MASTER OF TECHNOLOGY

POWER SYSTEMS

CURRICULUM

EFFECTIVE FROM 2024-2025 ONWARDS

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

Master of Technology
(Power Systems)

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 Systems are to equip the students with adequate knowledge and skills in Power Systems Engineering and to prepare them for the following career options:

PEO1	Research programmes in power systems engineering
PEO2	Employment in power research and development organisations
PEO3	To work in electric power industries and energy sectors
PEO4	Faculty positions in reputed institutions

PROGRAMME OUTCOMES

A student who has undergone M.Tech. programme in Power Systems (PS) 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 SYSTEMS)

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

* 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 Systems is **80**.

SEMESTER I

Sl. No.	Code	Course of Study	Credit
1	MA603	Advanced Engineering Mathematics	4
2	EE601	Advanced Power System Analysis	4
3	EE603	Power Conversion Techniques	4
4		Programme Elective I	3
5		Programme Elective II	3
6		Programme Elective III / Online (NPTEL)	3
7	EE607	Power Conversion Laboratory	2
8	EE611	Power System Computation Laboratory	2
		Total	**25**

SEMESTER II

Sl. No.	Code	Course of Study	Credit
1	EE602	Power System Operation and Control	4
2	EE604	Advanced Power System Protection	4
3	EE606	Power System Stability	4
4		Programme Elective IV	3
5		Programme Elective V	3
6		Programme Elective VI / Online (NPTEL)	3
7	EE608	Power Systems Laboratory	2
		Total	**23**

SUMMER TERM (Evaluation in the III semester)

Code	Course of Study	Credit
EE613	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	**2**

SEMESTER III

Code	Course of Study	Credit
EE609	Project Work - Phase I	12
	Total	**12**

SEMESTER IV

Code	Course of Study	Credit
EE610	Project Work - Phase II	12
	Total	**12**

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	EE679	Swarm Intelligent Techniques	3
2	EE686	Energy Auditing and Management	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.	EE663	Microcontroller Applications in Power Converters	3
4.	EE664	Advanced Digital Signal Processing	3
5.	EE665	Advanced Digital System Design	3
6.	EE667	Neural Networks and Deep Learning	3
7.	EE668	Digital Controllers in Power Electronics Applications	3
8.	EE669	Computer Networking	3
9.	EE670	Electrical Distribution Systems	3
10.	EE671	Fuzzy Logic Control Systems	3
11.	EE672	Transient Over Voltages in Power Systems	3
12.	EE673	Renewable Power Generation Technologies	3
13.	EE674	Power System Planning and Reliability	3
14.	EE675	Modeling and Analysis of Electrical Machines	3
15.	EE676	Power Quality	3
16.	EE677	Power System Restructuring and Pricing	3
17.	EE678	Computer Relaying and Wide Area Measurement Systems	3
18.	EE680	Smart Grid Technologies	3
19.	EE681	Electrical Systems in Wind Energy	3
20.	EE683	Embedded Processors and Controllers	3
21.	EE684	Distributed Generation and Micro-Grids	3
22.	EE685	Control Design Techniques for Power Electronic Systems	3
23.	EE688	Principles of VLSI Design	3
24.	EE695	Digital Control Systems	3
25.	EE696	Power System Automation	3
26.	EE703	E-Vehicle Technology and Mobility	3
27.	EE705	Design of Magnetics for Power Electronic Applications	3
28.	EE706	Power Management Integrated Circuits	3
29.	EE707	Electric Power Market	3
30.	EE711	Cybersecurity of Smart Grids	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	EE601 Advanced Power System Analysis		
Course Type	Core	No of Credits	4
Course Learning Objective (CLO)	To perform steady state analysis and fault studies for a power system of any size and to explore the nuances of estimation of different states of a power system.		
Prerequisites	A basic knowledge on the subjects viz., Power System Analysis, Matrix Manipulations, Alternating Machines and Network 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	Construct models of power system components and apply them.	3	2	3
CO2	Solve ac and dc load flow for single and three-phase systems.	3	2	3
CO3	Analyse the faults in the power system networks.	3	2	3
CO4	Apply the concepts of optimization in power system.	3	2	3
CO5	Explain the concept of state estimation in power system and the role of statistics in state estimation.	3	2	3

Course Content:

Network modeling – Single phase and three phase modeling of alternators, transformers and transmission lines, Conditioning of Y Matrix –- Incidence matrix method, Method of successive elimination, Triangular factorization – Sparse matrix

Load flow analysis - Newton Raphson method, Fast Decoupled method, AC-DC load flow –Single and three phase methods – Sequential solution techniques and extension to multiple and multi-terminal DC systems.

