SCHOOL OF ELECTRICAL ENGINEERING

M. TECH CURRICULAR & SYLLABI

2019 - 2020

Contents

Credit Distribution (M.Tech. in Electrical Engineering)

Semester	Credit
1st Semester	21
2st Semester	19
3st Semester	14
4st Semester	16
Total Credit	**70**

A. University Level Subject Core

Sl. No.	Course Code	Subject Name	Credit
1	RS 6001	Fundamentals of Research Methodology	3

B. Departmental level Common Subject across all Specialization in School of Electrical Engineering

Sl. No.	Course Code	Subject Name	Credit
1	EE 6130	Nonlinear Control Theory	3

SPECIALIZATION IN POWER ELECTRONICS & DRIVES

1st semester

Sr. No.	Subject Code	Subject	Teaching Hours			Credit
		Theory	L	T	P	
1		University Level Subject Core	3	0	3	3
2	EE 6105	Power Converters	3	0	3	3
3	EE 6107	Power Electronic Drives	3	0	3	3
4	EE 6109	Power Quality Issues and Mitigation	3	0	3	3
5	EE 6111	Control Techniques in Power Electronics	3	0	3	3
6		Dept. Elective-I	3	0	3	3
Total Theory					18	18
		Practical				
1	EE6197	Power Electronics Converter and Drives Lab	0	0	3	1.5
2	EE6199	Modeling and Control Laboratory	0	0	3	1.5
Total Practical					6	3
		Sessional				
		Total Semester Credit			24	21

2nd Semester

Sr. No.	Subject Code	Subject	Teaching Hours			Credit
		Theory	L	T	P	
1		Department level common Subject	3	0	3	3
2	EE 6110	Design of SMPS and PWM converters	3	0	3	3
3	EE6108	Vector Control of Electric Drives	3	0	3	3
4		Dept. Elective-II	3	0	3	3
5		Dept. Elective-III	3	0	3	3
		Total Theory			15	15
	Practical					
1	EE 6196	Industrial Automation Laboratory	0	0	3	1.5
		Total Practical			**3**	**1.5**
	Sessional					
1	EE 6182	Seminar			2	1
2	EE 6184	Comprehensive Viva-Voce		-		1.5
		Semester Total			20	19

3rd Semester

	EE 6185	Thesis Part-I	-	14
		Total		14

4th Semester

	EE 6186	Thesis Part-II	-	16

Electives for Specialization in POWER ELECTRONICS & DRIVES

Elective – I

Corse Code	Subject	Credit
EE 6303	Computer Analysis in Power System	3
EE 6211	Integration and Control of Renewables	3
EE 6141	Microcontroller Applications	3
EE 6235	Discrete and Digital Signal Processing	3

Elective-II

Corse Code	Subject	Credit
EE 6154	Flexible AC Transmission Systems	3
EE6142	Soft Computing Techniques	3
EE 6206	Energy Auditing and Management	3
EE 6144	Analysis and Design of Power Converters	3

Elective-III

Corse Code	Subject	Credit
EE 6146	Electric Hybrid Vehicles	3
EE 6148	Harmonics Elimination in Power System	3
EE 6150	Switch Mode Power Conversion	3
EE 6152	DC- AC Conversion Systems	3

SPECIALIZATION IN POWER AND ENERGY SYSTEM

1st semester

Sr. No.	Subject Code	Subject	Teaching Hours			Credit
		Theory	L	T	P	
1		University Level Subject Core	3	0	3	3
2	EE 6211	Integration and Control of Renewable	3	0	3	3
3	EE 6213	Electrical System Management and Control	3	0	3	3
4	EE 6105	Power Converters	3	0	3	3
5	EE 6109	Power Quality Issues and Mitigation	3	0	3	3
6		Dept. Elective-I	3	0	3	3
		Total Theory			18	18
		Practical				
7	EE6295	Renewable Energy Laboratory	0	0	3	1.5
8	EE6199	Modeling and Control Laboratory	0	0	3	1.5
		Total Practical			6	3
		Sessional				
		Total Semester Credit			24	21

