MASTER OF TECHNOLOGY

POWER ELECTRONICS

CURRICULUM

EFFECTIVE FROM
2024-2025 ONWARDS

DEPARTMENT OF
ELECTRICAL AND ELECTRONICS ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI-620015

Master of Technology

(Power Electronics)

CURRICULUM

(Effective from 2024 - 25 Onwards)

DEPARTMENT OF
ELECTRICAL AND ELECTRONICS ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015, INDIA

VISION OF THE INSTITUTE

To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.

To create a converging learning environment to serve a dynamically evolving society.

To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.

To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

To be a centre of excellence in Electrical Energy Systems.

MISSION OF THE DEPARTMENT

Empowering students and professionals with state-of-art knowledge and Technological skills.

Enabling Industries to adopt effective solutions in Energy areas through research and consultancy.

Evolving appropriate sustainable technologies for rural needs.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

The major objectives of the M.Tech. Programme in Power Electronics are to equip the students with adequate knowledge and skills in Power Electronics Engineering and to prepare them for the following career options:

PEO1	Research programmes in power electronics and related areas
PEO2	Employment in R & D organisations related to sustainable technologies
PEO3	To work in power electronic circuit design and fabrication industries
PEO4	Faculty positions in reputed institutions

PROGRAMME OUTCOMES

A student who has undergone M.Tech. Programme in Power Electronics (PE) will have the following:

PO1	An ability to independently carry out research/investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

CURRICULUM STRUCTURE

M.Tech. (POWER ELECTRONICS)

Components	No. of Courses	No. of Credits
Programme Core (PC)	3/semester (6/year)	42
Programme Elective (PE)	3/semester (6/year)	
Essential Laboratory Requirements (ELR)	3/year	6
Internship / Industrial Training / Academic Attachment (I/A)	1	2
Open Elective (OE) / Online Course (OC)*	2	6
Project Phase-I	1	12
Project Phase-II	1	12
Total Credits		**80**

* Open Elective (OE) / Online Course (OC) can be completed between I – IV semester

CURRICULUM

The total minimum credits for completing the M.Tech. Programme in Power Electronics is **80**.

SEMESTER I

Sl. No.	Code	Course of Study	Credit
1	MA603	Advanced Engineering Mathematics	4
2	EE651	Power Converters	4
3	EE653	Linear and Non-Linear System Theory	4
4		Programme Elective I	3
5		Programme Elective II	3
6		Programme Elective III / Online (NPTEL)	3
7	EE657	Design and Simulation of Power Electronic Circuit Laboratory	2
8	EE659	Power Electronics Systems Laboratory	2
		Total	**25**

SEMESTER II

Sl. No.	Code	Course of Study	Credit
1	EE652	Switched Mode Power Conversion	4
2	EE654	Power Electronic Drives	4
3	EE656	Industrial Control Electronics	4
4		Programme Elective IV	3
5		Programme Elective V	3
6		Programme Elective VI / Online (NPTEL)	3
7	EE658	Power Converters and Drives Laboratory	2
		Total	**23**

SUMMER TERM (Evaluation in the III semester)

Code	Course of Study	Credit
EE713	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	**2**

SEMESTER III

Code	Course of Study	Credit
EE709	Project Work - Phase I	12
	Total	**12**

SEMESTER IV

Code	Course of Study	Credit
EE710	Project Work - Phase II	12
	Total	

OPEN ELECTIVES

(Open Elective (OE) / Online Course (OC) can be completed between I – IV semester)

Code	Course of Study	Credit
	Open Elective I	3
	Open Elective II	3
	Total	**6**

LIST OF OPEN ELECTIVES

Sl. No.	Code	Course Title	Credit
1	EE687	Electric and Hybrid Vehicles	3
2	EE712	Home Energy Management Systems	3

Note:

- Department will give the list of recommended online courses for PE and OE in every session.
- Students shall opt the online courses from the list of recommended courses by any department of the institute as open elective.
- **MICROCREDITS (MC)** (Students can opt 3 courses of 1 credit (4 weeks) each as microcredits instead of 1 OE/OC)

LIST OF PROGRAMME ELECTIVES

Sl. No.	Course Code	Course Title	Credit
1.	EE661	Flexible AC Transmission System	3
2.	EE662	High Voltage DC Transmission	3
3.	EE664	Advanced Digital Signal Processing	3
4.	EE665	Advanced Digital System Design	3
5.	EE667	Neural Networks and Deep Learning	3
6.	EE668	Digital Controllers in Power Electronics Applications	3
7.	EE669	Computer Networking	3
8.	EE670	Electrical Distribution Systems	3
9.	EE671	Fuzzy Logic Control Systems	3
10.	EE672	Transient Over Voltages in Power Systems	3
11.	EE673	Renewable Power Generation Technologies	3
12.	EE674	Power System Planning and Reliability	3
13.	EE675	Modeling and Analysis of Electrical Machines	3
14.	EE676	Power Quality	3
15.	EE677	Power System Restructuring and Pricing	3
16.	EE678	Computer Relaying and Wide Area Measurement Systems	3
17.	EE680	Smart Grid Technologies	3
18.	EE681	Electrical Systems in Wind Energy	3
19.	EE684	Distributed Generation and Micro-Grids	3
20.	EE685	Control Design Techniques for Power Electronic Systems	3
21.	EE688	Principles of VLSI Design	3
22.	EE689	Advanced Topics in Power Electronics Applications	3
23.	EE690	Design Techniques for SMPS	3
24.	EE691	Energy Storage Systems	3
25.	EE692	Digital Simulation of Power Electronic Systems	3
26.	EE693	PWM Converters and Applications	3
27.	EE695	Digital Control Systems	3
28.	EE696	Power System Automation	3
29.	EE698	Grid Converters for Renewable Energy Applications	3
30.	EE699	Topics in Power Electronics and Distributed Generation	3
31.	EE700	Wireless Sensor Networks and Applications	3
32.	EE701	Soft Switching Power Converters	3
33.	EE702	Solar PV Systems	3
34.	EE703	E-Vehicle Technology and Mobility	3
35.	EE704	Design of Embedded Controllers for Smart Micro-Grid	3
36.	EE705	Design of Magnetics for Power Electronic Applications	3

37.	EE706	Power Management Integrated Circuits	3
38.	EE708	Electric Vehicle Charging Systems	3

Course Code & Name	**MA603 Advanced Engineering Mathematics**		
Course Type	**Core**	**No of Credits**	**4**
Course Learning Objective (CLO)	• To learn essential optimization techniques for applying day to day problems. • To learn the numerical techniques to solve ordinary differential equations. • To learn the fundamentals of probability & statistical methods to apply in practical problems.		
Prerequisites	-		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Apply appropriate optimization technique and analyze unconstrained one dimensional problems.	1	-	-
CO2	Apply appropriate optimization technique and analyse unconstrained multi-dimensional problems.	1	-	-
CO3	Appraise and evaluate constrained optimization problems related to Power Systems/Power Electronics by appropriate methods.	1	-	-
CO4	Solve ordinary differential equations numerically.	1	-	-
CO5	Demonstrate applications of probability theory	2	-	-

(Correlation levels 1, 2 or 3 as defined below: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) , "-" for no correlation)

Course Content:

Introduction to Linear Programming Techniques- Unconstrained one dimensional optimization techniques - Necessary and sufficient conditions – Unrestricted search methods - Fibonacci and Golden section method.

Unconstrained n dimensional optimization techniques –Descent methods - Steepest descent, conjugate gradient. Constrained optimization Techniques - Necessary and sufficient conditions – Equality and inequality constraints - Kuhn-Tucker conditions - Gradient projection method

Numerical Solution of Ordinary Differential Equations- Euler's method - Euler's modified method - Taylor's method and Runge-Kutta method for simultaneous equations and 2nd order equations - Multistep methods - Milne's and Adams' methods.

Random variable – two dimensional random variables – standard probability distributions – Binomial Poisson and normal distributions - moment generating function.

Sampling distributions – confidence interval estimation of population parameters – testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test – curve fitting-method of least squares.

Reference Books:

1. Rao,S.S., 'Optimization :Theory and Application', Wiley Eastern Press, 2nd edition 1984.
2. Taha, H.A., 'Operations Research –An Introduction', Prentice Hall of India,2003.
3. Jain, M.K., Iyengar, S.R., and Jain, R.K., 'Numerical Methods for Scientific and Engineering Computation', Wiley Eastern, 1992.
4. S. C. Gupta, Fundamentals of Statistics, Himalaya Publishing House, Seventh Revised Edition, 2009.
5. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, Eleventh Revised Edition.

Course Code & Name	EE651 Power Converters		
Course Type	Core	No of Credits	4
Course Learning Objective (CLO)	To give a systematic approach for transient and steady state analysis of all power electronic converters with passive and active loads.		
Prerequisites	Power Electronics in UG		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Study and analyze transient response of basic power electronic circuits	3	2	3
CO2	Understand the working of various power converters.	3	2	3
CO3	Analyze and design various power converter systems.	3	3	3

Course Content:

Analysis of power semiconductor switched circuits with R, L, RL, RC loads, DC motor load, battery charging circuit.

Single-Phase and Three-Phase AC to DC converters-half controlled configurations- operating domains of three phase full converters and semi-converters – Reactive power considerations

Analysis and design of DC to DC converters- Control of DC-DC converters, Buck converters, Boost converters, Buck-Boost converters, Cuk converters

Single phase and Three phase inverters, Voltage source and Current source inverters, Voltage control and harmonic minimization in inverters

AC to AC power conversion using voltage regulators, choppers and cyclo-converters, consideration of harmonics, introduction to Matrix converters

Reference Books:

1. Ned Mohan, Undeland and Robbin, ‘Power Electronics: converters, Application and design’, John Wiley and sons. Inc, New York, 2006.
2. Rashid M.H., ‘Power Electronics-Circuits, Devices and Applications‘, Prentice Hall India, New Delhi, 2009.
3. P.C Sen., ‘Modern Power Electronics’, Wheeler publishing Company, 1st Edition, New Delhi, 2005.

Course Code & Name	EE653 Linear and Non-Linear System Theory				
Course Type	Core	No of Credits	4		
Course Learning Objective (CLO)	The main objective of this course is to understand the fundamental of physical systems in terms of its linear and nonlinear models. Exploit the properties of linear systems such as controllability and observability				
Prerequisites	Basic Control, Linear Algebra				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand and model physical systems using state vectors	2	3	2
CO2	Analyze the stability of linear systems.	3	2	3
CO3	Design state feedback controllers and observers.	2	2	2
CO4	Understand and analyze non-linear systems using linear approximations.	3	3	3
CO5	Inspect the stability of non-linear systems by direct and indirect methods	3	1	3

Course Content:

Introduction to state space modeling, modeling of physical systems. Solution to vector differential equations and state transition matrix.

Stability analysis of linear systems. Controllability and Observability definitions and Kalman rank conditions. Detectability and Stabilizability, Kalman decomposition.

State feedback controller design using pole placement. Observer design using Kalman filter algorithm. LQR and LQG controller design

Introduction to nonlinear systems. Phase plane analysis of nonlinear system using linear approximation. Limit cycle and periodic solutions. Singular points (equilibrium points) and qualitative behavior near singular points.

Stability of nonlinear systems. Lyapunov direct and indirect methods. Input-to-state stability and relative stability

Reference Books:

1. Ogata, K., ‘Modern Control Engineering’, Prentice Hall of India, 2010.
2. C.T. Chen, ‘Linear Systems Theory and Design’’ Oxford University Press, 3rd Edition, 1999.
3. M. Vidyasagar, ‘Nonlinear Systems Analysis’, 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey 07632.
4. Hassan K. Khalil, ‘Nonlinear Systems’, Pearson Educational International Inc. Upper Saddle River, 3rd Edition.

Course Code & Name	EE657 Design and Simulation of Power Electronic Circuits Laboratory		
Course Type	**Laboratory**	**No of Credits**	**2**
Course Learning Objective (CLO)	The experiments will be conducted based on the following criteria. From the requirement of the load, the ratings of components such as power devices, L and C are identified using standard steady state equations. The performance is verified through simulations in relevant software and the design can be validated.		
Prerequisites	Basics of Power Electronics		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	**PO2**	**PO3**
CO1	Design of conventional power electronic converters such as AC-DC, DC-DC, DC-AC, AC-AC converters.	2	2	2
CO2	Steady state analysis of various power electronic converters	2	2	2
CO3	Simulation, testing and applications of various power electronic converters.	2	2	2

Course Content:

1) Single-phase and three-phase half-controlled rectifiers
2) Single-phase and three-phase fully-controlled rectifiers
3) Buck, Boost and Buck-Boost converters
4) Single-phase and three-phase Voltage-source inverters
5) Single-phase and three-phase Current-source inverters
6) Single-phase and three-phase AC voltage regulators

Course Code & Name	EE659 Power Electronics Systems Laboratory		
Course Type	**Laboratory**	**No of Credits**	**2**
Course Learning Objective (CLO)	To enhance the hardware concepts for the elements of Power Electronic System		
Prerequisites	Basics of Power Electronics		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Understand the switching characteristic of Power Electronics Switches	3	2	2
CO2	Develop the various elements of Power Electronic Systems	3	2	3
CO3	Test and Evaluate the Power Electronic Converters	3	3	3

Course Content:

1. Study and analysis of generic Power Electronic Converter
2. Analyse the switching characteristics of Power Electronic Devices
3. Design of high frequency inductor/transformer for Power Electronic applications
4. Design of MOSFET/IGBT gate drivers
5. Introduction to programming with digital controllers
6. PWM Generation using Digital Controller- Part 1
7. PWM Generation using Digital Controller-Part 2
8. Test and verification of Power Electronic Converter
9. Mini-Project

Course Code & Name	EE652 Switched Mode Power Conversion				
Course Type	Core	No of Credits		4	
Course Learning Objective (CLO)	Understand the concepts, operation, analysis, control and magnetics design of switched- mode power converters				
Prerequisites	Power Converters				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the concepts and operation of switched mode power converters	3	2	3
CO2	Develop steady state analysis and design of switched mode power converters	3	3	3
CO3	Model and design of control techniques for switched mode power converters	3	3	3
CO4	Apply concepts of SMPC in case studies	3	3	3

Course Content:

Design constraints of reactive elements in Power Electronic Systems: Design of inductor, transformer and capacitors for power electronic applications, filter design

Basic concepts and steady-state analysis of second and higher order Switched Mode power converters: PWM DC - DC Converters (CCM and DCM) - operating principles, constituent elements, characteristics, comparisons and selection criteria

Dynamic Modelling and control of second and higher order switched Mode power converters: analysis of converter transfer functions, Design of feedback compensators, current programmed, frequency programmed and critical conduction mode control

Soft-switching DC - DC Converters: zero-voltage-switching converters, zero-current- switching converters, Multi-resonant converters and Load resonant converters

Pulse Width Modulated Rectifiers: Properties of ideal rectifier, realization of near ideal rectifier, control of the current waveform, single phase and three-phase converter systems incorporating ideal rectifiers and design examples

Reference Books:

1. Robert W. Erickson and Dragan Maksimovic, ‘Fundamentals of Power Electronics’, Springer, 2nd Edition, 2001.
2. Marian K. Kazimierczuk, ‘Pulse-width Modulated DC-DC Power Converters’ John Wiley & Sons Ltd., 1st Edition, 2008.
3. Batarseh, ‘Power Electronic Circuits’, John Wiley, 2nd Edition, 2004.
4. H. W. Whittington, B. W. Flynn, D. E. Macpherson, ‘Switched Mode Power Supplies’, John Wiley & Sons Inc., 2nd Edition, 1997
5. Simon Ang, Alejandro Oliva “Power-Switching Converters”,3rd edition, CRC Press, 2010.
6. Abraham Pressman, Keith Billings and Taylor Morey “Switching Power Supply Design”, 3rd Ed., McGraw-Hill Professional, 2009.