Fault Studies -Analysis of balanced and unbalanced three phase faults – fault calculations – Short circuit faults – open circuit faults.

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

State Estimation – method of least squares – statistics – errors – estimates – test for bad data – structure and formation of Hessian matrix – power system state estimation.

Reference Books:

1. Grainger, J.J. and Stevenson, W.D. ‘Power System Analysis’ Tata McGraw hill, New Delhi, 2003.
2. Hadi Saadat, ‘Power System Analysis’, Tata McGraw hill, New Delhi, 2002.
3. Arrillaga, J and Arnold, C.P., ‘Computer analysis of power systems’ John Wiley and Sons, New York, 1997.
4. Pai, M.A., ‘Computer Techniques in Power System Analysis’, Tata McGraw Hill, New Delhi, 2006.

Course Code & Name	EE603 Power Conversion Techniques				
Course Type	Core	No of Credits		4	
Course Learning Objective (CLO)	To present the concepts of typical power converter circuit topologies, operation and control. Analysis, mathematical modeling, design and control aspects will be discussed. Applications of power converters will be introduced.				
Prerequisites	Knowledge on the power semiconductor devices, electronic circuits, circuit theory and mathematics, such as Fourier series analysis and Laplace transform and differential equations are essential.				

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 the mathematical models and illustrate the operation of different types of power converters	3	2	3
CO2	Design suitable switching technique for the devices in the converter circuits	3	2	3
CO3	Evaluate the performance of various converter circuits	3	3	3
CO4	Analyse the device losses and thermal aspects of designing for power converters	3	2	3

Course Content:

DC-DC converters - Buck converter, boost converter, buck - boost converter, averaged circuit modeling, input-output equations, ripple calculations, filter design, case studies

DC-AC inverters -Single phase VSI, Three-phase VSI, Single-phase CSI, Three-phase CSI, voltage control and harmonic reduction in inverters-standard PWM techniques, case studies

AC-DC converters- Uncontrolled rectifiers, single and three phase fully controlled and semi controlled converters, continuous current conduction, discontinuous current conduction, Reactive compensation, Harmonic compensation techniques, case studies

AC-AC converters-single phase and three phase circuits employing Phase angle control, on-off control. AC choppers, case studies

Loss calculations and thermal management: Device models for loss calculations, ratings, safe operating areas, data sheets, forward conduction loss, switching losses, heat sink design, snubber design drive and protection circuits, commutation circuits, Soft switching

Reference Books:

1. Ned Mohan, Undeland and Robbin, ‘Power Electronics: converters, Application and design’, John Wiley and sons. Inc, 3rd Edition, 2002.
2. Rashid M.H., ‘Power Electronics Circuits, Devices and Applications’, Prentice Hall India, 3rd Edition2004.
3. Singh M.D., Khanchandani K. B., ‘Power Electronics’, Tata McGraw-Hill, 2nd Edition, 2008.
4. Umanand L., ‘Power Electronics: Essentials & Applications’, Wiley India Pvt. Ltd., 2009.
5. Daniel W. Hart, “Power Electronics”, Tata McGraw Hill, 2011.

<table>
<tr><td>Course Code & Name</td><td colspan="5">EE607 Power Conversion Laboratory</td></tr>
<tr><td>Course Type</td><td>Laboratory</td><td colspan="2">No of Credits</td><td colspan="2">2</td></tr>
<tr><td>Course Learning Objective (CLO)</td><td colspan="5">To enable the Power System students to get an insight into the basic Power Electronic Circuits</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">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>Test and analyse power converters</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td>CO2</td><td>Test and analyse pulse generation circuits for power converters.</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td>CO3</td><td>Design and implement power electronic system for various applications.</td><td>3</td><td>3</td><td>3</td></tr>
</table>

Course Content:

To simulate, test and analyse the following Power Electronic Circuits:

1) Single- Phase and Three- Phase Controlled Rectifier

2) Single- Phase Inverter

3) Three- Phase Inverter (120° and 180° modes of operation)

4) DC – DC Converters

5) Phase Controlled Circuits

6) DC and AC Circuit Breakers

7) Mini Project

Note:

A simple closed loop control shall be performed as a simulation experiment or mini project in the course.

