan K. Khalil, Pearson, 2001, 3rd Edition.
3. Applied Nonlinear Control, Slotine& W. LI, Pearson, 1991, 1st Edition.

References Books:

1. Nonlinear Dynamic control Systems, H. Nijmeijer & A.J. Vander Schaft, Springer, 2016, 1st Edition.
2. Introduction to Applied Nonlinear Dynamical Systems and chaos, S. Wiggins, Springer, 2010, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/106/108106162/
2. http://web.mit.edu/nsl/www/videos/lectures.html
3. https://nptel.ac.in/courses/108/101/108101002/

EE5165	Advanced Control Techniques for Power Converters	3-0-0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand and analyze the different types of converter model and its usage
CO2	Design the advanced PID controller with its fractional version and resonant controller for converters
CO3	Design the robust controller for converter using the loop-shaping methods and the Sliding mode control
CO4	Design the controller using fuzzy logic and AI techniques for converters and drives

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	3	2
CO2	3	0	3	1	3	2
CO3	2	0	3	1	3	2
CO4	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Modeling of Power converters: Types of Models- Linearized Averaged models- Large signal and Small signal models- Switched models- Relation between various model types- Control goals in converter operation- Review of classical control methods.

Advanced PID controller: PID controller-Tuning methods of PID controller- Set point weighting- Integrator Windup- Controller degrees of freedom- Model based Design methods: Direct Synthesis (DS) method, Internal Model Control (IMC) method- Fractional Control System (FOS) -Design of Fractional PID controller- Case Study: PID controller design for DC-DC boost converter.

Resonant Controller: Necessity of resonant controller- Principle of Proportional Resonant (PR) control- Design methods of PR controller- Example of PR controller design for DC-DC boost converter.

Loop-shaping design: Concept of Loop shaping- Robust controller design using the loop shaping methods: H∞ Control, Quantitative feedback theory (QFT)- Case Study: Loop shaping methods to design the robust controller for DC-DC converter.

Sliding mode controller (SMC): Nonlinear control preliminaries-Types of Uncertainty-Sliding surface design- Stability of SMC- Equivalent control concept- Integral Sliding Mode Control (ISMC) design- Case study: Application of SMC to design the robust controller for DC-DC converter.

Fuzzy logic control and artificial Intelligence (AI) techniques: Introduction to fuzzy logic and AI techniques, application of fuzzy logic to power converters and electric drives, hardware system description, application of AI techniques to electric machines and drives.

Learning Resources:

Text Books:

1. Power Electronic Converters Modeling and Control with Case Studies, S. Bacha, I. Munteanu, A.I. Bratcu, Springer- Verlag London, 2014, 1st Edition.
2. PID and Predictive control of Electrical Drives and Power Converters using MATLAB/Simulink, L. Wang, S. Chai, D. Yoo, L. Gan, K. Ng, Wiley Press, 2015, 1st Edition.
3. Robust Linear Control of DC-DC Converters: A Practical Approach to the Synthesis of Robust Controllers, C. Olalla, Ramon Leyva, I. Queinnec, VDM Verlag- Dr. Muller, 2010, 1st Edition.
4. Sliding Mode controllers for Power Electronic Converters, A. Mehta, B. Naik, Springer Nature, 2019.

Reference Books:

1. Sliding Mode Control of Switching Power Converters: Techniques and Implementation, S-C. Tan, Y-M. Lai, C.K. Tse, CRC Press, 2012, 1st Edition.
2. Control Design Techniques in Power Electronic Devices, Hebertt Sira-Ramirez, Ramon Silva-Ortigoza, Springer- Verlag London, 2006, 1st Edition.
3. Control of Power Electronic Converters and Systems, Freede Blaabjerg, Academic Press, 2018. 1st Edition.
4. Control of Power Inverters in Renewable Energy and Smart Grid Integration, Q- C. Zhong, T. Hornik, Wiley Press, 2013, 1st Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/103/108103007/
2. https://nptel.ac.in/courses/101/108/101108047/
3. http://web.mit.edu/nsl/www/videos/lectures.html
4. https://people.ee.ethz.ch/~apnoco/

EE5166	Power Converters and Control Techniques for Microgrids	3-0-0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Compare types of microgrid architectures and their standards.
CO2	Modeling of power electronic converters in microgrid applications.
CO3	Develop power converters and control techniques for micro grid applications.
CO4	Evaluate dynamics and stability of microgrids.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	2	1
CO2	1	0	3	1	3	2
CO3	1	0	3	1	3	2
CO4	1	0	3	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Micro-Grid: Power system resilience, The concept of micro-grids, Types of micro-grids, Autonomous and non- autonomous grids, Sizing of micro-grids, Microgrid Modeling &Analysis, Micro-grids with multiple DGs. Standards and regulation issues associated with AC&DC microgrids, Comparison between AC and DC Microgrids.