2nd Semester

Sr. No.	Subject Code	Subject	Teaching Hours			Credit
		Theory	L	T	P	
1		Department level common Subject	3	0	3	3
2	EE 6208	Renewable Power Generation Technology	3	0	3	3
3	EE 6206	Energy Auditing and Management	3	0	3	3
4		Dept. Elective-II	3	0	3	3
5		Dept. Elective-III	3	0	3	3
		Total Theory	15		15	15
		Practical				
7	EE 6196	Industrial Automation Laboratory	0	0	3	1.5
		Total Practical			**3**	**1.5**
		Sessional				
8	EE 6282	Seminar			2	1
9	EE 6284	Comprehensive Viva-Voce		-		1.5
		Semester Total			20	19

3rd Semester

	EE 6285	Thesis Part-I	-	14
		Total		14

4th Semester

	EE 6286	Thesis Part-II	-	16

Electives for Specialization in POWER AND ENERGY SYSTEM

Elective - I

Corse Code	Subject	Credit
EE 6303	Computer Analysis in Power System	3
EE 6141	Microcontroller Applications	3
EE 6313	Reactive power control and Management	3
EE 6111	Control Techniques in Power Electronics	3

Elective-II

Corse Code	Subject	Credit
EE 6154	Flexible AC Transmission Systems	3
EE 6142	Soft Computing Techniques	3
EE 6144	Analysis and Design of Power Converters	3
EE 6322	Distributed Generation	3

Elective-III

Corse Code	Subject	Credit
EE 6306	Digital Protection in Power System	3
EE 6132	Solar Power Engineering	3
EE 6136	Wind Power Engineering	3
EE 6328	Restructuring of Power System	3

SPECIALIZATION IN POWER SYSTEM ENGINEERING

1st semester

Sr. No.	Subject Code	Subject	Teaching Hours			Credit
		Theory	L	T	P	
1		University Level Subject Core	3	0	3	3
2	EE 6301	Power System Stability and Control	3	0	3	3
3	EE 6303	Computer Analysis in Power System	3	0	3	3
4	EE 6313	Reactive Power Control and Management	3	0	3	3
5	EE 6305	Planning and Automation of Distribution System	3	0	3	3
6		Dept. Elective-I	3	0	3	3
Total Theory			18			18
	Practical					
1	EE 6395	Power System and Distributed Generation Laboratory	0	0	3	1.5
2	EE6199	Modeling and Control Laboratory	0	0	3	1.5
Total Practical			6			3
	Sessional					
		Total Semester Credit			24	21

2nd Semester

Sr. No.	Subject Code	Subject	Teaching Hours			Credit
		Theory	L	T	P	
1		Department level common Subject	3	0	3	3
2	EE 6308	High Voltage DC Transmission	3	0	3	3
3	EE 6306	Digital Protection in Power System	3	0	3	3
4		Dept. Elective-II	3	0	3	3
5		Dept. Elective-III	3	0	3	3
Total Theory			15		15	15
		Practical				
1	EE 6196	Industrial Automation Laboratory	0	0	3	1.5
Total Practical					**3**	**1.5**
		Sessional				
1	EE 6382	Seminar			2	1
2	EE 6384	Comprehensive Viva-Voce		-		1.5
		Semester Total			**20**	**19**

3rd Semester

	EE 6385	Thesis Part-I	-	14
		Total		14

4th Semester

	EE 6386	Thesis Part-II	-	16

Electives for Specialization in POWER SYSTEM ENGINEERING

Elective - I

Corse Code	Subject	Credit
EE 6211	Integration and Control of Renewables	3
EE 6128	Power System Transients	3
EE 6109	Power Quality Issues and Mitigation	3
EE 6105	Power Converters	3