Course Code & Name	**EE611 Power System Computation Laboratory**		
Course Type	**Laboratory**	**No of Credits**	**2**
Course Learning Objective (CLO)	• To understand and analyze the core concepts of power systems with focus on steady-state analysis and load frequency control. • To analyze the power system network for various contingencies and estimate the power system states under normal and outage conditions. • To evaluate the performance of forecasting model in the modern-day electric grid.		
Prerequisites	Power System Analysis, Transmission and Distribution Networks		

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	Analyze the steady-state power transmission and distribution networks with hands-on experience.	3	2	3
CO2	Assess, evaluate, and compare the performance of forecasting models with hands-on experience.	3	2	3
CO3	Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.	1	3	2

List of Experiments:

- Formation of bus admittance matrix.
- Formation of bus impedance matrix.
- Load flow study of a power transmission network.
- Load flow study of a radial distribution network.
- State estimation of a power transmission network.
- Line/Transformer/Generator contingency analysis of a power transmission network.
- Short circuit study of a power system network.
- Load frequency control of single-area and two-area systems.
- Forecasting study of load demand/solar power/wind power/weather.
- Symmetrical and unsymmetrical fault classification.

Course Code & Name	EE602 Power System Operation and Control		
Course Type	Core	No of Credits	4
Course Learning Objective (CLO)	• To understand the economics of power system operation with thermal and hydro units • To realize the requirements and methods of real and reactive power control in power system • To be familiar with the power system security issues and contingency studies		
Prerequisites	Optimization Techniques, 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	Develop generation dispatching schemes for thermal and hydro units	3	3	3
CO2	Apply control and compensation schemes on a power system.	3	3	3
CO3	Perform contingency analysis for security assessments of power systems	3	3	3

Course Content:

Economic operation - Load forecasting - Unit commitment – Economic dispatch problem of thermal units – Gradient method- Newton's method – Base point and participation factor method.

Hydro-thermal co-ordination-Hydroelectric plant models – short term hydrothermal scheduling problem - gradient approach – Hydro units in series - pumped storage hydro plants-hydro - scheduling using Dynamic programming and linear programming.

Automatic generation control - Review of LFC and Economic Dispatch control (EDC) using the three modes of control viz. Flat frequency – tie-line control and tie-line bias control – AGC implementation – AGC features - static and dynamic response of controlled two area system.

MVAR control - Application of voltage regulator – synchronous condenser – transformer taps – static VAR compensators.

Power system security - Contingency analysis – linear sensitivity factors – AC power flow methods – contingency selection – concentric relaxation – bounding-security constrained optimal power flow-Interior point algorithm-Bus incremental costs.

Reference Books:

1. Robert H. Miller, James H. Malinowski, 'Power system operation', Tata McGraw-Hill, 2009
2. Allen J. Wood, Bruce F. Wollenberg, 'Power Generation, Operation and Control', Wiley India Edition, 2nd Edition, 2009.
3. Abhijit Chakrabarti & Sunita Halder, 'Power system Analysis-Operation & Control', PHI, 3rdEdition, 2010.
4. T J Miller, 'Reactive Power Control in Electric Systems', Wiley, 1982.

Course Code & Name	EE604 Advanced Power System Protection		
Course Type	Core	No of Credits	4
Course Learning Objective (CLO)	To introduce, select and design appropriate protection schemes for various power system components such as generators, transformers, busbars, and transmission lines. Moreover, to choose and apply suitable protective instrumentation transformers for the design of protective relays.		
Prerequisites	Basic knowledge on short circuit 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	Choose appropriate protective instrumentation transformers based on international standards and guidelines	3	2	3
CO2	Analyze and design appropriate over-current and directional relay for a given situation.	3	3	3
CO3	Analyze and design appropriate differential and distance relay for a given situation.	3	3	3
CO4	Select and design an appropriate protection scheme for various power system equipment.	3	3	3

Course Content:

Introduction-philosophy of protection, elements of protection system; Sensing- CT and PT characteristics and selection, IEEE and IEC standards and ANSI numbers for protective relays

Over current relay - settings, classification, and relay coordination; Directional relay – need, polarization settings and applications.