Course Code & Name	EE654 Power Electronic Drives		
Course Type	Core	No of Credits	4
Course Learning Objective (CLO)	To introduce basic concepts of load and drive interaction, speed control concepts of ac and dc drives, speed reversal, regenerative braking aspects, design methodology.		
Prerequisites	A course in Power Electronics and Electrical Machines.		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand and analyze dc and ac motors supplied from different power converters.	3	3	2
CO2	Simulate and study motor characteristics with different converter configurations.	3	3	3
CO3	Design and implement a prototype drive system.	3	3	3

Course Content:

Basic power electronic drive system, components. Different types of loads, shaft-load coupling systems. Stability of power electronic drive.

Conventional methods of DC motor speed control, single phase and three phase converter fed DC motor drive. Power factor improvement techniques, four quadrant operation.

Chopper fed drives, input filter design. Braking and speed reversal of DC motor drives using choppers, multiphase choppers. PV fed DC drives.

Conventional methods of induction motor speed control. Solid state controllers for Stator voltage control, soft starting of induction motors, Rotor side speed control of wound rotor induction motors. Voltage source and Current source inverter fed induction motor drives – d-q axis modeling and vector control.

Speed control of synchronous motors, field-oriented control, load commutated inverter drives, switched reluctance motors and permanent magnet motor drives. Introduction to design aspects of machines.

Reference Books:

1. P.C Sen, ‘Thyristor DC Drives’, John Wiley and Sons, New York, 1991.
2. R. Krishnan, ‘Electric Motor Drives – Modeling, Analysis and Control’, Prentice-Hall of India Pvt. Ltd., New Delhi, 2003.
3. Bimal K .Bose, ‘Modern Power Electronics and AC Drives’, Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2003.

Course Code & Name	EE656 Industrial Control Electronics		
Course Type	Core	No of Credits	4
Course Learning Objective (CLO)	• Comprehend various control electronics used in the industries. • Know and appreciate the key factors in design of analog and digital controllers. • Implement power electronic circuits for practical applications		
Prerequisites	Fundamental knowledge about Analog, Digital and Power Electronic Circuits.		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the working of various power electronic circuits and components used in industrial applications	2	2	3
CO2	Analyze various analog controllers and signal conditioning circuits	2	2	3
CO3	Design control circuits for industrial applications	3	3	3

Course Content:

Review of uninterrupted power supplies - offline and on-line topologies - analysis of UPS topologies, solid state circuit breakers and solid-state tap changing of transformer - advance energy storage systems, battery, ultra-capacitors, flywheel energy storage, fuel cells characteristics and applications.

Overview of sensors in industrial applications – current sensors, current transformer, hall effect sensors - voltage sensors, non-isolated measurement, hall effect, temperature sensors, thermal protection of power components – speed sensors – position sensors.

Analog controllers - proportional controllers, proportional – integral controllers, PID controllers, derivative overrun, integral windup, cascaded control, feed forward control. Signal conditioners - instrumentation amplifiers – voltage to current, current to voltage, voltage to frequency, frequency to voltage converters

Solid state welding power source - introduction, classification, basic characteristics, volt ampere relationship and its measurements, control of volt ampere characteristics, volt control, slope control and dual control– pulsing techniques – testing of welding power source. Introduction to heating, classification, characteristics – applications

Introduction to programmable logic controllers, architecture, programming. Supervisory control and data acquisition (SCADA) Systems, components of SCADA systems, SCADA basic functions, SCADA application functions in electrical engineering. Energy saving in electrical drive systems.

Reference Books:

1. Michael Jacob, 'Industrial Control Electronics – Applications and Design', Prentice Hall, 1995.
2. Thomas E. Kissell, 'Industrial Electronics', Prentice Hall India, 2003 2. Curtis D. Jhonson 'Process Control Instrumentation technology' Pearson New International Eighth edition,2014
3. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi 'Modern Electric, Hybrid Electric and Fuel Cell Vehicles Fundamentals, Theory and Design' CRC Press 2004.
4. Mini S. Thomas, John D McDonald, Power Systems SCADA and Smart Grid, CRC Press, Taylor and Francis.
5. Welding Handbook, Volume-2, Seventh Edition, American Welding Society.
6. Power Electronics Applied to Industrial Systems and Transports. Volume 5: Measurement Circuits, Safeguards and Energy Storage, Imprint - ISTE Press – Elsevier.

Course Code & Name	EE658 Power Converters and Drives Laboratory		
Course Type	Laboratory	No of Credits	2
Course Learning Objective (CLO)	To facilitate in-depth understanding of power converter topologies and its operation with typical electric machines		
Prerequisites	Power Electronics, Electric Drives		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	design and simulate various power converter topologies	3	3	2
CO2	implement control techniques for electric drive systems	3	3	3
CO3	fabricate and test power converters	3	3	3

Course Content:

List of Experiments:

1. Simulation of a power factor corrected (PFC) AC-DC converter
2. Simulation of isolated DC-DC converters
3. Simulation of a vector-controlled induction motor
4. Simulation of a direct torque-controlled induction motor
5. Gate pulse generation using FPGA/DSP controller and gate driver design for MOSFET
6. Experimental study on a permanent magnet brushless dc machine
7. Experimental study on a permanent magnet synchronous machine
8. Design and hardware implementation of a DC-DC converter
9. Design and hardware implementation of an AC-AC matrix converter
10. Experimentation on a switched reluctance motor drive

Reference Books:

1. R. Krishnan, 'Electric Motor Drives – Modeling, Analysis and Control', Prentice-Hall of India Pvt. Ltd., New Delhi, 2003
2. Ali Emadi, "Handbook of Automotive Power Electronics and Motor Drives", Taylor & Francis, 2005
3. Bimal K. Bose, 'Modern Power Electronics and AC Drives', Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2003
4. Robert W. Erickson and Dragan Maksimovic, 'Fundamentals of Power Electronics', Springer, 2nd Edition, 2001
5. Ned Mohan, Undeland and Robbin, 'Power Electronics: Converters, Application and Design', John Wiley and sons. Inc, New York, 2006.

Course Code & Name	**EE661 Flexible AC Transmission System**		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	To familiarize students with the transmission challenges of modern electrical power systems. The course will present the basic concepts, principles and operation of fast high power electronic controllers known as Flexible AC Transmission Systems (FACTS) that enhance power system stability and effectively increase transmission capacity thus yielding significantly higher flexibility of operation. The course will focus on concepts and applications various configurations of FACTS controllers. Both thyristor based and also voltage source converters based FACTS Controllers are discussed		
Prerequisites	Power System Analysis, Power Conversion Techniques or equivalent		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Describe the principles of series/ shunt reactive power compensation to enhance the power flows in conventional power systems	1	2	1
CO2	Explain the mechanism of performance enhancement of a transmission system network with the implementation of a typical FACTS controller for series/ shunt reactive compensation	2	2	2
CO3	Analyse the modes of operation and compute the performance of different topologies of series and shunt connected FACTS controllers	2	2	3
CO4	Explain the capability of different types of FACTS controllers with reference to exchange of active and reactive power with the power system network	2	2	3

Course Content:

Fundamentals of ac power transmission - transmission problems and needs - emergence of FACTS - FACTS control considerations - FACTS controllers

Principles of shunt compensation – Variable Impedance type & switching converter type - Static Synchronous Compensator (STATCOM) configuration - characteristics and control

Principles of static series compensation using GCSC, TCSC and TSSC – applications - Static Synchronous Series Compensator (SSSC)

Principles of operation - Steady state model and characteristics of a static voltage regulators and phase shifters - power circuit configurations

UPFC - Principles of operation and characteristics - independent active and reactive power flow control - comparison of UPFC with the controlled series compensators and phase shifters.

Reference Books:

1. Song, Y.H. and Allan T. Johns, ‘Flexible AC Transmission Systems (FACTS)’, Institution of Electrical Engineers Press, London, 1999.
2. Hingorani ,L. Gyugyi, ‘Concepts and Technology of Flexible AC Transmission System’, IEEE Press New York, 2000 ISBN –078033 4588.
3. Mohan Mathur R. and Rajiv K. Varma , ‘Thyristor - based FACTS controllers for Electrical transmission systems’, IEEE press, Wiley Inter science , 2002.
4. Padiyar K.R., ‘FACTS controllers for Transmission and Distribution systems’ New Age International Publishers, 1st Edition, 2007.
5. Enrique Acha, Claudio R. Fuerte-Esqivel, Hugo Ambriz-Perez, Cesar Angeles-Camacho ‘FACTS –Modeling and simulation in Power Networks’ John Wiley & Sons, 2002.

Course Code & Name	EE662 High Voltage DC Transmission		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To facilitate the students understand the basic concepts and recent trends in HVDC transmission system and its applications.		
Prerequisites	Basic knowledge in Circuit Analysis, Control Systems, Power System and Power Electronic Devices and Circuits.		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Appraise the need of HVDC technology for bulk power transmission and choose appropriate type of HVDC link and converter.	2	2	3
CO2	Analyse the operation of Graetz circuit as rectifier and inverter without and with overlap	2	2	3
CO3	Evaluate the operation and efficacy of different controllers and analyse the different faults in HVDC systems	3	3	3
CO4	Discriminate and evaluate the issues related with harmonics, reactive power control and protection of HVDC system.	3	3	3
CO5	Recognize and appraise the recent trends in HVDC transmission systems	3	3	3

Course Content:

Introduction to HVDC transmission, Comparison between HVAC and HVDC systems - economic, technical and reliability, limitations, Types of HVDC links - monopolar, bipolar and homopolar links, Components of HVDC transmission system

Analysis of HVDC Converters, Rectifier and Inverter operation of Graetz circuit without and with overlap. Output voltage waveforms and DC voltage in both rectifier and inverter operation, Equivalent circuit of HVDC link.

Basic means of HVDC system control, desired features, power reversal, Basic controllers - constant ignition angle, constant current and constant extinction/ advance angle control, power control, high level controllers. Converter maloperations - misfire, arc through, commutation failure

Harmonics in HVDC system - Characteristic and uncharacteristic harmonics - troubles due to harmonics – harmonic filters - active and passive filters - Reactive power control of converters, Protection issues in HVDC, over voltage and over current protection, voltage and current oscillations, DC reactor design, DC Circuit breakers

Recent trends in HVDC transmission-CCC based HVDC system, VSC based HVDC system– Multi-terminal HVDC systems and HVDC system applications in wind power generation, Interaction between AC and DC systems

Reference Books:

1. Kimbark, E.W., ‘Direct Current Transmission-vol.1’, Wiley Inter science, New York, 1971.
2. Padiyar, K.R., ‘HVDC transmission systems’, Wiley Eastern Ltd., 2010.
3. Kamakshaiah, S and Kamaraju, V, ‘HVDC Transmission’, 1st Edition, Tata McGraw Hill Education (India), New Delhi 2011.
4. Arrilaga, J., ‘High Voltage Direct Current Transmission’, 2nd Edition, Institution of Engineering and Technology, London, 1998.
5. Vijay K. Sood, ‘HVDC and FACTS Controllers’, Kluwer Academic Publishers, New York, 2004.

Course Code & Name	**EE664 Advanced Digital Signal Processing**				
Course Type	**Elective**	**No of Credits**	**3**		
Course Learning Objective (CLO)	• Review and understanding of discrete-time systems and signals, Discrete-Time Fourier Transform and its properties, the Fast Fourier Transform. • Design of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, implementation of digital filters				
Prerequisites	Familiarity with Signals and Systems and Scientific Programming Language				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Understand the basics of discrete-time signals, systems and Z-Transforms	2	2	2
CO2	Perform discrete-time Fourier Transform and discrete Fourier Transform	3	2	2
CO3	Design and analyse digital filters.	3	3	2
CO4	Understand the multirate DSP systems	2	3	3
CO5	Analyse the power spectrum estimation	2	3	3

Course Content:

Review of Discrete-Time Signal & LTI Systems: Convolution, System representation in Z-Transform domain, Inverse Z-Transform, System characterization in Z-domain.