Elective-II

Corse Code	Subject	Credit
EE 6154	Flexible AC Transmission Systems	3
EE6142	Soft Computing Techniques	3
EE 6206	Energy Auditing and Management	3
EE 6322	Distributed Generation	3

Elective-III

Corse Code	Subject	Credit
EE 6311	State Estimation and Security Analysis	3
EE 6336	Smart Grid	3
EE 6328	Restructuring of Power System	3
EE 6148	Harmonics Elimination in Power System	3

POWER AND ENERGY SYSTEM

RS 6001 FUNDAMENTALS OF RESEARCH METHODOLOGY Cr-3

Course Outcomes: At the end of the course, the students will be able to:

CO1. Conduct review of literature effectively
CO2. Formulate a viable research problem
CO3. Effectively write a technical paper based on research findings
CO4. Analyze and interpret research data
CO5. Develop awareness on IPR and allied issues
CO6. Follow ethical practices in research

Module1: Introduction (8 Hrs)
Types of research, Literature review, Research gap, Motivation, Research objectives and specifications, Formulation of research questions, Research approach, Research hypothesis.

Module 2: Research Writing (8 Hrs)
Methodology to write a technical paper/short communication/research proposal/monograph, Abstract writing, Report or presentation of results, Bibliography.

Module 3: Data Analysis (8 Hrs)
Classification of data, Methods of data collection, Statistical techniques, Design of experiments and choosing an appropriate statistical technique, Introduction to mathematical modeling (regression, model fitting), Hypothesis testing, Statistical inference.

Module 4: Intellectual Property (8 Hrs)
Intellectual property, Patent, Trademark, GI, Copyright and related rights, Research Incentives, PCT and WIPO.
Plagiarism: Definition, Plagiarism and consequences, IPR Violation and Detection.

Module 5: Research Ethics (4 Hrs)
Professional ethics in research, Ethical issues, Definition and importance, Ethical guidelines, Peer review, Research misconduct, Conflicts of interest.

Text Books:

1. C. R. Kothari, Research Methodology, New Age International, 2004.
2. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.

Reference Books:

1. J. W. Barnes, Statistical Analysis for Engineers and Scientists, Tata McGraw-Hill, New York.
2. Donald Cooper, Business Research Methods, Tata McGraw-Hill, New Delhi.
3. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.
4. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
5. Manna, Chakraborti, Values and Ethics in Business Profession, Prentice Hall of India, New Delhi, 2012.
6. R. Subramanian, Professional Ethics, Oxford University Press, 2013.

EE6211 INTEGRATION AND CONTROL OF RENEWABLES Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1 Understand the effects of renewable energy penetration into the grid
CO2 Know various MPPT control techniques for solar PV system
CO3 Understand different synchronization techniques.
CO4 Control real and reactive power fed to the grid
CO5 Study of integration of different Energy Conversion Technologies
CO6 Analyze grid connected and islanding mode of operations

Module-1: Introduction (8Hrs)

Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements

Module 2: MPPT control techniques in solar PV system: (8Hrs)

MPPT Control approach, Perturb and Observe (P&O) Method, Incremental Conductance Method (INCond.), Open-Circuit Voltage Method, Short-Circuit Current Method, Fuzzy Logic Controller, Other MPPT algorithms.

Module-3: Real and reactive power control (10Hrs)

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

Module-4: Integration of different Energy Conversion Technologies (10Hrs)

Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

Text Books:

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

References Books:

1. Quing-Chang Zhong, "Control of Power Inverters in Renewable Energy and Smart Grid Integration", Wiley, IEEE Press

EE6213 ELECTRICAL SYSTEM MANAGEMENT AND CONTROL Cr-3

Course Outcome: At the end of the course, students will be able to:

CO1 Understand load curves, load profiling and load management and control
CO2 Analyze capacitor sizing and placement towards power factor improvement
CO3 Know economics of power transmission and distribution
CO4 Understand power generation management and unit allocation
CO5 Learn the planning and control of maintenance in power plants
CO6 Know power system security evaluation

Module-1: Management and control of electrical load: (10 Hrs)
Load curve, load profiling, load control; energy efficiency, load management, demand side management, marketing, customer incentives; reactive power, power factor, capacitor sizing, capacitor losses, location, placement and maintenance.