Differential relay - circulating current differential, biased differential protection and high impedance current differential, pilot wire protection; Distance relaying- need and principle of distance protection, basic characteristics, and their operating regions under various conditions – Applications

Generator protection- various faults and abnormal conditions, protection against rotor faults and out of step protection, induction motor protection; Transformer protection - various faults and abnormal conditions, percentage differential protection, inrush phenomenon and inter-turn faults.

Bus bar layout and protection- differential bus bar protection, selection of CTs, protection during high impedance faults; Transmission line protection - distance protection, carrier aided protection, special cases and relevant protection schemes.

Reference Books:

1. Lewis Blackburn, J., ‘Protective Relaying – Principles and Applications’, Marcel Dekkar, INC, New York, 2006.
2. S. H. Horowitz and A. G. Phadke., ‘Power System Relaying’, John Wiley and Sons Ltd, 2008
3. The Electricity Training Association, ‘Power System Protection Vol1-4’, The IEE, U.K.,2005.
4. P M Anderson, ‘Power System Protection’, IEE Press, 2012.
5. J C Das, ‘Power System Protective Relaying’, CRC Press, 2018

Course Code & Name	EE606 Power System Stability				
Course Type	Core	No of Credits		4	
Course Learning Objective (CLO)	This course aims to give basic knowledge about the dynamic mechanisms behind angle and voltage stability problems in electric power systems, including physical phenomena and modeling issues.				
Prerequisites	Numerical Methods, Electrical Machines, 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	Understand the basic modeling and stability considerations of power system.	2	2	3
CO2	Investigate transient stability issues of single and multiple synchronous machines in power systems	3	3	3
CO3	Appraise and analyze the small signal stability and the effects of excitation systems on small signal stability.	3	3	3
CO4	Evaluate the various aspects of voltage stability in power systems	3	3	3
CO5	Interpret and devise different schemes for improving transient stability and voltage stability	3	3	3

Course Content:

Power system stability considerations – definitions-classification of stability - rotor angle and voltage stability - synchronous machine – Modeling - load modeling concepts - modeling of excitation systems - modeling of prime movers.

Transient stability - swing equation-equal area criterion - solution of swing equation- Numerical methods - Euler method-Runge - Kutte method - critical clearing time and angle - effect of excitation system and governors-Multimachine stability – extended equal area criterion - transient energy function approach.

Small signal stability – state space representation – eigen values - modal matrices - small signal stability of single machine infinite bus system – effect of field circuit dynamics - effect of excitation system-small signal stability of multi machine system.

Voltage stability – generation aspects - transmission system aspects – load aspects – PV curve – QV curve – PQ curve – analysis with static loads – loadability limit - sensitivity analysis - continuation power flow analysis - instability mechanisms – examples.

Methods of improving stability – transient stability enhancement – high speed fault clearing – steam turbine fast valving - high speed excitation systems - small signal stability enhancement - power system stabilizers – voltage stability enhancement – reactive power control

Reference Books:

1. Kundur, P., 'Power System Stability and Control', McGraw-Hill International Editions, 1994.
2. Van Cutsem, T. and Vournas, C., 'Voltage Stability of Electric Power Systems', KluwerAcademic Publishers, 1998.
3. AbhijitChakrabarti, D.P. Kothari, A.K. Mukhopadhyay and Abhinandan De, 'An Introduction to Reactive Power Control and Voltage Stability in Power Transmission Systems', PHI Learning Private Ltd., 2010.
4. R.Ramanujam, 'Power System Dynamics: Analysis and Simulation', PHI Learning Private Ltd., 2009.

Course Code & Name	EE608 Power Systems Laboratory		
Course Type	**Laboratory**	**No of Credits**	**2**
Course Learning Objective (CLO)	To understand and analyzing different concepts of the power system which includes generation, transmission and distribution along with control and protection system through the hardware setup.		
Prerequisites	Power System Analysis, Transmission and Distribution, Switch gear and 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	Realize the operation of generation/ Transmission and/or Distribution networks and their performance.	3	-	2
CO2	Experiment and analyse various protection and compensation schemes.	3	-	3
CO3	Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner	3	3	-

List of Experiments:

Study of

1. Measurement of A, B, C, D constants of a long transmission line
2. Microprocessor based Static VAR compensator (SVC)
3. Complete protection scheme for generator
4. Various faults using D.C. network analyzer
5. Microprocessor based Thyristor controlled series capacitor (TCSC)
6. Operation of microprocessor based numerical over current relay
7. Microprocessor based Power factor controller.
8. Manual power factor controller.
9. Power transfer through a short transmission line
10. Three zone protection of a numerical distance relay.
11. Power flow through HVDC transmission system.
12. Design and Analysis of Communication infrastructure for Smart Grid Applications