Microgrid Control: Centralized control, Hierarchical principle: Primary, secondary and tertiary control – Distributed control, Protection issues and Communication based techniques.

Modeling of Power Electronic Converters in Microgrid application : Modeling of voltage source PWM rectifier, modeling of voltage source inverter in current controlled mode and voltage controlled mode, modelling of boost DC-DC converter and its control, modeling of isolated bidirectional DC-DC converter and its control.

Microgrid Dynamics: Modeling of AC & DC microgrid and its dynamic studies.

Control of grid connected inverter in AC Microgrid: Basics of Voltage-frequency control and P-Q control in AC microgrid, control of grid-forming inverter, control of grid-feeding inverter, control of grid-supporting power inverter, synchronization of inverters in ac microgrids.

Control of DC-DC converter in DC Microgrid: Voltage control and power control in DC microgrid, control of parallel DC-DC converters in a DC microgrid.

Linear and nonlinear Stability system in AC&DC Microgrid: System models and stability analysis of AC&DC Microgrid, stabilization strategies-impedance and admittance stability criteria, stabilization using nonlinear techniques-feedback linearization and sliding mode control, intelligent control of microgrids-fuzzy logic control and ANN control. Future Perspectives.

Learning Resources:

Text Books:

1. Microgrid Technology and Engineering Application, Fusheng Li, Ruisheng Li, Fengquan Zhou, Elsevier, 2015.
2. Microgrids and Active Distribution Networks, S. Chowdhury, P. Crossley, Institution of Engineering and Technology, 2009.
3. Microgrids Architectures and Control, Nikos Hatziargyriou, John Wiley Sons, 2014.
4. Microgrid Dynamics and Control, Hassan Bevrani, BrunoFrançois, Toshifumi Ise, John Wiley Sons, 2017.

Reference Books:

1. Intelligent Control and Power Flow Optimization, Manuela Sechilariu, Fabrice Locment, Urban DC Microgrid, Butterworth-Heinemann, 2016 .
2. Distributed Generation Systems:Design, Operation and Grid Integration, Gevork B. Gharehpetian, S. Mohammad Mousavi Agah, Butterworth Heinemann, 2017.
3. IEEE Transactions

Online Resources:

1. https://nptel.ac.in/courses/108/107/108107143/

EE5167	Predictive Control of Power Converters and Drives	3 –0– 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Develop the mathematical models of predictive control for power converters and drives
CO2	Design the predictive controller scheme for power converters and drives
CO3	Optimize the cost function through analysis and simulation of power converters and drives
CO4	Implement model predictive control schemes for electric drive systems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	3	1	3	2
CO2	2	0	3	1	3	2
CO3	2	0	3	1	3	2
CO4	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Classical Control Methods for Power Converters and Drives: Power converter control in the past, power converter control today, control requirements and challenges, digital control platforms, why predictive control is particularly suited for power electronics.

Model Predictive Control: Predictive control methods for power converters and drives, basic principles of model predictive control, model predictive control for power electronics and drives, controller design, implementation, general control scheme.

Predictive Control of a Three-Phase Inverter: Introduction, predictive current control, cost function converter model, load model, discrete-time model for prediction, working principle, implementation of the predictive control strategy, comparison to a classical control scheme, predictive control simulation of three-phase inverter

Predictive Control of a Three-Phase Neutral-Point Clamped Inverter: Introduction, system model, predictive current control method, implementation, reduction of the switching frequency, capacitor voltage balance.

Control of an Active Front-End Rectifier: Introduction, rectifier model, space vector model, discrete-time model, predictive current control in an active front-end, cost function, predictive power control, cost function and control scheme, predictive control of an ac – dc – ac, control of the inverter side, control of the rectifier side, control scheme.

Predictive Control of Induction Machines: Introduction, dynamic model of an induction machine, predictive torque control of an induction machine fed by a voltage source inverter, comparison to a classical control scheme, predictive control simulation – torque control of an induction machine fed by a two-level voltage source inverter.

Predictive Control of Permanent Magnet Synchronous Motors: Introduction, machine equations, discrete-time model of field-oriented control using predictive current control, and discrete-time model of predictive speed control, predictive control simulation – torque control of PMSM fed by a two-level voltage source inverter.

Design and Implementation issues of Model Predictive Control: Cost function selection, weighting factor design, cost function classification, weighting factors adjustment and examples.