Module-2: Economics of power transmission and distribution: (10 Hrs)
Voltage regulation, losses, efficiency; survey of transmission lines, plotting of profiles, planning and locating line supports; comparison of high voltage AC and high voltage DC transmission, Kelvin's law, types of distribution systems and their design criteria.

Module-3: Power generation management and control: (8 Hrs)
Types of generating stations, governor system, generation planning, unit commitment- spinning reserve.

Module-4: Planning and control of maintenance in power plants: (4 Hrs)
Importance of maintenance, objectives, functions, maintenance management strategies for power stations and their organization, advantage of planned maintenance, scientific maintenance, safety in maintenance.

Module-5: Power system security evaluation: (4 Hrs)
Factors affecting power system security, major components of security assessment,on-line security assessment, contingency analysis, tools for contingency analysis.

Text Books:

1. Kirchmeyer, L.K., "Economic Operation of Power Systems", Wiley, 1958
2. Rao, S., "EHV-AC, HVDC Transmission and Distribution Engineering", Khanna Publishers, 1993.
3. Gupta, B.R., "Generation of Electrical Energy", S.Chand, 1983.
4. Clifton, R.H., "Principle of Planned Maintenance", McGraw Hill, 1983.
5. Venkatesh, P., Manikandan, B.V., Charles Raja, S., Srinivasan A., "Electrical Power Systems Analysis, Security and Deregulation", PHI Learning Private Limited, 2012.

References Books:

1. S.C. Tripathy, Electric Energy Utilization and Conservation, Tata McGraw Hill, 1991.
2. Kothari, D.P, "Power System Engineering", Tata-McGraw Hill, 2008

POWER CONVERTERS **Cr-3**

EE 6105

Course Outcomes: At the end of the course, students will be able to

CO1 Learn the characteristics and operation of power semiconductor devices.
CO2 Analyze the operation of Ac-DC converters.
CO3 Derive DC-DC converters for wider applicability
CO4 Conceptualize of DC-AC conversion techniques
CO5 Realize the operation of AC-AC converters
CO6 Design and apply the converters in various fields of application.

Module 1: Power Semiconductor Devices (5 hrs)

Review of power semiconductor switching devices, Thyristors, MOSFET, IGBT and modern devices, characteristics and Applications, Introduction to Turn-ON/Turn-OFF mechanism of switching devices, Gate-drive circuits, Switching-aid circuits, protection, Heat sink design.

Module 2: AC-DC Conversion Techniques (8 hrs)

Line- commutated rectifiers, single and three-phase rectifiers (controlled/ uncontrolled), performance analysis, harmonics, Ripple reduction techniques, Introduction to multi-pulse converters, applications.

Module 3: DC-DC Conversion Techniques (10 hrs)

Switch-mode DC-DC Converters, pulse width modulation, Nonisolated and isolated Topologies, design of transformer for switch-mode power converters, continuous and discontinuous modes of operations, steady-state analysis, impact of voltage and current stress on the switches and reduction techniques, energy storage elements design, higher-order topologies, applications.

Module 4: DC-AC Conversion techniques (8 hrs)

Inverters, single and three-phase inverter configurations, voltage and current source inverters and their operating modes, voltage control in inverters and harmonic reduction using PWM strategies, Introduction to Multi-level Inverters, applications.

Module 5: AC-AC Conversion Techniques (5 hrs)

AC-AC voltage controllers, configurations, performance analysis, harmonics, Cyclo-converters, introduction to Matrix converters and their applications.

Text Books:

1. V. Ramanarayanan Course Material on Switched Mode Power Conversion, Department of Electrical Engineering, Indian Institute of Science, Bangalore 560012.
2. Elements of Power Electronics, by Philip T. Krein, Oxford University Press,25 Sept 1997.
3. Power Electronics By M. H. Rashid, Pearson Education, 3rd Edition, 2009.