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 ee 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), Newdelhi 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	EE663 Microcontroller Applications in Power Converters		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	Study the internal structure and operation of PIC 16F876 microcontroller and 8051 microcontroller; assembly language program for the generation of firing and control signals employing these microcontrollers.		
Prerequisites	Knowledge on any digital controller and power electronics may be desirable		

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 8051 and 16F876 microcontrollers.	3	2	2
CO2	Develop assembly language programs employing 8051 & 16F876 microcontrollers.	3	2	3
CO3	Analyse the microcontroller programming using MPLAB and develop typical programs for power converter applications.	3	2	2

Course Content:

8051 microcontroller – architecture – addressing modes – I/O ports - instruction sets – simple assembly language programming.

Use of microcontrollers for pulse generation in power converters - Overview of Zero- Crossing Detectors – typical firing/gate-drive circuits –firing / gate pulses for typical single- phase and three-phase power converters - PIC16F876 Micro-controller – device overview – pin diagrams.

PIC16F876 micro-controller memory organization – Special Function Registers - I/O ports – Timers – Capture/ Compare/ PWM modules (CCP).

Analog to Digital Converter module – Instruction set - instruction description – introduction to PIC microcontroller programming – oscillator selection – reset – interrupts – watch dog timer.

Introduction to MPLAB IDE and PICSTART plus – Device Programming using MPLAB and PICSTART plus – generation of firing / gating pulses for typical power converters.

Reference Books:

1. PIC16F87X Datasheet 28/40 – pin 8 bit CMOS flash Microcontrollers, Microchip technology Inc., 2001. and MPLAB IDE Quick start guide, Microchip technology Inc., 2007.
2. John B. Peatman, 'Design with PIC Microcontrollers', Prentice Hall, 2003.
3. MykePredko, 'Programming and customizing the PIC Microcontroller', Tata McGraw-Hill, 3rd Edition, 2008.
4. M.A. Mazidi, J.G. Mazidi and R.D. McKinlay, 'The 8051 microcontroller and embedded systems', Prentice Hall India, 2nd Edition, New Delhi, 2007.

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.

Course Code & Name	EE670 Electrical Distribution Systems				
Course Type	**Elective**	**No of Credits**	**3**		
Course Learning Objective (CLO)	• 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				
Prerequisites	Transmission and Distribution of Electrical Energy, 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	Perform modeling and power flow studies in the distribution system	2	3	2
CO2	Carry out planning and reliability analysis of electrical distribution systems	2	2	3
CO3	Select the protective components for distribution systems	2	2	2

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, 4th 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 be 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.

Course Code & Name	EE675 Modeling and Analysis of Electrical Machines				
Course Type	Elective	No of Credits		3	
Course Learning Objective (CLO)	To give a systematic approach for modeling and analysis of all rotating machines under both transient and steady state conditions.				
Prerequisites	Electromagnetic Field Theory, Vector Algebra and Fundamentals of all Electrical rotating 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	Analyze the operation of rotating machines.	2	1	2
CO2	Construct machine models based on different reference frames.	3	2	3
CO3	Analyze and synthesize equivalent circuit parameters for synchronous and asynchronous machines.	3	3	3
CO4	Understand and analyze special machines.	3	3	3

Course Content:

Principles of Electromagnetic Energy Conversion, General expression of stored magnetic energy, coenergy 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

<table>
<tr><td>Course Code & Name</td><td colspan="5">EE676 Power Quality</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">Understand the various power quality phenomenon, their origin, impact and monitoring methods.
Equip the necessary skills to handle power quality problems.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Power Systems, Signals and Systems.</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>PO2</td><td colspan="2">PO3</td></tr>
<tr><td>CO1</td><td>Understand different types of power quality problems with their source of generation.</td><td>2</td><td>3</td><td colspan="2">2</td></tr>
<tr><td>CO2</td><td>Interpret and analyse the results of power quality monitoring equipment</td><td>3</td><td>3</td><td colspan="2">2</td></tr>
<tr><td>CO3</td><td>Develop different methodologies for detection and classification of power quality problems.</td><td>3</td><td>3</td><td colspan="2">3</td></tr>
<tr><td>CO4</td><td>Interpret and analyse the results of power quality monitoring equipment</td><td>3</td><td>3</td><td colspan="2">3</td></tr>
</table>

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.