Learning Resources:

Text Books:

1. Predictive Control of Power Converters and Electrical Drives, Jose Rodriguez and Patricio Cortes, Wiley-IEEE Press, 2012, 1st Edition.
2. Model Predictive Control of High Power Converters and Industrial Drives, Tobias Geyer, Wiley, 2016, 1st Edition.

Reference Books:

1. Advanced Control Systems for Electric Drives, Adel Merabet, Mdpi AG, 2020.
2. Predictive Control: Fundamentals and Developments, Yugeng Xi and Dewei Li, Wiley, 2019, 1st Edition.

Online Resources:

1. https://nptel.ac.in/courses/127/106/127106225/
2. https://onlinecourses.nptel.ac.in/noc21_ge01/preview

EE5263	Energy Auditing and Management	3 – 0 –0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand the need and significance of energy audit and management
CO2	Identify the equipment and domain of energy conservation and audit in power system
CO3	Assess the need and type of instruments for energy audit and energy management
CO4	Design, analyze and evaluate an energy audit and the benefits of different energy management techniques

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

ENERGY AUDIT AND DEMAND SIDE MANAGEMENT (DSM) IN POWER UTILITIES:

Energy Scenario & Conservation -Demand Forecasting Techniques- Integrated Optimal Strategy for Reduction of T&D Losses – DSM Techniques and Methodologies- Loss Reduction in Primary and Secondary Distribution system and capacitors – Energy Management – Role of Energy Managers – Energy Audit – Metering

ENERGY AUDIT: Energy audit concepts, Basic elements and measurements, Mass and energy balances, Scope of energy auditing in industries,

ENERGY AUDIT OF ELECTRICAL EQUIPMENT: Evaluation of energy conservation opportunities and environmental management- Preparation and presentation of energy audit reports, case studies for Induction motors, Transformers, Cables, Lighting, AC systems, Pumps, Capacitor banks and potential energy savings.

INSTRUMENTATION: Evaluation and instrumentation techniques for renewable energy systems (solar thermal, photovoltaic and wind energy); energy management devices; micro controller based systems.

ENERGY CONSERVATION: Energy conservation in HVAC systems and thermal power plants, Solar systems, Fan and Lighting Systems – Different light sources and luminous efficacy, Energy conservation in electrical devices and systems, Economic evaluation of energy conservation measures, Electric motors and transformers, Inverters and UPS, Voltages stabilizers,

Learning Resources:

Text Books:

1. Energy Engineering and management, Amlan Chakrabarti, PHI, 2018.
2. Energy auditing in Electrical utilities, Rajiv Shanker, Viva books Pvt. Ltd., 2015.

Reference Books:

1. Industrial energy management and utilization, Larry C. Witte, Schmidt & Brown, Hemisphere publishing, Co. New York, 1988.
2. Energy management handbook, Wayne. C Turner, Wiley Inter-science publications. New York, 1982.
3. ,Analysis and Design of Energy Systems, Hodge B.K, Prentice Hall, 2002.

Online Resources:

1. NPTEL :: Electrical Engineering - Energy Management Systems and SCADA.

EE5264	Evolutionary Algorithms application in Power Engineering	3 – 0 – 0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems.
CO2	Examine the importance of exploration and exploitation of evolutionary algorithm to attain near global optimal solution.
CO3	Distinguish the functioning of various evolutionary algorithms.
CO4	Employ various bio-inspired algorithms for Power engineering applications.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO-1	3	0	3	0	0	0
CO-2	3	0	3	0	0	0
CO-3	3	0	3	0	2	0
CO-4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

FUNDAMENTALS OF SOFT COMPUTING TECHNIQUES: Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

GENETIC ALGORITHM and PARTICLE SWARM OPTIMIZATION: Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters– GA and PSO algorithms for solving ELD problem.

ARTIFICIAL BEE COLONY ALGORITHM and DIFFERENTIAL EVOLUTION: Artificial bee colony (ABC) algorithms-binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units. The Motivation for Differential Evolution (DE), Introduction to Parameter Optimization, Single-Point, Derivative-Based Optimization, Local Versus Global Optimization, Differential Mutation, Recombination, Selection, Benchmarking Differential Evolution, DE Versus Other Optimizers, DE on Parallel Processors

SHUFFLED FROG-LEAPING ALGORITHM and BAT OPTIMIZATION ALGORITHM: Bat Algorithm-Echolocation of bats- Behavior of microbats- Acoustics of Echolocation- Movement of Virtual Bats-Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogs-comparison of memes and genes -memeplex formation- memeplex updation - BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem.

MULTI OBJECTIVE OPTIMIZATION: Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and applications.

Learning Resources:

Text Books:

1. Recent Advances in Swarm Intelligence an Evolutionary Computation, Xin-She Yang, Springer International Publishing, Switzerland, 2015, 1st Edition.
2. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley & Sons, 2001, 1st Edition.