Fourier Transforms: Discrete Fourier Transform, FFT Algorithm, Radix-2 DIT & Radix-2 DIF Structures, Higher Radix schemes.

Filter Design and Filter Structures: Classification of digital filters, design and implementation of IIR filters, design of FIR filters

Sampling and Multirate DSP: Aliasing, Quantization, Decimation, Interpolation, Arbitrary sampling rate conversion.

Power Spectrum Estimation: Introduction to Non-parametric and parametric methods, Eigen analysis Algorithms

Reference Books:

1. John G. Proakis and Dimitris G. Hanolakis, ‘Digital Signal Processing, Principles, Algorithms & Applications’ 4th Edition, Pearson Education, 2006.
2. Oppenheim and Schaffer, ‘Discrete time Signal processing’, Pearson Education, 2007.
3. Sanjit K Mitra: Digital Signal Processing, Third Edition, Tata McGraw Hill Edition- 2006.
4. Ludemann L. C., ‘Fundamentals of Digital Signal Processing’, Harper and Row publications,2009.
5. P.P. Vaidyanathan: Multirate Systems and Filter Banks, Pearson Education India 2006.

Course Code & Name	EE665 Advanced Digital System Design				
Course Type	Elective	No of Credits	3		
Course Learning Objective (CLO)	To impart the knowledge on the advanced topics of Digital systems, design aspects and testing of the circuits.				
Prerequisites	Digital Electronics				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the concepts of synchronous sequential circuits	2	2	2
CO2	Formulate the state tables and ASM charts for digital system	3	3	3
CO3	Design circuits using programmable logic devices	3	2	2
CO4	Identify faults in the digital circuits.	3	3	3
CO5	Analyse and synthesize asynchronous sequential circuits.	3	3	3

Course Content:

Review of sequential circuits - Mealy & Moore Models - Analysis & Synthesis of Synchronous sequential circuits

Digital system design Hierarchy - ASM charts - Hardware description language - Control logic Design Reduction of state tables - State Assignments

Analysis and synthesis of Asynchronous sequential circuits - critical and non-critical races - Essential Hazard

Combinational and sequential circuit design with PLD's - Introduction to CPLD's & FPGA's.

Fault classes and models – Stuck at faults, Bridging faults - Transition and Intermittent faults. Fault Diagnosis of combination circuits by conventional methods - Path sensitization technique - Boolean different method and Kohavi algorithm

Reference Books:

1. Donald D. Givone, 'Digital principles and design', Tata McGraw-Hill, 2003.
2. Morris Mano, 'Digital Design', Prentice Hall India, 3rd Edition, 2007. 3. Samuel C. Lee, 'Digital circuits and logic design', Prentice Hall India, 1984.
3. N. N. Biswas, 'Logic Design Theory', Prentice Hall India, 1993.
4. ZviKohavi, 'Switching and Finite Automata Theory', Tata McGraw-Hill, 3rd Edition, 2010.

Course Code & Name	**EE667 Neural Networks and Deep Learning**				
Course Type	**Elective**	**No of Credits**		**3**	
Course Learning Objective (CLO)	To apply artificial neural networks and deep learning in various engineering applications				
Prerequisites	Introduction to Electrical and Electronics Engineering, Basic Mathematics and Probability				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Understand the fundamentals of neural networks.	3	2	2
CO2	Apply neural networks for various applications	3	3	3
CO3	Employ deep learning to various applications to improve the decision outcomes for both 1D and 2D data.	3	3	3

Course Content:

Biological Neural networks, Artificial neural Networks – Classifications, McColloch Pitt's neuron, Linear Separability- XOR problem, Types of Learning – Supervised/unsupervised-Hebb rule- Delta rule-Perceptron rule- Adaline and Madaline neural networks

Back propagation neural networks, Kohonen neural network, Maxnet, Hamming net, Bidirectional Associative Memory, Applications

ART architecture – Comparison layer – Recognition layer – ART classification process – ART implementation, Boltzmann Machine, Applications

Recurrent Neural Networks: Hopfield networks, Jordan networks, Elman networks, regular RNN-limitations, Long Short-Term Memory, Gated Recurrent Unit, Deep Belief Network, Autoencoders, Applications

Convolutional Neural networks-2 Dimensional CNN- LeNet, AlexNet, ZF-Net, VGGNet, GoogLeNet, ResNet -1 Dimensional CNN- 3 Dimensional CNN-

Ensemble methods: Bagging and Boosting. transfer learning, Applications

Reference Books:

1. Martin T. Hagan , Howard B.Demuth, M, and Mark H. Beale 'Neural network design', Vikas Publishing House, 2003.
2. Laurene Fausett, "Fundamentals of Neural. Networks: Architectures, Algorithms, and. Applications" , Prentice-. Hall, 1994.
3. Ian Goodfellow and Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press, 2016. J.
4. Neural Networks and Deep Learning, Charu C Aggarwal, Second Edition, Springer Publisher, 2023.
5. Dr. Neeraj Kumar and Dr. Rajkumar, Applied Deep Learning, BPB Publishers, 2023.

Course Code & Name	EE668 Digital Controllers in Power Electronics Applications				
Course Type	Elective	No of Credits	3		
Course Learning Objective (CLO)	To enrich the learner with digital controller concepts and its application in the field of Power Electronic Systems				
Prerequisites	Digital Electronics, Digital Signal Processing, Computer Architecture.				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the architecture of DSP core and its functionalities	2	3	2
CO2	Explain the operation of interrupts and peripherals	2	3	2
CO3	Explore the aspects of hardware implementation using PLDs and FPGAs.	3	3	3
CO4	Design of controllers for power converters.	3	3	3

Course Content:

Introduction to the C2xx DSP core and code generation - The components of the C2xx DSP core -Mapping external devices to the C2xx core - peripherals and Peripheral Interface - System configuration registers - Memory - Types of Physical Memory - Memory Addressing Modes - Assembly Programming using C2xx DSP - Instruction Set - Software Tools

Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software.

ADC Overview - Operation of the ADC in the DSP - Overview of the Event manager (EV) - Event Manage interrupts - General Purpose (GP) Timers - Compare Units - Capture Units and Quadrature Enclosed Pulse (QEP) Circuitry - General Event Manager Information

Code composer studio, Embedded Coding through MATLAB and other modern simulation tools, PWM Generation, Dead band unit, Phase shifted PWM for full bridge converters, PWM for interleaved converters.

Controlled Rectifier - Switched Mode Power Converters - PWM Inverters - DC motor control – Induction, Motor Control.

Reference Books:

1. Hamid.A.Toliyat and Steven G.Campbell, ‘DSP Based Electromechanical Motion Control’ CRC Press New York , 2004.
2. XC 3000 series datasheets (version 3.1). Xilinx, Inc., USA, 1998.
3. XC 4000 series datasheets (version 1.6). Xilinx, Inc., USA, 1999.
4. Wayne Wolf, ‘FPGA based system design’, Prentice hall, 2004.
5. Dragan Maksimovic, Luca Corradini, Paolo Mattavelli, Regan Zane ‘Digital Control of High-Frequency Switched-Mode Power Converters’ Wiley-IEEE Press, 2015.

Course Code & Name	EE669 Computer Networking				
Course Type	Elective	No of Credits	3		
Course Learning Objective (CLO)	This course provides an introduction to the computer networking fundamentals, design issues, functions and protocols of the network architecture				
Prerequisites	Data Structures and Communication Systems.				

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the different layers of the network architecture models and their functions	2	2	2
CO2	Appraise the need of various protocols across different layers	2	2	2
CO3	Suggest a particular routing protocol and congestion technique for an application	3	2	2

Course Content:

Computer Network – Hardware and Software, OSI and TCP reference Model, Transmission media, Wireless transmission, public switched telephone network - Structure, multiplexing and switching.

Data link layer - design issues, Data link protocols. Medium access sub layer - channel allocations, Multiple Access protocols, IEEE protocols.

Network layer - Design issues, routing algorithms, congestion control algorithms, QoS , Transport layer- Design issues, Connection management .

Application layer – DNs, Electronic mail, World Wide Web, multimedia, Cryptography.

Internet transport protocols - TCP and UDP.

Reference Books:

1. James F. Kurose and Keith W. Ross, ‘Computer Networking’, Pearson Education, 2nd Edition, 2003.
2. Tanenbaum, A.S., 'Computer Networks', Prentice Hall of India, 4th Edition, 2003.
3. Stallings W., 'Data and Computer Communication', Prentice Hall of India, 5th Edition, 2000.

<table>
<tr><td>Course Code & Name</td><td colspan="5">EE670 Electrical Distribution Systems</td></tr>
<tr><td>Course Type</td><td>Elective</td><td colspan="2">No of Credits</td><td colspan="2">3</td></tr>
<tr><td>Course Learning Objective (CLO)</td><td colspan="5">• To explain the principles of design and operation of electric distribution feeders and other components
• To make the students to understand the distribution system expansion planning and reliability analysis procedures</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Transmission and Distribution of Electrical Energy, Power System Analysis</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">CO-PO Matrix</td></tr>
<tr><td rowspan="2">Course Outcomes (COs)</td><td rowspan="2">Upon completion of the course, the students will be able to</td><td colspan="4">Aligned Programme Outcomes (POs)</td></tr>
<tr><td>PO1</td><td colspan="2">PO2</td><td>PO3</td></tr>
<tr><td>CO1</td><td>Perform modeling and power flow studies in the distribution systems.</td><td>2</td><td colspan="2">3</td><td>2</td></tr>
<tr><td>CO2</td><td>Carry out planning and reliability analysis of electrical distribution systems</td><td>2</td><td colspan="2">2</td><td>3</td></tr>
<tr><td>CO3</td><td>Select the protective components for distribution systems</td><td>2</td><td colspan="2">2</td><td>2</td></tr>
</table>

Course Content:

Industrial and commercial distribution systems – Energy losses in distribution system – system ground for safety and protection – comparison of O/H lines and underground cable system. Network model – power flow - short circuit and loss calculations.

Distribution system - reliability analysis – reliability concepts – Markov model – distribution network reliability – reliability performance

Distribution system expansion - planning – load characteristics – load forecasting – design concepts – optimal location of substation – design of radial lines – solution technique.

Voltage control – Application of shunt capacitance for loss reduction – Harmonics in the system – static VAR systems – loss reduction and voltage improvement.

System protection and grounding – requirement – fuses and section analyzers-over current - Under voltage and under frequency protection – coordination of protective device

Reference Books:

1. Pabla, A.S., ‘Electrical Power Distribution System’, 5th edition, Tata McGraw hill, 2011.
2. Tuvar Goner, ‘Electrical Power Distribution System Engineering’, McGraw hill, 2008.
3. Sterling, M.J.H., ‘Power System Control’, Peter Peregrinus, 1986.

Course Code & Name	**EE671 Fuzzy Logic Control Systems**		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	To learn fuzzy logic concepts To apply Fuzzy logic principles towards control system design of non-linear plants and model-free systems.		
Prerequisites	Control Systems		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Assimilate the uncertainty concept	3	1	3
CO2	Apply and analyze fuzzy logic theory for linear systems.	3	2	3
CO3	Develop fuzzy logic theory for non-linear plants and engineering applications.	2	3	2

Course Content:

Review of control systems, Modelling of systems, Non-linear plants, Concept of uncertainty, Various forms of ambiguity.

Review of crisp sets. Concept of a Fuzzy set, commonly employed Fuzzy sets. Fuzzy set operations-Union, Intersection, Complement- illustration with case studies.

Review of feedback control systems and controller design aspects. Architecture of Fuzzy logic controller. Fuzzification, Rule base design, Implication and Defuzzification methods.

Fuzzy logic controller design through experts- Direct and Indirect methods. Fuzzy set design through iterative approach. Adaptive Fuzzy control schemes. Fuzzy logic controller design through dynamic response analysis.

Fuzzy decision making, Fuzzy genetic algorithms, Neuro Fuzzy systems, Fuzzy controller based washing machine, Fuzzy logic control of DC motor speed control.

Text Books:

1. Chen G, Pham T, “Introduction to Fuzzy sets, Fuzzy logic, and Fuzzy control systems”, CRC Press, 2019
2. D. Driankov, H. Hellendoorn, M.Reinfrank, “An Introduction to Fuzzy control”, Springer, 2013 (Second Edition)
3. Timothy J. Ross, Fuzzy Logic with Engineering Applications, John Wiley & Sons Ltd Publications, 4^{th} edition, 2016.
4. Sundareswaran K,"A Learner's Guide to Fuzzy Logic Systems" (Second edition), CRC Press, 2019.

Reference Books:

1. Satish Kumar, Neural Networks: A classroom approach, Tata McGraw-Hill Publishing Company Limited, 2013
2. Zdenko Kovacic, Stjepan Bogdan, “Fuzzy Controller Design: Theory and Applications”, CRC Press, 2017

Course Code & Name	**EE672 Transient Over Voltages in Power Systems**		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	To make the students familiar with the theoretical basis for various forms of over voltages such as lighting strokes, surges, switching transients etc., and to introduce some of the protection measures against such over voltages are described. Also to depict the necessity and methods for generating impulse voltages and currents.		
Prerequisites	Advanced Power System Analysis		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Recognize and construct different circuits representing lightning and travelling waves	2	2	3
CO2	Analyze various switching transients in power systems.	2	2	3
CO3	Appraise voltage surges in different electrical machines.	2	3	3
CO4	Understand basic protection of machines, stations and lines.	2	3	3
CO5	Appreciate methods of generating and measuring A.C. and D.C., impulse voltages.	2	3	3

Course Content:

Transients in electric power systems – Internal and external causes of over voltages -– Lightning strokes – Mathematical model to represent lightning, Travelling waves in transmission lines – Circuits with distributed constants – Wave equations – Reflection and refraction of travelling waves – Travelling waves at different line terminations.