Course Code & Name	EE677 Power System Restructuring and Pricing				
Course Type	Elective	No of Credits	3		
Course Learning Objective (CLO)	To understand the electricity power business and technical issues in a restructured power system in both Indian and world scenario.				
Prerequisites	Power System Analysis, Power System Transmission and Distribution.				

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 deregulated electricity market models functioning around the world.	3	2	3
CO2	Understand the operational and planning activities in power generation	3	2	3
CO3	Analyse various transmission pricing schemes	3	3	3
CO4	Study the development of competition in electricity distribution companies.	3	3	3
CO5	Outline the salient features of Indian Electricity Act and operation of Indian power exchanges.	3	2	3

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 relay 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	EE679 Swarm Intelligent Techniques		
Course Type	Open Elective	No of Credits	3
Course Learning Objective (CLO)	To cater the knowledge of swarm intelligent techniques like genetic algorithm, particle swarm optimization, artificial bee colony algorithms, artificial immune systems, firefly algorithms, cuckoo search algorithms etc. and their applications in electrical engineering		
Prerequisites	Basic Electrical and Electronics, Engineering Mathematics		

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	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems	3	2	3
CO2	Examine the importance of exploration and exploitation of swarm intelligent system to attain near global optimal solution.	2	2	3
CO3	Distinguish the functioning of various swarm intelligent systems	3	3	3
CO4	Explain and employ various bio-inspired algorithms for engineering applications.	3	3	3

Course Content:

Introduction to intelligent systems- soft computing techniques- Conventional Computing versus Swarm Computing; Classification of meta-heuristic techniques- single solution based and population based algorithms – exploitation and exploration in population based algorithms; Properties of Swarm intelligent Systems; Application domain-discrete and continuous problems- single objective and multi-objective problems .

Evolutionary programs – genetic algorithms, genetic programming and evolutionary programming; Genetic Algorithm versus Conventional Optimization Techniques; Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators; Optimization problems using GA-discrete and continuous- single objective and multi-objective problems; Procedures in evolutionary programming.

Biological ant colony system - artificial ants and assumptions; Stigmergic communications; Pheromone updating- local-global; Pheromone evaporation; Pseudo- probabilistic decision making. Travelling salesman problem- ant System-ant quantity- ant density- ant cycle-ant colony system. ACO models-touring ant colony system-max min ant system-concept of elistic ants –continuous and discrete ACO; Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions-PSO topologies-swarm types- control parameters-constriction coefficient; ACO and PSO applications in electrical engineering applications.

Task partitioning in honey bees-balancing foragers and receivers; artificial bee colony (ABC) algorithms, binary ABC and continuous ABC algorithms; Bacterial foraging techniques- taxes-elimination-dispersals bacteria motility and swarming; Biological immune systems and artificial immune systems affinity measures- representations; Basic immune models and algorithms-bone marrow models-negative selection algorithms-clonal selection algorithms- somatic hyper mutation-immune network models- applications in electrical engineering.

Differential search algorithms, harmony Search algorithms, cuckoo search algorithms, firefly algorithms, gravitational search Algorithms, Hybrid swarm intelligent systems; Applications in electrical engineering.

Reference Books:

1. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, 'Swarm Intelligence-From natural to Artificial Systems', Oxford university Press, 1999
2. David Goldberg, 'Genetic Algorithms in Search, Optimization and Machine Learning', Pearson Education, 2007.
3. James Kennedy and Russel E Eberheart, 'Swarm Intelligence', The Morgan Kaufmann Series in Evolutionary Computation, 2001
4. Castro, Leandro Nunes, Timmis and Jonathan, 'Artificial Immune Systems- A new computational approach', Springer publications, 2002
5. N P Padhy, 'Artificial Intelligence and Intelligent Systems', Oxford University Press, 2005.