Reference Books:

1. Swarm Intelligence-From natural to Artificial Systems, Eric Bonabeau, Marco Dorigo and Guy Theraulaz, Oxford university Press, 1999.
2. Swarm Intelligence, James Kennedy and Russel E Eberheart, The Morgan Kaufmann Series in Evolutionary Computation, 2001.
3. Artificial Intelligence and Intelligent Systems, N P Padhy, Oxford University Press, 2005.

Online Resources:

1. https://www.youtube.com/playlist?list=PLJ5C_6qdAvBFqAYS0P9INAogIMklG8E-9
2. https://www.youtube.com/playlist?list=PL53BE265CE4A6C056

EE5265	Flexible AC Transmission Systems	3 – 0 –0: 3

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Understand the need for control of Real and Reactive power flows.
CO2	Identify the objectives of series and shunt compensation of power systems.
CO3	Analyze the performance of Series, Shunt and combined FACTS controllers
CO4	Evaluate the performance and stability of power systems with FACTS controllers

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: Introduction- Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers. Overview of power converters used in FACTS controllers.

Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, FC-TCR configurations, STATCOM, basic operating principle, control approaches and characteristics

Objectives of series compensator, variable impedance type of series compensators, switching converter type compensators, TCSC, TSSC- operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating

Static Phase Angle Regulators – power flow control by phase angle regulator and improvement of transient stability.

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Control structure of UPFC, Interline power flow controller.

Learning Resources:

Text Books:

1. Flexible AC Transmission Systems (FACTS), Yong Hua Song & Allan T Johns, IEE power and energy series, 2008.
2. Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems, Narain G.Honorani, Laszlo Gyugyi, Wiley-IEEE Press, 1999.

Reference Books:

1. Facts Controllers in Power Transmission and Distribution, K.R. Padiyar, New Age International Publishers, 2016.
2. Thyristor- Based FACTS controllers for electrical transmission systems, R. Mohan Mathur and Rajiv K. Varma, IEEE Press, 2002.

Online Resources:

1. https://www.youtube.com/playlist?list=PLLy_2iUCG87AVyRAN4QwVQrC8vSg1vWa6

2. https://nptel.ac.in/courses/108/107/108107114/

EE6147	Comprehensive Viva-voce	2 Credits

Pre-requisites: Both I & II Semester course work of I year.

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Assimilate knowledge of different courses studied.
CO2	Develop overall comprehension about power electronics and drives area.
CO3	Analyze real life Power Electronics and Drives engineering problems with theoretical knowledge learned.
CO4	Interpret and Articulate solutions to real life Electrical engineering problems in general and Power Electronics and Drives problems in particular.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	2	0
CO2	3	0	2	0	2	0
CO3	3	0	3	0	2	0
CO4	3	0	3	0	2	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: Entire course of study (All the required courses studied) up to II Semester of I Year

Learning Resources:

1. Reading Material of all the courses.
2. Case Studies/Industrial training reports
3. Mini projects taken up.

EE6149	DISSERTATION PART – A	12 Credits

Pre-requisites: Both I & II Semester course work of I year.

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Define Research Problem Statement.
CO2	Critically evaluate literature in chosen area of research & establish scope of work.
CO3	Develop a detailed study methodology.
CO4	Carryout pilot theoretical study/experiment

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	2
CO2	3	2	2	2	2	2
CO3	3	2	3	3	2	2
CO4	3	2	3	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no prescribed syllabus. Students are required to search, collect, and review various research articles published in chosen area of research. A student must select a topic for his / her dissertation, based on his/her interest and the available facilities at the commencement of dissertation work. Students are required to submit a dissertation report on the research work carried out by him/her.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE6199	DISSERTATION PART – B	20 Credits

Pre-requisites: Both I & II Semester course work of I year, Dissertation Part -A.

Course Outcomes (COs): At the end of the course, student will be able to

CO1	Expand on the defined Research Problem statement
CO2	Formulate the objectives and plan experimental / theoretical study
CO3	Conduct Laboratory/analytical studies
CO4	Analyze Data, develop models and offer solutions

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	2
CO2	3	2	2	2	2	2
CO3	3	2	3	3	2	2
CO4	3	2	3	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: There is no prescribed syllabus. Students are required to search, collect, and review various research articles published in chosen area of research. A student must select a topic for his / her dissertation, based on his/her interest and the available facilities at the commencement of dissertation work. Students are required to submit a dissertation report on the research work carried out by him/her.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

NOTE: Refer to the following link for the guidelines to prepare dissertation report:
https://www.nitw.ac.in/path/?dept=/nitwForms