Switching transients – double frequency transients – abnormal switching transients – Transients in switching a three-phase reactor - three phase capacitor

Voltage distribution in transformer winding – voltage surges-transformers – generators and motors Transient parameter values for transformers, reactors, generators and transmission lines

Basic ideas about protection – surge diverters-surge absorbers - protection of lines and stations Modern lighting arrestors - Insulation coordination - Protection of alternators and industrial drive systems

Generation of high AC and DC-impulse voltages, currents - measurement using sphere gaps-peak voltmeters - potential dividers and CRO

Reference Books:

1. Allen Greenwood, ‘Electrical transients in power systems’, Wiley Interscience, 1991.
2. Bewley, L.V., ‘Travelling waves on Transmission systems’, Dover publications, New York, 1963.
3. Gallaghar, P.J. and Pearman, A.J., 'High voltage measurement, Testing and Design', John Wiley and sons, New York, 2001.

Course Code & Name	EE673 Renewable Power Generation Technologies		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	This course makes the student • to aware of various forms of renewable energy • to understand in detail the wind energy conversion system and photovoltaic conversion system		
Prerequisites	Basic Electronics and Machines, Power Electronics		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Appraise the need and possibility of extracting solar energy and converting into electrical energy using PV cell.	2	2	3
CO2	Design and analyze stand-alone and grid connected PV system.	3	3	3
CO3	Describe the dynamics of wind turbine and electrical generator.	3	2	2
CO4	Select and design suitable configuration of the wind energy conversion system based on application.	3	3	3
CO5	Design and analyze hybrid energy systems.	2	2	3

Course Content:

Sun and Earth-Basic Characteristics of solar radiation-angle of sunrays on solar collector-Photovoltaic cell-characteristics-equivalent circuit-Photovoltaic modules and arrays

PV Systems - Design of PV systems-Standalone system with DC and AC loads with and without battery storage-Grid connected PV systems-Maximum Power Point Tracking

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

Wind turbine generator systems - fixed speed induction generator-performance analysis-semi variable speed induction generator-variable speed induction generators with full and partial rated power converter topologies -isolated systems-self excited induction generator- permanent magnet alternator performance analysis

Hybrid energy systems - wind-diesel system-wind - PV system-micro hydro-PV system – biomass PV-diesel system-geothermal-tidal and OTEC systems

Reference Books:

1. Chetan Singh Solanki, 'Solar Photovoltaics -Fundamentals, Technologies and Applications', PHI Learning Pvt. Ltd., New Delhi, 2011
2. Van Overstraeton and Mertens R.P., 'Physics, Technology and use of Photovoltaics', Adam Hilger, Bristol,1996.
3. John F.Walker & Jenkins. N , 'Wind energy Technology', John Wiley and sons, Chichester, UK, 1997.
4. Freries LL ,'Wind Energy Conversion Systems', Prentice Hall, U.K., 1990 .

Course Code & Name	EE674 Power System Planning and Reliability				
Course Type	**Elective**	**No of Credits**		**3**	
Course Learning Objective (CLO)	To acquire skills in planning and building reliable power system				
Prerequisites	Power system analysis, Power system transmission and distribution, Matrices, Probability and Calculus				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Explain the characteristics of loads, concepts of load forecasting and its types for power system planning.	3	3	3
CO2	Comprehend the significance of reliability in power system, various methods and tools used for reliability analysis	3	3	3
CO3	Describe the concepts of reliability in generation and transmission system, and system interconnection.	3	3	3
CO4	Discriminate the different modes of system failure and to explain various approaches to assess power system failure	3	3	3

Course Content:

Objectives of planning – Long and short term planning - Load forecasting – characteristics of loads – methodology of forecasting – energy forecasting – peak demand forecasting – total forecasting – annual and monthly peak demand forecasting.

Reliability concepts – exponential distributions – meantime to failure – series and parallel system – MARKOV process – recursive technique. Generator system reliability analysis – probability models for generators unit and loads – reliability analysis of isolated and interconnected system – generator system cost analysis – corporate model – energy transfer and off peak loading

Transmission system reliability model analysis – average interruption rate - LOLP method - frequency and duration method

Two plant single load system - two plant two load system - load forecasting uncertainly interconnections benefits

Introduction to system modes of failure – the loss of load approach – frequency & duration approach – spare value assessment – multiple bridge equivalents

Reference Books:

1. Sullivan, R.L., ‘Power System Planning’, Heber Hill, 1987.
2. Roy Billington, ‘Power System Reliability Evaluation’, Gordan& Breach Scain Publishers,1990.
3. Eodrenyi, J., ‘Reliability modelling in Electric Power System’ John Wiley, 1980.

<table>
<tr><th>Course Code & Name</th><th colspan="6">EE675 Modeling and Analysis of Electrical Machines</th></tr>
<tr><td>Course Type</td><td>Elective</td><td>No of Credits</td><td colspan="4">3</td></tr>
<tr><td>Course Learning Objective (CLO)</td><td colspan="6">To give a systematic approach for modeling and analysis of all rotating machines under both transient and steady state conditions.</td></tr>
<tr><td>Prerequisites</td><td colspan="6">Electromagnetic Field Theory, Vector Algebra and Fundamentals of all Electrical Rotating Machines</td></tr>
<tr><td colspan="7"></td></tr>
<tr><th colspan="7">CO-PO Matrix</th></tr>
<tr><th rowspan="2">Course Outcomes (COs)</th><th rowspan="2" colspan="3">Upon completion of the course, the students will be able to</th><th colspan="3">Aligned Programme Outcomes (POs)</th></tr>
<tr><th>PO1</th><th>PO2</th><th>PO3</th></tr>
<tr><td>CO1</td><td colspan="3">Analyze the operation of rotating machines.</td><td>2</td><td>1</td><td>2</td></tr>
<tr><td>CO2</td><td colspan="3">Construct machine models based on different reference frames.</td><td>3</td><td>2</td><td>3</td></tr>
<tr><td>CO3</td><td colspan="3">Analyze and synthesize equivalent circuit parameters for synchronous and asynchronous machines.</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>CO4</td><td colspan="3">Understand and analyze special machines.</td><td>3</td><td>3</td><td>3</td></tr>
</table>

Course Content:

Principles of Electromagnetic Energy Conversion, General expression of stored magnetic energy, co-energy and force/torque, example using single and doubly excited system.

Basic Concepts of Rotating Machines-Calculation of air gap mmf and per phase machine inductance using physical machine data; Voltage and torque equation of dc machine.

Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form; Application of reference frame theory to three phase symmetrical induction and synchronous machines, dynamic direct and quadrature axis model in arbitrarily rotating reference frames.

Determination of Synchronous Machine Dynamic Equivalent Circuit Parameters, Analysis and dynamic modeling of two-phase asymmetrical induction machine and single phase induction machine.

Special Machines - Permanent magnet synchronous machine: Surface permanent magnet (square and sinusoidal back emf type) and interior permanent magnet machines. Construction and operating principle, dynamic modeling and self-controlled operation; Analysis of Switch Reluctance Motors

Reference Books:

1. Charles Kingsley,Jr., A.E. Fitzgerald, Stephen D.Umans, 'Electric Machinery', Tata McgrawHill, 5th Edition, 1992.
2. R. Krishnan, 'Electric Motor & Drives: Modeling, Analysis and Control', Prentice Hall ofIndia, 2nd Edition, 2001.
3. Miller, T.J.E., 'Brushless Permanent Magnet and Reluctance Motor Drives', Clarendon Press, 1st Edition, 1989

Course Code & Name	EE676 Power Quality		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	• Understand the various power quality phenomenon, their origin, impact and monitoring methods. • Equip the necessary skills to handle power quality problems.		
Prerequisites	Power Systems, Signals and Systems.		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand different types of power quality problems with their source of generation.	2	3	2
CO2	Interpret and analyse the results of power quality monitoring equipment.	3	3	2
CO3	Develop different methodologies for detection and classification of power quality problems.	3	3	3
CO4	Interpret and analyse the results of power quality monitoring equipment	3	3	3

Course Content:

Electric power quality phenomena: Introduction to power quality, IEEE and IEC - EMC standards, overview, sources and impact of power quality disturbances – RMS voltage variations, interruptions, voltage fluctuation, transients, waveform distortion and power frequency variations.

Harmonics: Harmonic sources, measurement of harmonic distortion, current and voltage limits of distortion, harmonic analysis using Fourier transform, effects of harmonic distortion and harmonic filters

Power definitions: Instantaneous power and other power definitions for single-phase system under sinusoidal and non-sinusoidal conditions, three-phase balanced and unbalanced systems under sinusoidal and non-sinusoidal conditions

Power Quality Monitoring: importance and introduction to power quality monitoring, overview of power quality disturbance classification, signal processing of disturbances, power quality indices estimation, case studies.

Custom Power Devices: Introduction to shunt and series compensators, DSTATCOM, Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC) – case studies.

Reference Books:

1. Dugan R. C., Mc Granaghan M. F. Surya Santoso, and Beaty H. W., 'Electrical Power System Quality', McGraw-Hill 2003.
2. Bollen, M. H. J., 'Understanding Power Quality Problems; Voltage sags and interruptions', IEEE Press, New York, 2000.
3. Mishra, Mahesh Kumar, 'Power Quality in Power Distribution Systems Concepts and Applications', CRC Press, Taylor & Francis, New York, 2024.
4. Ghosh, Arindam, and Gerard Ledwich, 'Power quality enhancement using custom power devices' Springer Science & Business Media, 2012.
5. Arrillaga, J., Watson, N. R., Chen, S., 'Power System Quality Assessment', Wiley, New York, 2011.

<table>
<tr><td>Course Code & Name</td><td colspan="5">EE677 Power System Restructuring and Pricing</td></tr>
<tr><td>Course Type</td><td>Elective</td><td colspan="2">No of Credits</td><td colspan="2">3</td></tr>
<tr><td>Course Learning Objective (CLO)</td><td colspan="5">To understand the electricity power business and technical issues in a restructured power system in both Indian and world scenario.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Power system Analysis, Power system Transmission and distribution.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">CO-PO Matrix</td></tr>
<tr><td rowspan="2">Course Outcomes (COs)</td><td rowspan="2">Upon completion of the course, the students will be able to</td><td colspan="4">Aligned Programme Outcomes (POs)</td></tr>
<tr><td colspan="2">PO1</td><td>PO2</td><td>PO3</td></tr>
<tr><td>CO1</td><td>Explain the deregulated electricity market models functioning around the world.</td><td colspan="2">3</td><td>2</td><td>3</td></tr>
<tr><td>CO2</td><td>Understand the operational and planning activities in power generation</td><td colspan="2">3</td><td>2</td><td>3</td></tr>
<tr><td>CO3</td><td>Analyse various transmission pricing schemes</td><td colspan="2">3</td><td>3</td><td>3</td></tr>
<tr><td>CO4</td><td>Study the development of competition in electricity distribution companies.</td><td colspan="2">3</td><td>3</td><td>3</td></tr>
<tr><td>CO5</td><td>Outline the salient features of Indian Electricity Act and operation of Indian power exchanges.</td><td colspan="2">3</td><td>2</td><td>3</td></tr>
</table>

Course Content:

Introduction – Market Models – Entities – Key issues in regulated and deregulated power markets; Market equilibrium- Market clearing price- Electricity markets around the world.

Operational and planning activities of a Genco - Electricity Pricing and Forecasting -Price Based Unit Commitment Design - Security Constrained Unit Commitment design. - Ancillary Services for Restructuring- Automatic Generation Control (AGC).

Introduction-Components of restructured system-Transmission pricing in Open-access system-Open transmission system operation; Congestion management in Open-access transmission systems- FACTS in congestion management - Open-access Coordination Strategies; Power Wheeling-Transmission Cost Allocation Methods

Open Access Distribution - Changes in Distribution Operations- The Development of Competition – Maintaining Distribution Planning

Power Market Development – Electricity Act, 2003 - Key issues and solution; Developing power exchanges suited to the Indian market - Challenges and synergies in the use of IT in power-Competition- Indian power market- Indian energy exchange- Indian power exchange-Infrastructure model for power exchanges- Congestion Management-Day Ahead Market- Online power trading

Reference Books:

1. Loi Lei Lai, 'Power System Restructuring and Deregulation', John Wiley & Sons Ltd., 2001.
2. Mohammad Shahidehpour, Hatim Yamin, 'Market operations in Electric power systems', John Wiley & son ltd., 2002.
3. Lorrin Philipson, H. Lee Willis, 'Understanding Electric Utilities and Deregulation' Taylor & Francis, 2006.
4. Steven Stoft , 'Power System Economics: Designing Markets for Electricity', Wiley-IEEE Press,2002.
5. Daniel S.Kirschen, Goran Strbac,'Fundamentals of power System Economics,Wiley,2018.
6. Mohammad Shahidehpour, Muwaffaq Alomoush, 'Restructured Electrical Power Systems', Marcel Dekker, Inc., 2001.

Course Code & Name	EE678 Computer Relaying and Wide Area Measurement Systems		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	The goal of this course is to provide basic knowledge on computer relaying and its applications in wide area measurement systems. The internal architecture and algorithms employed in a numerical relays will be discussed. Understanding about wide area measurement systems, mathematical background for relaying algorithms and also examining line relaying algorithms for protection of power system components		
Prerequisites	Digital Signal Processing, Power System Protection		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Demonstrate knowledge of fundamental aspects of the theories, principles and practice of computer relaying	3	3	3
CO2	Understand the application of numerical relay to power system equipment protection	3	3	3
CO3	Understand and design wide area measurement systems application in Smart grid	3	3	3

Course Content:

Introduction to DSP, Use of computer relay, Analog to Digital Converters, Sampling, Anti – aliasing filters. Evolution of power system relaying from electromagnetic to static to computer relaying; Relay operating principles for computer relaying; Expected benefits of computer relaying, Computer relay architecture.

Three zone protection of transmission line, algorithms for impedance calculations- Mann-Morrison algorithm - Three sample technique - Two sample technique - First and second derivative algorithms - Numerical integration methods.