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	EE683 Embedded Processors and Controllers		
Course Type	Elective	No of Credits	3
Course Learning Objective (CLO)	To enrich the learner with processor and controller design concepts with special concentration on system-on-chip and system-on-programmable chip.		
Prerequisites	Digital Electronics, Microprocessors & Microcontrollers, 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 functionality of MSP430 microcontroller.	2	3	2
CO2	Acquire knowledge on peripherals of MSP430	2	3	2
CO3	Appraise the blocks of ARM processor architecture	2	3	2
CO4	Adapt the concepts of SoC and hardware/software design.	2	3	3
CO5	Recognize the use of multi-core SoC.	2	3	2

Course Content:

MSP 430 Microcontroller – Functional block diagram – memory – Interrupts and Resets – Input/ Output units – Instruction set – Addressing modes – Constant generator and Emulated Instructions.

MSP 430 Timers – on-chip data conversion systems – ADC and DAC – on-chip communication peripherals – SPI, I2C, UART – Programming concepts.

ARM7TDMI – architecture overview - processor modes – data types – Registers – program status registers – Simple programs. Introduction to STM microcontroller-qualitative analysis of architecture.

Introduction to Design of Systems on a chip – Core architectures for Digital media and compilation techniques – Microsystems technology and applications – Hardware/ software co-design concepts.

Multi-core System-on-Chip (McSoC) design – Application specific McSoC design – QueueCore Architecture – Synthesis and evaluation results – Reconfigurable multi-core architectures.

Reference Books:

1. John H. Davies, ‘MSP 430 Microcontroller Basics’, Elsevier Ltd., 2008.
2. William Hohl, ‘ARM Assembly Language, Fundamentals and Techniques’, CRC Press,2009.
3. Abderazek Ben Abdallah, ‘Multi-core systems on-Chip: Practical software and Hardware design’, Atlantis press, 2010.
4. Ricardo Reis, Marcelo Lubaszewski, Jochen A.G. Jess, ‘Design of Systems on a chip: Design and Test’ Springer, 2006.

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,
6. 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.

Modeling 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	EE686 Energy Auditing and Management				
Course Type	Open Elective		No of Credits	3	
Course Learning Objective (CLO)	• To emphasize the energy management on various electrical equipment and metering • To illustrate the energy management in lighting systems and cogeneration • To study the concepts behind the economic analysis and load management				
Prerequisites	Electrical Machines, Transmission and Distribution of Electrical Energy, Utilization of Electrical Energy				

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 Energy auditing and Energy management.	2	2	3
CO2	Employ energy management strategies for electric machines and cogeneration.	3	3	3
CO3	Employ energy management strategies in lighting systems	3	3	3
CO4	Devise and select appropriate metering and instrumentation for energy management studies.	3	3	3
CO5	Carry out economic analysis involved in various energy management strategies.	3	3	3

Course Content:

Basics of Energy – Need for energy management – energy accounting- energy monitoring, targeting and reporting-energy audit process

Energy management for electric motors – Transformer and reactors-capacitors and synchronous machines, energy management by cogeneration –forms of cogeneration – feasibility of cogeneration – electrical interconnection

Energy management in lighting systems – task and the working space - light sources – ballasts – lighting controls – optimizing lighting energy – power factor and effect of harmonics, lighting and energy standards

Metering for energy management – units of measure - utility meters – demand meters – paralleling of current transformers – instrument transformer burdens – multitasking solid state meters, metering location vs requirements, metering techniques and practical examples

Economic analysis – economic models- time value of money - utility rate structures – cost of electricity – loss evaluation, load management – demand control techniques – utility monitoring and control system – HVAC and energy management – economic justification

Reference Books:

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, 'Guide to Energy Management', 5th Edition, The Fairmont Press, Inc., 2006
2. Amit K. Tyagi, 'Handbook on Energy Audits and Management', The Energy and Resources Institute, 2003
3. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.

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	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, 2020.
2. Electric Power Substation Engineering John D. Mc Donald CRC Press, Taylor and Francis, 2007.
3. Control and Automation of Electrical Power Distribution systems, James Northcote- Green, R Wilson, CRC Press, Taylor and Francis, 2007.
4. Electric Power Distribution, Automation, Protection and Control, James Momoh, CRC press, Taylor and Francis,2008.