Reference Books:

1. Power Electronics, Converters, Applications and Design N. Mohan, Undeland and Robbins, John WileyandSons , 3rd Edition ,2009.
2. Modern Power Electronics by P. C Sen, S Chand Publisher- 2013

POWER QUALITY ISSUES AND MITIGATION Cr-3

EE 6109

Course Outcomes:

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

CO1 Know importance of power quality, terms and definitions of power quality.

CO2 Understand flickers and transients in power system.

CO3 Know Voltage Sag, Swells, Interruptions and its impact on power system.

CO4 Analyze the waveform distortion, harmonics effect in measuring power quality.

CO5 Know the impact of harmonics on power system.

CO6 Know different power quality monitoring techniques.

Modue-1: Introduction (6 Hrs)

Importance of power quality, terms and definitions of power quality as per IEEE std. 1159. such as transients, short and long duration voltage variations, interruptions, short and long voltage fluctuations, imbalance, flickers and transients. Symptoms of poor power quality.

Modue-2: Flickers & Transient Voltages: (8 Hrs)

RMS voltage variations in power system and voltage regulation per unit system, complex power. Principles of voltage regulation. Basic power flow and voltage drop. Various devices used for voltage regulation and impact of reactive power management. Various causes of voltage flicker and their effects. Short term and long term flickers. Various means to reduce flickers. Transient over voltages, sources, impulsive transients, switching transients, Effect of surge impedance and line termination, control of transient voltages.

Modue-3: Voltage Sag, Swells and Interruptions: (8 Hrs)

Voltage sags versus interruptions. Economic impact of voltage sag. Major causes and consequences. characteristics. assessment. Influence of fault location and fault level on voltage sag. Areas of vulnerability. Assessment of equipment sensitivity to voltage sags, CBEMA, ITIC, SEMI F 42 curves. Representation of the results of voltage sags analysis. Voltage sag indices. Mitigation measures for voltage sags, such as UPS, DVR, SMEs, CVT etc.

Modue-4: Waveform Distortion: (8 Hrs)

Definition of harmonics, Causes and effect of harmonics. Voltage versus current distortion. Harmonic indices. A.C. quantities under non-sinusoidal conditions. Triplen harmonics, characteristics and non characteristics harmonics. Harmonics series and parallel resonances. Consequences of harmonic resonance. Principles for controlling harmonics. Reducing harmonic currents in loads. Harmonic study procedure. Computer tools for harmonic analysis. Locating sources of harmonics.

Modue-5: Power Quality Monitoring: (6 Hrs)

Need of power quality monitoring and approaches followed in power quality monitoring. Power quality monitoring objectives and requirements. Initial site survey. Power quality Instrumentation. Selection of power quality monitors, selection of monitoring location and period. Setting thresholds on monitors, data collection and analysis. Transient monitoring, event recording and flicker monitoring.

Text Books:

1. Electrical Power System Quality , by R C Dugan, M.F Mcgranaghan, S. Santoso& H W Beaty, 2nd Edition TMH publication- 2008.
2. Electric Power Quality by Heydt, G T, Stars in a circle publications, Indiana 2nd edition-1994

Reference Books:

1. Arrillaga J and Watson RN, Chen S, Power system Quality Assessment, Wiley New York-2000.
2. Bollen M H J, Understanding Power Quality Problems,: Voltage Sag and interruptions, IEEE press NY-2000.

EE 6303 COMPUTER ANALYSIS IN POWER SYSTEM Cr-3

Course Outcomes (CO) : At the end of the course, the students will be able to

CO1 Formulate Bus admittance matrix during load flow study.
CO2 Model for power system components using graph theory.
CO3 Formulate incidence and network matrix of 3-phase networks.
CO4 Formulate the Bus impedance matrix using Bus impedance building algorithm.
CO5 Analyze the different fault study of 3-phase network using Z_{bus}.
CO6 Know the transient stability analysis.