Problems associated with differential protection of transformer and bus-bar, magnetic inrush current, LSQ algorithm, Fourier analysis of transformer protection.

Introduction to Phasor measurement units (PMUS), global positioning system (GPS), Functional requirements of PMUs and PDCs, phasor estimation of nominal frequency inputs

Wide Area Measurement Systems (WAMS), WAMS Applications in Smart Grid, WAMS Based Protection Concepts, Adaptive Relaying, State estimation.

Reference Books:

1. John G. Prokis and Dimitris G. Hanolakis, 'Digital Signal Processing, Principles, Algorithms & Applications' 4th Edition, Pearson Education, 2006.
2. A.G. Phadke, J.S. Thorp, 'Computer Relaying for Power Systems', John Wiley and Sons Ltd., Research Studies Press Limited, 2nd Edition, 2009.
3. A.G. Phadke, J.S. Thorp, 'Synchronized Phasor Measurements and Their Applications', Springer Publications, 2008.

Course Code & Name	**EE680 Smart Grid Technologies**		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	• to understand the need and concept of Smart Grid. • to study different EMS and DMS functions and smart meters. • to get familiarized with the communication networks for Smart Grid applications		
Prerequisites	Fundamentals of Power Distribution Systems .		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the EMS and DMS functionalities, AMI, and smart energy resources.	2	3	3
CO2	Analyze the operation of modern power distribution system with prosumers and EV owners.	3	3	3
CO3	Evaluate suitable information and communication technologies for smart grid applications.	2	3	3

Course Content:

Introduction - Evolution of Electric Grid, Smart Grid Concept - Definitions and Need for Smart Grid – Functions – Opportunities – Benefits and challenges, Difference between conventional & Smart Grid, Technology Drivers.

Energy Management System (EMS) - Substation Automation - Feeder Automation – Protocols, Wide area monitoring protection and control - Smart integration of renewable energy resources — Energy Storage, Distribution Management System (DMS) – Network Reconfiguration, Outage management System, Customer Information System - Application of Geographical Information System.

Introduction to Smart Meters – Advanced Metering infrastructure (AMI), AMI protocols – Standards and initiatives, Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.

P2G paradigm – feed-in-tariff-net metering, P2P energy trading – community energy management – market operations – pricing mechanism, Plug in Hybrid Electric Vehicles – G2V – V2G – effect of grid interaction of electric vehicles – energy management.

Elements of communication and networking – architectures, standards, PLC, Zigbee, GSM, BPL, Local Area Network (LAN) – HAN, NAN, FAN - Wide Area Network (WAN) – Protocols-STTP Protocol, Modbus Protocol, IEEE 2030.5. Basics of CLOUD Computing – Basics of Blockchain - Cyber Security for Smart Grid.

Reference Books:

1. Stuart Borlase ‘Smart Grid: Infrastructure, Technology and Solutions’, CRC Press 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, ‘Smart Grid: Technology and Applications’, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, ‘Power System SCADA and Smart Grids’, CRC Press, 2015
4. Kenneth C. Budka, Jayant G. Deshpande, Marina Thottan, ‘Communication Networks for Smart Grids’, Springer, 2014.
5. Wayes Tushar, Chau Yuen, Tapan K. Saha, Thomas Morstyn, Archie C. Chapman, M. Jan E. Alam, Sarmad Hanif, H. Vincent Poor, “Peer-to-peer energy systems for connected communities: A review of recent advances and emerging challenges,” Applied Energy, Volume 282, Part A, 2021. https://doi.org/10.1016/j.apenergy.2020.116131

Course Code & Name	EE681 Electrical Systems in Wind Energy		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To introduce the various electrical generators and appropriate power electronic controllers employed in wind energy systems. To teach the students the steady-state analysis and operation of different existing configurations of electrical systems in wind energy and also the recent developments taking place in this field.		
Prerequisites	Electrical Machines and Power Electronics.		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the operation of electrical generators used in wind energy systems	2	2	2
CO2	Analyse the steady-state performance of the wind energy conversion systems	2	2	2
CO3	Design closed-loop controllers for specific applications	3	3	3

Course Content:

Principle of operation – steady-state analysis-characteristics of GCIGs- operation of GCIGs with different power electronic configurations.

Process of self-excitation – steady-state equivalent circuit of SEIG and its analysis - performance equations - widening the operating speed-range of SEIGs by changing the stator winding connection with suitable solid state switching schemes - power electronic controllers used in standalone systems.

Need for single-phase operation –typical configurations for the single-phase operation of three-phase GCIGs and SEIGs –stead state equivalent circuit and analysis using symmetrical components.

Different operating modes- steady-state equivalent circuit- performance analysis- DFIG for standalone applications- operation of DFIGs with different power electronic configurations for standalone and grid connected operation

Operation of PMSGs- steady-state analysis- performance characteristics- operation of PMSGs with different power electronic configurations for standalone and grid-connected operation.

Reference Books:

1. Marcelo Godoy Simões and Felix A. Farret, ‘Renewable Energy Systems: Design and Analysis with Induction Generators’, CRC Press, ISBN 0849320313, 2004.
2. Ion Boldea, ‘Variable speed Generators’, CRC Press, ISBN 0849357152, 2006.
3. S.N. Bhadra, D.Kastha and S.Banerje, ‘Wind Electrical Systems’, Oxford University Press, 2005.
4. Siegfried Heier, Rachel Waddington, ‘Grid Integration of Wind Energy Conversion Systems, 2nd Edition’, Wiley, June 2006, ISBN: 978-0-470-86899-7.
5. Freries LL , ‘Wind Energy Conversion Systems’, Prentice Hall, U.K., 1990.

Course Code & Name	EE684 Distributed Generation and Micro-Grids		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	• To understand the planning and operational issues related to Distributed Generation • To understand various configurations of Microgrids		
Prerequisites	The students are preferred to have a basic knowledge in Power System Analysis and Distribution Systems		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the current scenario and need for the implementation of DGs.	3	2	3
CO2	Investigate the types of interfaces and control schemes for the grid integration of DGs	3	3	3
CO3	Evaluate the technical and economic impacts of DGs	3	3	3
CO4	Understand different configurations of microgrid and its modeling.	3	3	2

Course Content:

Need for Distributed generation, renewable sources in distributed generation, current scenario in Distributed Generation, Planning of DGs – Siting and sizing of DGs – optimal placement of DG sources in distribution systems.

Grid integration of DGs – Different types of interfaces - Inverter based DGs and rotating machine based interfaces - Aggregation of multiple DG units. Energy storage elements: Batteries, ultra-capacitors, flywheels Technical impacts of DGs – Transmission systems, Distribution systems, De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems

Introduction to micro-grids – Types of micro-grids – autonomous and non-autonomous grids – Sizing of micro-grids- modeling & analysis- Micro-grids with multiple DGs – Micro- grids with power electronic interfacing units. Transients in micro-grids - Protection of micro-grids – Case studies

Economic and control aspects of DGs –Market facts, issues and challenges - Limitations of DGs. Voltage control techniques, Reactive power control, Harmonics, Power quality issues. Reliability of DG based systems – Steady-state and Dynamic analysis.

Reference Books:

1. H. Lee Willis, Walter G. Scott ,'Distributed Power Generation – Planning and Evaluation', Marcel Decker Press, 2000.
2. M.GodoySimoes, Felix A.Farret, 'Renewable Energy Systems – Design and Analysis with Induction Generators', CRC press.
3. Robert Lasseter, Paolo Piagi, ' Micro-grid: A Conceptual Solution', PESC 2004, June 2004.
4. F. Katiraei, M.R. Iravani, 'Transients of a Micro-Grid System with Multiple Distributed Energy Resources', International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005.
5. Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson 'Facility Microgrids', Subcontract report, May 2005, General Electric Global Research Center, Niskayuna, New York.

Course Code & Name	EE685 Control Design Techniques for Power Electronic Systems		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	The main objective of this course is to study the application of modern control theory to power electronic converters and drives		
Prerequisites	Classical Control, Systems Theory, Power Converters		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Recognize different control techniques and design of compensators, controllers and observers	2	1	2
CO2	Model and analyze various closed loop controllers	1	2	3
CO3	Design controllers for different rectifiers and to analyze various modes of operation	2	1	3
CO4	Model and design of various controllers for BLDC and Reluctance motors.	2	3	3

Course Content:

Review of basic control theory – control design techniques such as P, PI,PID and lead lag compensator design. Review of state space control design approach – state feedback controller and observer design.

Control of DC-DC converters. State space modeling of Buck, Buck-Boost, Cuk, Sepic, Zeta Converters. Equilibrium analysis and closed loop voltage regulations using state feedback controllers and sliding mode controllers

Control of rectifiers. State space modeling of single phase and three phase rectifiers. State feedback controllers and observer design for output voltage regulation for nonlinear loads. Analysis of continuous and discontinuous mode of operation.

Modelling of Brushless DC motors and its speed regulations – State space model, sensor less speed control of BLDC motor and Sliding mode control design for BLDC motor. Modelling and control of switched reluctance motor

Modeling of multi input DC-DC converters and its application to renewable energy. Output voltage regulation of Multi input DC-DC converter using state feedback controllers.

Reference Books:

1. Sira -Ramirez, R. Silva Ortigoza, 'Control Design Techniques in Power Electronics Devices', Springer, 2006.
2. Siew-Chong Tan, Yuk-Ming Lai, Chi Kong Tse, 'Sliding mode control of switching Power Converters', CRC Press, 2011.
3. Bimal Bose, 'Power electronics and motor drives', Elsevier, 2006.
4. Ion Boldea and S.A Nasar, 'Electric drives', CRC Press, 2005.

Course Code & Name	EE687 Electric and Hybrid Vehicles				
Course Type	**Open Elective**	**No of Credits**	**3**		
Course Learning Objective (CLO)	This course introduces the fundamental concepts, principles, analysis and design of hybrid and electric vehicles.				
Prerequisites	Power Conversion Techniques, Electrical Machines				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Understand mathematical models, performance and characteristics of hybrid and electric vehicles.	2	2	2
CO2	Analyze the concepts, topologies and power flow control of electric traction systems	2	2	3
CO3	Appraise the configuration and control of various hybrid electric motor drives.	2	2	3
CO4	Plan and design appropriate vehicle management system.	3	3	3

Course Content:

History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.

Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. Basic concepts of electric traction, introduction to various electric drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Introduction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems.

Introduction to energy management strategies used in hybrid and electric vehicle, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy strategies.

Reference Books:

1. Bimal Bose, 'Power electronics and motor drives', Elsevier, 2006.
2. Ion Boldea and S.A Nasar, 'Electric drives', CRC Press, 2005.
3. C.C. Chan and K.T. Chau, "Modern electric Vehicle Technology", Oxford University Press,2001.
4. Ali Emadi, "Advanced Electric Drive Vehicles", CRC Press, Taylor and Francis ,2014.
5. Mehrdad Ehsani, Yimin Gao, Sebastien E.Gay, Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles fundamentals, theory and design", CRC Press, Taylor and Francis, 2010.

Course Code & Name	EE688 Principles of VLSI Design		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	Enables the student to get exposure on low power electronic system design and its application		
Prerequisites	Digital Electronics, Electronic Circuits		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the concepts and characteristics of MOS devices.	3	3	3
CO2	Model the system using Hardware Description languages.	3	3	3
CO3	Design the CMOS logic circuits and memory units.	3	3	2
CO4	Acquire knowledge on PLDS.	3	3	2
CO5	Appraise the possibilities of ASIC design.	3	3	3

Course Content:

MOS and Fabrication: VLSI technology- NMOS, CMOS and BICMOS circuit fabrication. Comparison of IC technologies. Operation characteristics, design equations, models and second order effects of MOS transistors, Fabrication of resistors and capacitors. Latch up, Driver circuits.

Hardware Description languages: VHDL- Modeling styles –Design of simple/ complex circuits using VHDL. Overview of Verilog HDL -Design of simple circuits using Verilog HDL.

CMOS Logic Circuits: Implementation of logic circuits using MOS and CMOS, Pass transistor and transmission gates ,design of combinational and sequential circuits – memory design.

Programmable Devices: Simple and Complex Programmable logic devices (SPLD and CPLDs), Field Programmable Gate Arrays (FPGAs), Internal components of FPGA, Case study: A CPLD and a 10 million gates type of FPGA.

ASIC: Types of ASICs-Design flow-Programmable ASICs-Programmable ASIC logic cells and interconnect for Xilinx and Altera families.

Reference Books:

1. Neil Weste, David Harris, 'CMOS VLSI Design: A Circuits and Systems Perspective', Addison-Wesley, 4th Edition,2010
2. M. J. Smith, 'Application Specific Integrated Circuits', Addison Wesley, 1997.
3. Uyemura, 'Introduction to VLSI Circuits and Systems', Wiley, 2002.
4. J. Bhaskar, 'A Verilog HDL Primer', Star Galaxy, 2nd Edition, 2000.

Course Code & Name	EE689 Advanced Topics in Power Electronics				
Course Type	Elective	No of Credits	3		
Course Learning Objective (CLO)	To give an introduction to the recent developments of power electronics from components, topology, control techniques to thermal & EMC. This course drives on the application requirements of power electronics. This is a higher level of subject that will help to work in demanding areas of power electronics.				
Prerequisites	Power Electronics course in UG with knowledge on Basics of Semiconductor Switches, Basics of Converter Topology (AC-DC,AC-AC & DC-DC), Basic Control Techniques of Power Electronic Equipment, Basics of Reactive Elements, Storage and High Frequency Magnetic, Basics of EMC & any Power Simulation Environment.				

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the principles of operation of advanced Silicon devices	2	2	3
CO2	Appraise various advanced converter topologies and the suitable control schemes	3	3	3
CO3	Recognize recent developments in design aspects of reactive elements such as the material, the structure etc and the effect on performance	2	2	3
CO4	Understand nuances of advanced energy storage systems such as battery energy storage system (BESS), ultra-capacitors, etc and strategies for power management in such systems	3	2	2
CO5	Distinguish between various possible solutions pertaining to thermal management and EMI/EMC problems and devise solutions for simple power electronic systems	3	3	3

Course Content:

Introduction to switches - Advanced Silicon devices - Silicon HV thyristors, MCT, BRT & EST. SiC devices - diodes, thyristors, JFETs & IGBTs. Gallium nitrate devices - Diodes, MoSFETs.