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	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; Stabilizing 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	EE707 Electric Power Market				
Course Type	**Elective**	**No of Credits**		**3**	
Course Learning Objective (CLO)	To understand the principles and working of restructured power systems and electricity markets around the world				
Prerequisites	Basics of Power System Analysis and Power System Economics				

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	Illustrate and solve problems in the de-regulated power systems	3	3	3
CO2	Explain how electricity is priced in deregulated power markets.	3	3	3
CO3	Explain the working of various electricity markets around the world.	3	3	3

Course Content:

Power market fundamentals – Why deregulate? – What to deregulate – Pricing power, energy, and capacity – Power supply and demand – Market structure and architecture – Spot market – Day ahead market – Real time market – Reserve market – Ancillary services

Electricity pricing **–** concept of marginal cost – market equilibrium – market clearing price – congestion pricing fundamentals – locational marginal pricing – operating reserve pricing – value-of-lost-load-pricing – Pricing losses on lines – Pricing losses at nodes

Markets around the world – US and European market evolution – Reforms in Indian power sector – IEX India – Power purchase agreements in India

Derivative markets – Hedging risk – Contract for difference – Forwards – Futures – Options –Swaps

Local energy markets – Virtual power plant and microgrids – Microgrid prosumer consortium – Peer-to-Peer transactive energy markets – Roles of DSO – Business model

Reference Books:

1. Steven Stoft , 'Power System Economics: Designing Markets for Electricity', Wiley-IEEE Press,2002.
2. Daniel S.Kirschen, Goran Strbac,'Fundamentals of power System Economics,Wiley,2018.
3. Mohammad Shahidehpour, Muwaffaq Alomoush,'Restructured Electrical Power Systems: Operation: Trading, and Volatility', Marcel Dekker Inc.,2001
4. Mohammad Shahidehpour, Hatim Yamin Zuyi Li, 'Market Operations in Electric Power systems: Forecasting, Scheduling, and Risk Management', IEEE Press,2002.

Useful WEBLinks:

1. Indian Energy Exchange: http://www.iexindia.com/
2. Power Exchange India Limited: https://www.powerexindia.com/
3. Indian Electricity Regulations: https://www.cercind.gov.in/

Course Code & Name	**EE711 Cybersecurity of Smart Grids**		
Course Type	**Elective**	**No of Credits**	**3**
Course Learning Objective (CLO)	• To understand the concept of smart grid, metering infrastructures, communication protocols, resilient smart grid architectures and associated challenges • To assess the challenges in information security of smart grids, key technical threats, and its influence in various domains of smart grid. • To provide solution against cyber intrusion in smart grids.		
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 fundamentals of smart grid and related components and the challenges associated with metering and communication infrastructures	2	1	3
CO2	Understand the importance of information security and privacy aspects in smart grid context.	3	1	3
CO3	Analyse and assess cyber threats in various domains of smart grid and provide feasible solution against cyberattacks.	3	2	3

Course Content:

Introduction – Overview of conventional and smart electric grid – challenges, components, salient features, current policies and development: Indian and global context. Standards and protocols. Advanced metering infrastructures (AMI) – challenges, policies, and developments. AMI protocols and standards. Communication network architecture – Smart grid network protocols, wide area network (WAN) architecture, local area network (LAN) architecture, and home area network (HAN) architecture.

Security and Privacy - Introduction to information security, pillars of information security, overview of the security issues in smart grids, physical network security, privacy issues in smart grids, reliability in smart grid- preliminaries on reliability quantification.

Attack mechanisms – Confidentiality-based attacks, integrity-based attacks, availability-based attacks, types of threats, false data injection (FDI), stealth FDI, bad data detection (BDD), energy theft, denial of service (DoS) in generation, transmission, and distribution domains.

Defence mechanisms – mathematical models, machine learning and deep learning tools for defence against cyberattack, detection, classification, rectification, and scalability analysis. Current trends and future challenges.

Text Books:

1. Smart Grid: Fundamentals of Design and Analysis, J. A. Momoh, Wiley India, 2015, 1st Edition.
2. Security and Resiliency Analytics for Smart Grids, Al-Shaer, Ehab, Rahman and Mohammad Ashiqur, Springer Intr., 1st Edition, 2016.
3. Smart Grid Security, S. Goel, Y. Hong, V. Papakonstantinou, D. Kloza, Springer-Verlag, 2015, 1st Edition.

Reference Books:

1. Security and Privacy in Smart Grid, A. Abdallah and X. Shen, Springer Intr., 2018, 1st Edition.
2. Smart grids security challenges: Classification by sources of threat, Abdul Rahaman, Journal of Electrical Systems and Information Technology, 2018.
3. Power System State Estimation: Theory and Implementation, A. Abur and A. G. Exposito, CRC Press, 2004, 1st Edition.