Advance converter topologies for PEE - Interleaved converters, Z-Source converters, Multi level converters (Cascaded H-Bridge, Diode clamped, NPC, Flying capacitor) Multi pulse PWM current source converters, Advanced drive control schemes.

Advances in reactive elements - Advanced magnetic material, technology and design (Powder ferrite, Amorphous, Planar designs) Advance capacitive designs (Multilayer chip capacitors, double layers for storage, Aluminum electrolytic)

Advance storage systems - Developments in battery systems, Ultra capacitors, Fly wheel energy storage, Hybrid storage systems for EV/HEV, Power management in hybrid systems, Energy storage in renewable.

Thermal engineering with EMI/EMC techniques - Advanced thermal solutions (fan cooled, liquid cooled, heat pipes, hybrid techniques) EMC techniques (Conducted, Radiated emissions & Susceptibility), System design for EMC.

Reference Books:

1. Andrzej M Trzynadlowski, ‘Introduction to Modern Power Electronics, John Wiley and sons. Inc, New York, 1998

2. R D Middle Brook& Slobodan CUK, 'Advances in Switched Mode Power Conversion', Vol I, II, & III, Tesla Co 1983
3. B. Jayant Balinga, 'Advanced High Voltage Power Device Concepts', Springer New York 2011. ISBN 978 -1- 4614-0268-8
4. BIN Wu, ' High Power Converters and AC Drives', IEEE press Wiley Interscience, a John wiley& sons Inc publication 2006
5. Wurth Electronics, 'Trilogy of Magnetics, Design guide for EMI filter design in SMPS & RF circuits', 4th extended and revised edition.

Course Code & Name	EE690 Design Techniques for SMPS		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To give a practical step by step approach for design and assembly of Power Supplies and apply the necessary recent technology to comply the standards and certification requirements.		
Prerequisites	Power Electronics course in UG with knowledge on Basics of semiconductors, Basics of Power Supplies-LPS & SMPS, Basic Topologies in SMPC, Control of Power Semiconductors, Basics of High Frequency Magnetic, Basics of EMC & any Power Simulation Environment.		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Choose various converter topologies and appropriate components	3	2	3
CO2	Design measurement, monitoring and control circuitry for Switched Mode Power Supplies	3	3	3
CO3	Evaluate thermal performance of SMPS units and design appropriate filters	3	3	3
CO4	Explore the standards and recent advancements related to SMPS	3	3	3
CO5	Analyze and simulate various converter topologies	3	3	3

Course Content:

Introduction of Available Sources& demanding loads: Sources-AC mains, Lab supplies, Batteries, Solar Cells Loads - Requirements of load, battery as load, Selection of Topology :Step-Up/Step-Down, Multiple outputs, Continuous & discontinuous modes of operation, Isolated converters, Various configurations of Converters, Selection of Components: Selection of Resistors, Chokes, Capacitors, Diodes, MOSFETs & IGBTs, Connectors, Design of Magnetics Fundamentals & ideal conditions, design of High frequency chokes & transformers, Selection of wire gauge, sealing of magnetic.

Guide to Instrumentation: Basics of measurements using DMM, Oscilloscope, Electronic loads, etc Design of Magnetics Fundamentals & ideal conditions, design of High frequency chokes & transformers, Selection of wire gauge, sealing of magnetics Design of Feedback circuits Basic control requirements, Current &voltage mode control fundamentals& system stability conditions Design of Control and Monitoring circuits Practical Control circuitry & Monitoring circuitry requirements.

Evaluations and Thermal management Performance evaluations of SMPS & thermal loss calculations and cooling options& packaging of converter EMI control requirements Overview of EMC, differentiating signal and noise, Layout concepts Low & High frequency filtering requirements, Optimal filter design Worst case analysis Introduction to datasheet reading, operation tuned to datasheet, typical worst-case analysis

Standards governing the power supplies IEC standards for Electrical &Environmental testing, certification standards, Ingress protection standards Recent trend in Power supplies Recent advancements in components, Recent advancements in topologies, Digital control of power supplies, Power Integration &its Low power applications.

Analysis and Simulation using PSIM:BUCK, BOOST&BUCK, BOOST, Typical discrete power factor corrector circuit.

Reference Books:

1. Ned Mohan , Undeland and Robbins, 'Power Electronics Converters, Applications and Design',2ndEdition, JohnWiley&sons,1995.
2. Abraham I. Pressman, Keith Billings, Taylor Morey,'SwitchingPowerSupplyDesign',3rd Edition, McGraw-Hill 2009.
3. L. Umanand and SR Bhat, 'Design of Magnetic Components for Switched Mode Power Converters', Wiley Eastern Limited.
4. International Standard, IEC 60571 Edition 2.12006-12.

Course Code & Name	EE691 Energy Storage Systems				
Course Type	Elective		No of Credits	3	
Course Learning Objective (CLO)	To emphasize basic physics, chemistry, and engineering issues of energy storage devices, such as batteries, thermoelectric convertors, fuel cells, super capacitors.				
Prerequisites	Fundamental Chemistry and Material Science				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Recognize various issues related to energy market, its growth and its structural implications in India.	2	2	3
CO2	Analyze the performance of different battery storage systems.	3	3	3
CO3	Employ different thermoelectric measurement techniques appropriately.	2	1	3
CO4	Interpret the applications of supercapacitors for appropriate storage systems.	2	2	3
CO5	Understand and differentiate different types of fuel cells.	3	2	3

Course Content:

Prospect for both traditional and renewable energy sources - detailed analysis of Indian energy market and future need through 2020 - energy, economic growth and the environment, implications of the Kyoto Protocol, and structural change in the electricity supply industry.

Batteries - performance, charging and discharging, storage density, energy density, and safety issues, classical batteries - Lead Acid, Nickel-Cadmium, Zinc Manganese dioxide, and modern batteries -Zinc-Air, Nickel Hydride, Lithium Battery.

Thermoelectric - electron conductor and phonon glass, classical thermoelectric materials (i) four-probe resistivity measurement, Seebeck coefficient measurement, and thermal conductivity measurement.

Super capacitors - types of electrodes and some electrolytes, Electrode materials - high surface area activated carbons, metal oxide, and conducting polymers, Electrolyte - aqueous or organic, disadvantages and advantages of super capacitors - compared to battery systems, applications - transport vehicles, private vehicles, and consumer electronics - energy density, power density, price, and market.

Fuel cells - direct energy conversion - maximum intrinsic efficiency of an electrochemical converter, physical interpretation - carnot efficiency factor in electrochemical energy convertors, types of fuel cells - hydrogen oxygen cells, hydrogen air cell, alkaline fuel cell, and phosphoric fuel cell.

Energy converters for Battery and Fuel cells.

Reference Books:

1. Tetsuya Osaka, Madhav Datta, ‘Energy Storage Systems in Electronics’, Gordon and Breach Science Publishers, 2000.
2. R. M. Dell, D.A.J. Rand, ‘Understanding Batteries’, RSC Publications, 2001.
3. James Larminie, Andrew Dick, ‘Fuel Cell System Explained’, J. Wiley, 2003.
4. D.M. Rowe, ‘Thermo-electrics Handbook: Macro to Nano’, CRC Press, 2006.

Course Code & Name	EE 692 Digital Simulation of Power Electronic Systems		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To provide knowledge on modeling and simulation of power simulation circuits and systems		
Prerequisites	Knowledge in Power Electronics and machines		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	develop algorithm and software models for power electronics and drives applications	3	2	2
CO2	analyze the transient and steady state performance of the designed models.	3	2	2
CO3	choose suitable devices or models for appropriate applications.	2	2	2

Course Content:

Review of numerical methods. Application of numerical methods to solve transients in D.C. Switched R, L, RL, R-C and R-L-C circuits. Extension to AC circuits.

Modeling of diode in simulation. Diode with R, R-L, R-C and R-L-C load with ac supply. Modeling of SCR, TRIAC, IGBT and Power Transistors in simulation. Application of numerical methods to R, L, C circuits with power electronic switches. Simulation of gate/base drive circuits, simulation of snubber circuits.

State space modeling and simulation of linear systems. Introduction to electrical machine modeling: induction, DC, and synchronous machines, simulation of basic electric drives, stability aspects.

Simulation of single phase and three phase uncontrolled and controlled (SCR) rectifiers, converters with self commutated devices- simulation of power factor correction schemes, Simulation of converter fed dc motor drives ,Simulation of thyristor choppers with voltage, current and load commutation schemes, Simulation of chopper fed dc motor.

Simulation of single and three phase inverters with thyristors and self-commutated devices, Space vector representation, pulse-width modulation methods for voltage control, waveform control. Simulation of inverter fed induction motor drives.

Reference Books:

1. Simulink Reference Manual , Math works, USA.
2. Robert Ericson, ‘Fundamentals of Power Electronics’, Chapman & Hall, 1997.
3. Issa Batarseh, ‘Power Electronic Circuits’, John Wiley, 2004Simulink Reference Manual , Math works, USA.

Course Code & Name	EE693 PWM Converters and Applications		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	• To understand the concepts and basic operation of PWM converters, including basic circuit operation and design • To understand the steady-state and dynamic analysis of PWM converters along with the applications like solid state drives and power quality		
Prerequisites	Power Converters		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the basic operations of various PWM techniques for Power Converters.	2	3	3
CO2	Steady-State and transient modelling and analysis of power converters with various PWM techniques.	3	3	3
CO3	Analysis and Design of Control Loops for PWM power converters along with the applications like solid state drives and power quality	3	3	3

Course Content:

AC/DC and DC/AC power conversion, overview of applications of voltage source converters, pulse modulation techniques for bridge converters, Multilevel Inverter – diode clamped inverter – flying capacitor inverter.

Bus clamping PWM and advanced bus clamping PWM, space vector based PWM, advanced PWM techniques, practical devices in converter; calculation of switching and conduction losses.

Compensation for dead time and DC voltage regulation; dynamic model of a PWM converter, multilevel converters; constant V/F induction motor drives.

Estimation of current ripple and torque ripple in inverter fed drives; line – side converters with power factor compensation.

Active power filtering, reactive power compensation; harmonic current compensation.

Reference Books:

1. Mohan, Undeland and Robbins, ‘Power Electronics; Converters, Applications and Design’, John Wiley and Sons, 1989.
2. Erickson R W, ‘Fundamentals of Power Electronics’, Chapman and Hall, 1997.
3. Vithyathil J, ‘Power Electronics: Principles and Applications‘, McGraw Hill, 1995

Course Code & Name	EE695 Digital Control Systems		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	This course gives an idea about designing digital controllers, which are feasible to implement in digital computers, using both classical and modern techniques.		
Prerequisites	Classical control, modern control		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the difference between continuous time controller and discrete time controllers	2	2	3
CO2	Design of digital controllers	2	3	3
CO3	Implementation based on various applications	2	3	3

Course Content:

Introduction to Discrete time systems - Analogies with continuous-time systems, mathematical models for LTI discrete-time systems, convolution representation and difference equations in advanced and delayed form, Z-transformation, analysis of first, second, and higher order systems, stability of discrete time systems, the Jury's criterion.

Modeling of Sampled Data Systems **-** Sampled Data System; Models of Continuous Time Systems; Naturally Occurring Discrete Time Systems; Discretization of Continuous Time Systems; Approaches to Controller Design and Testing.

Digital Signal Processing **-** Linear System-Basic Concepts, Basic Discrete Time Signals, Input–Output Convolution Models; Z-Transform-Motivation and Definition of Z-Transform, Z-Transform Theorems and Examples, Transfer Function , Inverse of Z-Transform; Frequency Domain Analysis-Basics, Fourier Series and Fourier Transforms, Sampling and Reconstruction, Filtering, Discrete Fourier Transform.

Transfer Function Approach to Controller Design - Structures and Specifications-Control Structures ,Proportional Control , Other Popular Controllers; Proportional, Integral, Derivative Controllers Discretization Techniques, Discretization of PID Controllers; Pole Placement Controllers-Pole Placement Controller with Performance Specifications, PID Tuning Through Pole Placement Control ,Special Cases of Pole Placement Control; Minimum Variance Control-Generalized Minimum Variance Controller; Model Predictive Control-Generalized Predictive Control; Linear Quadratic Gaussian Control.

State Space Approach to Controller Design - State Space Techniques in Controller Design-Pole Placement, Estimators, Regulator Design, Linear Quadratic Regulator, Kalman Filter.

Reference Books:

1. Digital Control, "Kannan M. Moudgalya", John Wiley & Sons, Ltd,2007
2. Ogata K., "Discrete-time Control Systems", 2nd Edition, Prentice Hall Inc., New Jersey, 1992.

Course Code & Name	EE696 Power System Automation		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To familiarize the students with the basics of Power System Automation, Building blocks, Supervisory Control and Data Acquisition(SCADA) System, Remote Terminal Units(RTU), Master Stations etc.		
Prerequisites	Basic Knowledge of Transmission & Distribution systems and Measuring Instruments		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the concepts of power system automation.	2	2	3
CO2	Understand the components of SCADA systems.	2	2	3
CO3	Comprehend the RTU, IED and other components of automation systems	3	2	3
CO4	Understand the transfer of signals from the field to an operator control terminal	3	2	3
CO5	Design an interoperable powers automation system.	3	2	3

Course Content:

Evolution of Automation systems, History of Power system Automation, Supervisory Control and Data Acquisition(SCADA) Systems, Components of SCADA systems, SCADA Applications, SCADA in power systems, SCADA basic functions, SCADA application functions in Generation, Transmission and Distribution.

Advantages of SCADA in Power Systems, The Power system 'Field' , Types of data & signals in the Power system, Flow of Data from the field to the SCADA Control Center. Building blocks of SCADA systems, Classification of SCADA systems.

Remote Terminal Unit (RTU), Evolution of RTUs, Components of RTU, Communication, Logic, Termination and Test/HMI Subsystems, Power supplies, Advanced RTU Functionalities.

Intelligent Electronic Devices (IEDs), Evolution of IEDs , IED functional block diagram, The hardware and software architecture of IED, IED Communication subsystem, IED advanced functionalities, Typical IEDs, Data Concentrators and Merging Units, SCADA Communication Systems.

Master Station, Master station software and hardware configurations, Server systems in the master station, Small, medium and large master station configurations, Global Positioning Systems, Master station performance, Human Machine Interface (HMI), HMI components, Software functionalities, Situational awareness, Case studies in SCADA

Reference Books:

1. Mini S. Thomas, John D McDonald, Power Systems SCADA and Smart Grid, CRC Press, Taylor and Francis .
2. Electric Power Substation Engineering John D. Mc Donald CRC Press, Taylor and Francis
3. Control and Automation of Electrical Power Distribution systems, James Northcote- Green, R Wilson, CRC Press, Taylor and Francis.
4. Electric Power Distribution, Automation, Protection and Control, James Momoh, CRC press, Taylor and Francis.

Course Code & Name	EE698 Grid Converters for Renewable Energy Applications				
Course Type	Elective	No of Credits		3	
Course Learning Objective (CLO)	To understand the modeling, controlling of the grid connected converters for PV and wind applications.				
Prerequisites	-				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the grid requirements for PV and wind turbine system under normal and abnormal grid conditions	2	2	3
CO2	Design and analyse the converters structure for grid connected PV and wind systems	3	3	3
CO3	Investigate various control aspects and techniques for grid connected converters under normal and abnormal grid conditions	3	2	3

Course Content:

Photovoltaic power development, wind power development, grid converter structures, modeling and control of grid-tied converters.

International regulations, response to abnormal grid conditions (voltage deviations, frequency deviations), power quality issues on DC current injection, current harmonics, power factor.

Grid requirements for wind turbine systems, grid code evolution, frequency and voltage deviation under normal operation, active and reactive power control in normal operation, behavior under grid disturbance.

Grid synchronization with PV and wind turbine systems, voltage vector under normal and abnormal grid conditions, synchronous reference frame PLL under unbalanced and distorted grid conditions, operation of different PLL techniques.

Overview of control techniques for grid connected converters under unbalanced grid voltage conditions, control of grid converters under grid faults, control structures for unbalanced current injection, power control under unbalanced grid condition, flexible power control with current limitation.

Reference Books:

1. Remus Teodorescu, Marco Liserre, Pedro Rodriguez., Grid Converters for Photovoltaic and Wind power Systems, first edition, Wiley Publication 2011.
2. Amirnaser Yazdani, Reza Iravani., Voltage Sourced Converters in Power Systems, Modeling, Control and Applications, Wiley Publications 2010.
3. Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley 2002.
4. BinWu, Yongqiang Lang, Navid Zargari and Samir Kouro., 'Power Conversion and Control of Wind energy systems', John wiley & sons, inc., publication 2011.

<table>
<tr><th>Course Code & Name</th><th colspan="5">EE699 Topics in Power Electronics and Distributed Generation</th></tr>
<tr><td>Course Type</td><td>Elective</td><td>No of Credits</td><td colspan="3">3</td></tr>
<tr><td>Course Learning Objective (CLO)</td><td colspan="5">To understand the planning and operational issues related to distributed generation.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">CO-PO Matrix</td></tr>
<tr><td rowspan="2">Course Outcomes (COs)</td><td rowspan="2" colspan="2">Upon completion of the course, the students will be able to</td><td colspan="3">Aligned Programme Outcomes (POs)</td></tr>
<tr><td>PO1</td><td>PO2</td><td>PO3</td></tr>
<tr><td>CO1</td><td colspan="2">Understand the current scenario of distributed generation and the need to implement DG sources</td><td>1</td><td>2</td><td>2</td></tr>
<tr><td>CO2</td><td colspan="2">Investigate the different types of interfaces for grid integration of DGs.</td><td>2</td><td>3</td><td>2</td></tr>
<tr><td>CO3</td><td colspan="2">Appraise the technical impacts of DGs upon transmission and distribution systems.</td><td>2</td><td>3</td><td>3</td></tr>
</table>

Course Content:

Introduction to distribution systems, distribution system equipment, grounding, sequence analysis and fault calculations, relaying requirements for distributed generation (DG) systems.

Intentional and unintentional islanding, power converter topologies for grid interconnection, inverter modelling, filtering requirements.

Design of power converter components, DC bus design, considerations for power loss and reliability in the design procedure, thermal cycling of power semiconductor modules, insulation grade selection, and thermal design implications.

Control of grid interactive power converters, synchronization and phase locking techniques, current control, DC bus control, converter faults, grid parallel and stand alone operation.

Power quality, voltage unbalance, harmonics, flicker, voltage and frequency windows, and recent trends in power electronic DG interconnection

Reference Books:

1. Technical literature – papers published in power electronics related journals and IEEE standards.
2. Ramanarayanan V., Switched Mode Power Conversion, 2007.
3. Arthur R, Bergen, Vittal, Power Systems Analysis (2nd Ed) Prentice Hall, 1999
4. Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley 2002.
5. Sedra A. S and Smith K, Microelectronic Circuits: theory and Applications, (7 Edition) Oxford University Press, 2017.
6. Proakis J G and Manolakis D K, Digital Signal Processing, Pearson 2007.
7. Lucca Corradini, Dragan Maksimovic, Paolo Mattavelli, and Regan Zane, Digital Control of High Frequency Switched-Mode Power Converters, Wiley-Blackwell, 2015.
8. Patrick R. Schaumont, A Practical Introduction to Hardware/Software, Springer 2nd Edition, 2014.

Course Code & Name	EE700 Wireless Sensor Networks and Applications		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To understand the concepts of Wireless Sensor Network protocols, issues and its applications		
Prerequisites	-		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the concepts, node architecture, radio standards and communication protocols of Wireless Sensor Networks	3	3	2
CO2	Identify the required hardware and software components to build a Wireless sensor network.	3	3	2
CO3	Evaluate the performance of a Wireless Sensor Networks	3	3	2

Course Content:

Challenges for Wireless Sensor Networks-Characteristics requirements-required mechanisms, Difference between mobile ad-hoc and sensor networks, Applications of sensor networks-Enabling Technologies for Wireless Sensor Networks.

Single-Node Architecture - Hardware Components, Energy Consumption of Sensor Nodes, Network Architecture - Sensor Network Scenarios, Gateway Concepts.

Physical Layer and Transceiver Design Considerations, MAC Protocols for Wireless Sensor Networks, Low Duty Cycle Protocols and Wakeup Concepts, Address and Name Management, Assignment of MAC Addresses, Routing Protocols

Topology Control, Clustering, Sensor Tasking and Control, Berkeley Motes, SENSEnuts, Programming Challenges, Node-level software platforms, Node-level Simulators.

WSN Applications -Home Control -Building Automation -Industrial Automation -Medical Applications -Reconfigurable Sensor Networks -Highway Monitoring -Military Applications -Civil and Environmental Engineering Applications.

Reference Books:

1. Anna Hac, “Wireless Sensor Network Designs”, John Wiley, 2003.

2. Bhaskar Krishnamachari,” Networking Wireless Sensors”, Cambridge Press,2005.

3. K. Akkaya and M. Younis, “A survey of routing protocols in wireless sensor networks”, Elsevier Ad Hoc Network Journal, Vol. 3, no. 3, pp. 325—349.

4. Holger Karl & Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley, 2005.

5. Kazem Sohraby, Daniel Minoli, & Taieb Znati, “Wireless Sensor Networks- Technology, Protocols, And Applications”, John Wiley, 2007.

Course Code & Name	EE701 Soft Switching Power Converters		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	• To evaluate various soft switching techniques, • Design and control of soft switching converters (Soft switching PWM converters, resonant power converters) • Applications of soft switched converters in renewable energy, electric vehicle and power supplies		
Prerequisites	Power Converters, Basic Knowledge in Power Electronics		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand various soft switching techniques for Power Converters	3	2	3
CO2	Select suitable soft switching scheme for different semiconductor switches according to the applications.	3	2	3
CO3	Analysis and design of various soft switched converters for real-world applications.	3	3	3

Course Content:

Evaluation of switching loss in hard switched converters, Introduction to soft switching schemes, Comparison between hard switched and soft switching converters, Resonant switches, zero voltage switching (ZVS), zero current switching (ZCS), zero voltage zero-current switching (ZVSZCS), Parameters and selection of semiconductor switches for soft switching.

Concept of resonance, Classification of Quasi-Resonant Switches, Non isolated Zero-Current-Switching Quasi-Resonant Converters, Non isolated Zero-Voltage-Switching Quasi-Resonant Converters, Series-Loaded Resonant Converters, Parallel-Loaded Resonant Converters, Series-parallel resonant converters, isolated high order resonant converters.

PWM Soft switched converter, Active clamp power converters with soft switching, design of active clamp ZVS fly back converter, high voltage gains ZVS converters, high voltage gains ZVS/ZCS converters.

Soft switched PWM Full bridge converters, Theoretical Basis of Soft Switching for PWM Full-Bridge Converters, Classification of Soft-Switching PWM Full-Bridge Converters, Zero-VoltageSwitching PWM Full-Bridge Converters, Modulation of the Lagging Leg, Modulation of the Leading Leg, Dual active bridge (DAB) converters and modulation strategy.

Application of resonant and PWM soft switched converters I renewable energy, on –board battery charging, wireless power transfer, power factor correction, DAB converters in solid state transformer.

Reference Books:

1. Robert Erickson, Dragan Maksimovic “Fundamentals of power electronics”, Springer publications, 2001.
2. Marian K. Kazimierczuk, Dariusz Czarkowski, “Resonant Power Converters”, Wiley Publications, Second Edition, 2010.
3. Simon S. Ang, Alejandro Oliva, “Power-Switching Converters” CRC Press Publications, 3nd edition, 2010.
4. Xinbo Ruan, “Soft-Switching PWM Full-Bridge Converters: Topologies, Control, and Design” Wiley Publications, 2014.
5. Ivo Barbi, F. Pottker “Soft commutation Isolated DC/DC Converters” Springer Publications, 2019.

Course Code & Name	EE702 Solar PV Systems				
Course Type	**Elective**	**No of Credits**		**3**	
Course Learning Objective (CLO)	To understand the concepts, operation, MPPT techniques, power conditioning and applications of solar PV systems				
Prerequisites	-				
CO-PO Matrix					
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**			
		PO1	**PO2**	**PO3**	
CO1	Understand the fundamental concept of PV cell modelling and different electrical array configuration schemes	2	2	2	
CO2	Understand and implement various MPPT control strategies and selection of power converters for PV systems	3	3	2	
CO3	Study the different applications for off-grid and on-grid PV systems	2	3	2	

Course Content:

Introduction to solar PV system, history of photovoltaics, photovoltaic effect, photovoltaic cell, equivalent circuit, electrical characteristics, PV terminology, maximum power point tracking.

Partial shading of PV arrays, causes, effect of partial shading on PV power, hot spots, bypass diode, PV characteristics, interconnection schemes, series and parallel connection, total cross tied (TCT), honey comb(HC), bridge linked (BL), reconfiguration techniques, electrical array reconfiguration techniques, Su Do Ku based reconfiguration technique.

Maximum power point tracking algorithm, direct methods, differentiation method, feedback voltage or current method, perturb and observe method, incremental conductance method, parasitic capacitance method, indirect methods, curve fitting method, look up table method, open circuit voltage sensing method, short circuit current sensing method, artificial intelligence techniques, artificial neural network, fuzzy logic, genetic algorithm, algorithm for non-uniform insulation conditions, Fibonacci search method, short current pulse method, two stage method.

Power conditioning for PV System, maximum power point tracking, buck converter, boost converter, buck boost converter, CUK converter, SEPIC converter, charge controller, shunt controller, series controller, inverters, inverter operation, power quality standards, grid interconnection techniques.

Application of solar PV and energy storage - standalone systems, roof top system, street lighting systems, PV water pumping systems, grid connected systems, central inverter, string inverter, module inverter, need for energy storage in PV systems, selection of PV battery, battery charging and discharging characteristics, battery life time, battery protection and regulation.

Reference Books:

1. Chetan Singh Solangi, 'Solar Photovoltaics-Fundamentals, Technologies and Applications', PHI Learning Pvt Ltd, Delhi,2011.
2. Van Overstraeton and Metens R.P,. ‘Physics, Technology and use of Photovoltaics', Adam Hilger, Bristol, 1996.
3. Konrad Mertens, ‘Photovoltaics Fundamentals technology and Practice’, Wiley publications 2014.
4. Chetan Singh Solangi, ‘Solar Photovoltaics Technology and Systems’, 2013.

Course Code & Name	EE703 E-Vehicle Technology and Mobility		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	This introduces the fundamental concepts, principles, analysis and design of electric vehicles (EVs)		
Prerequisites	Electrical Machines and Power Converters, power conversion techniques		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the operating principle of electric vehicles.	2	2	2
CO2	Choose a suitable motor and power electronic interface for EVs.	3	2	3
CO3	Explain various battery technologies.	2	2	2
CO4	Understand various charging technologies for EVs	3	2	2
CO5	Understand policy perspectives and innovation in e-mobility.	2	2	2

Course Content:

Introduction to electric vehicles: EV verses gasoline vehicles, vehicle dynamics fundamentals, e-drivetrain, Electric motor, Power electronic in electric vehicles, Regenerative braking.

Battery Technology for EVs: Storage technologies for EV, Battery working principles, Battery losses, Li-ion batteries, Battery pack and battery management system.

Charging Technology of EVs: AC charging - Type 1,2,3, DC charging, Fast charging and its limitations, Smart charging and applications, Vehicle to X(V2X), X2V technology.

Future trends in e-Vehicles: Wireless charging of EV, On-road charging of EV, Battery swap technology, Solar powered EVs, Charging EVs from renewables. Vehicle communication protocol.

E-mobility: electrification challenges, business, connected mobility and autonomous mobility case study in Indian Roadmap Perspective, Policy- EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs

Reference Books:

1. Iqbal Hussain, “Electric & Hybrid Vehicles – Design Fundamentals”, Second Edition, CRC Press, 2011.
2. James Larminie, “Electric Vehicle Technology Explained”, John Wiley & Sons, 2003.Mehrdad Ehsani, Yimin Gao,
3. Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals”, CRC Press, 2010.
4. Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, 2013.
5. Sandeep Dhameja, “Electric Vehicle Battery Systems”, Newnes, 2000 .http://nptel.ac.in/courses/108103009/
6. Tariq Muneer and Irene Illescas García, “The automobile, In Electric Vehicles: Prospects and Challenges”, Elsevier, 2017.

Course Code & Name	EE704 Design of Embedded Controllers for Smart Micro-Grid		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	To enable the learner to understand the concepts of embedded controllers with its Objectives: Application to smart grids.		
Prerequisites	Digital Systems , Microprocessors/Microcontrollers		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the architecture of Embedded systems.	2	3	2
CO2	Identify suitable peripherals with the processor	2	2	3
CO3	Understand the requirements of the real time OS and embedded networks	3	3	3
CO4	Illustrate the typical use of FPGA as embedded controller	3	3	3
CO5	Apply the concepts of embedded controllers for smart grid.	3	3	3

Course Content:

Embedded System Architectures–ARM processor -architectural design- memory organization- data operation –bus configurations. System on-chip, scalable bus architectures, Design example: Alarm clock, hybrid architectures

Sensors and Special ICs – Voltage Sensor, Current Sensor, Speed Sensor, RMS calculation IC, Battery Management IC, Opto-couplers and Current amplification transistors

Real time operating systems(RTOS)–real time kernel– OS tasks–task states– task scheduling–interrupt processing – Embedded Networks –Distributed Embedded Architecture– Hardware and Software Architectures, Networks for embedded systems– I2C, CANBus, Ethernet, Internet, Network– Based design– Design Example: Elevator Controller.

Typical FPGA board qualitative analysis: FPGA IC interfacing with peripherals: ADC, DAC, display (LED, LCD), Communication networks like Ethernet.

Study of a Smart Micro-grid model – Sensors interfacing with FPGA board – Design of Source and Load Controllers – Communication between the controllers – Concepts of Source and Load management.

Reference Books:

1. Wayne Wolf, 'Computers as Components: Principles of Embedded Computing System Design', Morgan Kaufman Publishers,3rd Edition, 2012.
2. C.M.Krishna, Kang G. Shin ,'Real time systems', McGrawHill,2010.
3. Herma K., Real Time Systems: Design for Distributed Embedded Applications, Kluwer Academic, 2ndEdition, 2011.
4. WilliamHohl, 'ARM Assembly Language, Fundamentals and Techniques', CRC Press, 2009
5. Nazzareno Rossetti, "Managing Power Electronics: VLSI and DSP-driven Computing systems:, Wiley-Interscience Publications, 2006.
6. Krzysztof Iniewski, "Smart Grid Infrastructure & Networking", Mc-Graw Hill Education (India) Limited, 2012.

Course Code & Name	EE705 Design of Magnetics for Power Electronic Applications		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	This course introduces the fundamental concepts and design of magnetics for power electronic Applications		
Prerequisites	Electrical Machines and Power Electronics		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	**Aligned Programme Outcomes (POs)**		
		PO1	**PO2**	**PO3**
CO1	Review the concepts of different types of magnetic devices.	2	1	2
CO2	Choose a suitable core and wire for the design of inductor and transformers.	3	2	2
CO3	Understand the effects in the windings of the transformers at high frequencies.	2	1	2
CO4	Measurement of performance parameters of inductors and transformers.	2	2	2

Course Content:

Basic magnetics theory: Review of basic magnetics- transformer modelling-loss mechanisms in magnetic devices-eddy currents in winding conductors-several types of magnetic devices and their B-H loops.

Inductor design: Introduction- magnet wire-wire insulation- restrictions on inductors-window utilization factor- temperature rise of inductors-mean turn length of inductors-area product method-inductor design for power electronic applications.

Transformer design: Introduction-area product method-optimum flux density-area product for sinusoidal voltages-high frequency transformer design for power electronic applications.

High frequency effects in the windings: Skin effect factor-proximity effect factor-proximity effect factor for an arbitrary waveform-reducing proximity effects by interleaving the windings-leakage inductance in transformer windings.

Measurements: measurement of inductance- B-H loop-losses in a transformer-capacitance in transformer windings.

Reference Books:

1. Robert W. Erickson and Dragan Maksimovic, “Fundamentals of Power Electronics”, Third edition, Springer.
2. Marian K. Kazimierczuk, “High-Frequency Magnetic Components”, second edition, Wiley 2013.
3. W.G. Hurley and W.H. Wolfle, “Transformers and Inductors for power electronics Theory, design, and applications”, Wiley 2013.
4. Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics: Converters, Applications and Design”, Third edition, Wiley 2007.
5. L.Umanand and S.R. Bhat, “Design of magnetic components for switched mode power converters”, New age international 1992.
6. V.Ramanarayanan, “Course material on switched mode power conversion”, Department of Electrical Engineering Indian Institute of Science Bangalore, 2017.

Course Code & Name	EE706 Power Management Integrated Circuits		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	• To Review the modern Integrated circuit design concepts in power management chips. • Modelling and Design of voltage and current mode controllers. • IC Implementation of power management for Energy Harvesting Systems.		
Prerequisites	Fundamentals of Power Electronics and Digital Electronics		

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand the Integrated circuit design concepts in power management chips.	2	1	2
CO2	Design and Development of power management circuits for linear and switching regulators.	3	2	3
CO3	Apply switching regulator concepts for Energy Harvesting Systems.	2	2	2

Course Content:

Introduction to Power Management - Need, Linear versus Switching Regulator, Types of DC-DC Converters and Application. Type of Regulator in a Multi-Chip System; Performance Parameters - Efficiency, Accuracy, Line and Load Regulation, Line and Load Transient, PSRR; Remote versus Local Feedback, Point-of-Load Regulator, Kelvin Sensing, Droop Compensation; Current Regulators and their Applications; Bandgap Voltage Reference.

Introduction to Linear Regulator, review of Feedback Systems and Bode Plots, Loop Gain AC Analysis, Stability Criterion and Phase Margin. Finding the Poles of the Error Amplifier; Stabilising a Linear Regulator - Frequency Compensation Techniques, Dominant Pole Compensation. LDO with NMOS Pass Element; Load Regulation and Output Impedance of LDO; Line Regulation and PSRR of LDO; Sources of Error in a Regulator

Designing the Ramp Generator in a Pulse-Width Modulator, PWM modulators Trailing, Leading and Dual-Edge PW Modulators; Control Techniques for DC-DC Converters; Voltage Mode Control. Designing the Gate-Driver (Gate Buffer and Non-Overlap Clock Generator), Design Considerations of the Error Amplifier; Delays Associated with Pulse-Width Modulators.

Modelling of a DC-DC Converter, Loop Gain and Stability Analysis using Continuous-Time Model. Compensating a Voltage-Mode-Controlled Buck Converter; Designing Type-I (Integral), Type-II (PI) and Type-III (PID) Compensators; Implementation of Compensators using Op Amp-RC and Gm-C Architectures. Compensating a Voltage-Mode-Controlled Buck Converter; Designing Type-I (Integral), Type-II (PI) and Type-III (PID) Compensators; Implementation of Compensators using Op Amp-RC and Gm-C Architectures, Finding Compensation Parameters; Design Examples with Simulation and Demonstrations.

Introduction to Energy-Harvesting Systems, Energy-Harvesting Sources. Concepts of Energy-Harvesting Circuits, Energy-Harvesting Circuits for AC and DC source, MPPT tracking.

Reference Books:

1. Chen, Ke-Horng. “Power Management Techniques for Integrated Circuit Design”. John Wiley & Sons, 2016.
2. Hella, Mona M., and Patrick Mercier, eds. “Power Management Integrated Circuits”. CRC Press, 2017.
3. Erickson, Robert W., and Dragan Maksimovic. “Fundamentals of power electronics”. Springer Science & Business Media, 2007.
4. Grant, Duncan Andrew, and John Gowar. "Power MOSFETS: theory and applications." John Wiley & Sons, New York, 1989.
5. Razavi, Behzad. ‘Design of analog CMOS integrated circuits. MC Graw Hill Education, 2005.

Course Code & Name	EE708 Electric Vehicle Charging Systems				
Course Type	Elective	No of Credits	3		
Course Learning Objective (CLO)	To equip students with a thorough understanding of electric vehicle (EV) charging technologies, with a focus on the design of advanced power converters for EV charging enabling them to effectively address challenges in sustainable transportation.				
Prerequisites	Power Electronics				

CO-PO Matrix				
Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Design of battery technology for EVs.	3	3	2
CO2	Explore various power electronic converters for on-board battery chargers.	2	2	3
CO3	Understand the converter technologies for semi-fast chargers	2	1	3
CO4	Appreciate the concept of EV fast-chargers and renewable energy-based EV fast charging and its infrastructure	1	2	3

Course Content:

Introduction to EV and PHEV battery technologies: Electrical modelling of energy storage systems: batteries, ultra-capacitors, flywheel, and fuel cell. Battery pack design – battery management systems – thermal management – standards.

Introduction to power converters and PWM techniques for EV chargers: Slow chargers – operation, analysis, and design of on-board chargers (OBCs) – single-stage OBCs – twostage OBCs – standards.

Semi-Fast chargers: Introduction, operation, analysis, and design of integrated OBCs – single-phase charging – three-phase charging – multiphase charging – standards. Range extension perspectives.

Fast chargers: Introduction, operation, analysis, and design of fast chargers – grid facing AC/DC converters – isolated, non-isolated, modular DC/DC converters – standards.

Renewable energy based EV charging methods: Solar PV-based EV charging – Wind energy-based EV charging – Hydrogen energy for EV charging. Challenges, case studies, and policies

Reference Books:

1. Ibrahim Dincer, Halil S.Hamut, and Nader Javani, “Thermal management of electric vehicle battery systems”, Wiley – 2014.
2. Bruno scrosati, jurgen garche and werner tillmetz, “Advances in battery technologies for electric vehicles” Elesevier – 2015.
3. Ali Emadi, Mehrdad Ehsani, and John M.Miller, “Vehicular Electric Power Systems – Land, Sea, Air and Space Vehicles”, Marcel Dekker, Inc. 2004.
4. Sheldon S.Williamson, “Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles”, Springer, 2013.
5. Ali Emadi, “Handbook of Automotive Power Electronics and Motor Drives”, Taylor & Francis, 2005.
6. Mehrdad Ehsani, Yimin Gao, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles”, Second edition, CRC Press, 2010.

Course Code & Name	EE712 Home Energy Management Systems		
Course Type	Open Elective	No of Credits	3
Course Learning Objective (CLO)	• To understand the concept of home energy management, energy efficiency, automation, components, architecture and associated challenges. • To realize the importance of communication standards and protocols for smart homes. • To understand the concept of internet-of-things for smart home energy management and get exposure to smart appliances.		
Prerequisites	-		

CO-PO Matrix

Course Outcomes (COs)	Upon completion of the course, the students will be able to	Aligned Programme Outcomes (POs)		
		PO1	PO2	PO3
CO1	Understand and analyze the importance of home energy management system for optimal utilization of electrical energy.	3	1	3
CO2	Understand the communication standards and protocols for smart homes.	2	1	3
CO3	Design and analyze various appliances for smart home energy management.	3	1	3

Course Content:

Introduction – Concept and application of home energy management systems (HEMS) and automation, requirements and design considerations - efficiency of home automation system, architecture and components of HEMS.

Energy efficiency - Home energy conservation, energy sources in household building, system control - lighting, heating, energy benchmarking, energy efficiency improvement, green building – LEED concept & examples.

Smart Home Protocols: Communication protocols such as Bluetooth Mesh, Wi-Fi, ZigBee, PAN, and IEEE 802.15.4 standard, architecture-OSI model, ZigBee mesh networks, device types, green power, coexistence with Wi-Fi, IEEE 802.15.4 spectrum usage, and Z-Wave architecture.

Introduction to IoT – Sensing, actuation, basics of networking, communication protocols, sensor networks, machine-to-machine communications. interoperability in IoT.

Smart Appliances - Smart plugs, smart fans, smart Matic kit, smart EV charging, smart monitoring and maintenance devices, smart lighting, fire alarm, parking lights. Current trends and future challenges.

Text Books:

1. Antonio Moreno-Munoz, Neomar Giacomini (Editor), “Energy Smart Appliances: Applications, Methodologies, and Challenges”, Wiley-Blackwell, 1st Edition, 2023.
2. Fengji Luo, Gianluca Ranzi, Zhao Yang Dong, Building Energy Management Systems and Techniques Principles, Methods, and Modelling, 1st Edition - February 21, 2024, Imprint Elsevier.
3. Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy, Anandarup Mukherjee, CRC press,2021.
4. Kostas Siozios, Dimitrios Anagnostos, Dimitrios Soudris, Elias Kosmatopoulos, IoT for Smart Grids: Design Challenges and Paradigms, Springer publishers, 2019.

Reference Books:

1. Vinod Kumar Khanna, Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, CRC press, 2014, 1st Edition.
2. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress publishers, 2016.
3. Craig Di Louie, Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications, River publishers, 2006, e-book, 2021,1st Edition.
4. Geoff Levermore, “Building Energy Management Systems: An Application to Heating, Natural Ventilation, Lighting and Occupant Satisfaction”, Routledge, 2nd Edition, 2000