Module-1

Load Flow Study using Computer Techniques: (11 Hrs)

Formation of Y_{bus} with regulating transformer, Network matrices, Reference frame, Network graph, Tree, branch, Basic loop and Cut sets, Basic Incidence matrices, Augmented matrices, Primitive networks, Network matrices by Singular and Non-singular transformation with different Reference frame.

Module-2

Studies of Three Phase Networks: (17 Hrs)

Elements in impedance and admittance form, Balance and Un-balance excitation, Transformation matrices for symmetrical components, Incidence and network matrix for 3-phase elements, Formation of Z_{bus} through Bus impedance building algorithm, Short circuit study and analysis of symmetrical and un-symmetrical fault of balanced network using Z_{bus}.

Module-3

Transient stability Analysis: (8 Hrs)

Load representation, Network performance equation, Swing equation, Machine equation, Solution techniques in transient stability study using Eulers and Runge Kutta 4^{th} order method.

Text Books:

1.Computer Methods in Power System Analysis by Glenn W. Stagg, Ahmed H. El-Abiad, McGraw-Hill Book Company, International Editions, 2009.
2.Advanced Power System Analysis and Dynamics by L. P. Singh, New Age International (P) Limited, Publishers, Revised 4th Edition, 2011.

Reference Books:

1.Power System Analysis by N.V.Ramana, Pearson Publication,2011
2.Computer application techniques in Power System by M.A.Pai, TMH, 2006.
3.Computer Aided Power System Analysis, by George L. Kusic, PHI, 2005
4.Power System Analysis by John J. Grainger and William D.Stevenson, McGraw-Hill, 2016.

EE 6141 MICROCONTROLLER APPLICATIONS Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Know low cost microcontroller architecture.
CO2 Understand the Pin configuration of 8051 and ATMEL 89C51
CO3 Know AVR programming for ATMEGA 328.
CO4 Apply different programming techniques like shifting , branching in AVR.
CO5 Design interface circuit for stepper motor control using ATMEGA 328.
CO6 Generate PWM signals for single phase voltage source Inverter.

Module-1: 8051 and ATMEL 89C51 Microcontrollers: (12 Hrs)

Introduction, over view of 8051 family. Architecture of 8051 MC, Addressing modes, Instruction sets, timers & counters, simple programming. ATMEL 89C51 microcontroller: feature, description, pin configuration, pin descriptions, programming the flash and programming interface.

Module-2: AVR Microcontrollers: (14 Hrs)

Overview of AVR family, AVR microcontroller architecture, Register, ATMEGA 328 pin configuration & function of each pin, addressing modes of AVR, AVR status register, rotate and shift, branch and call instructions, AVR data types and assembler directives, AVR I/O port programming, AVR programming in assembly language and C, AVR development boards.

Module-3: Applications of Microcontrollers: (10 Hrs)

Microcontroller based DC and stepper motor control system, ADC and DAC interfacing with microcontrollers, PWM signal generation for single phase inverter, digital PID controller implementation using microcontroller, sensor interfacing with microcontrollers.

Text Books:

1. Desmukh, "Microcontrollers -Theory and Applications" 1st edition TMH publications, 2005
2. Muhammad Ali Mazidi, Sepehr Naimi, "Sarmad Naimithe AVR controller and embedded systems using assembly and C" Pearson Education Inc, 2017

Reference Books:

1. M.A. Mazidi, "The 8051 microcontroller and embedded systems" Pearson, 2nd edition, 2011
2. Md. Rafiquzzaman, "Microprocessors & Microcomputers based System Design" - UBS, 2nd edition, 1995
3. Udayashankara and M Mallikarjunaswamy, "8051 microcontroller-Hardware, software and applications, THM, 1st edition, 2009.
4. S. K. Venkat Rama, "Advanced microprocessors and microcontrollers" Laxmi publications, 1st edition, 2004.

EE 6313 REACTIVE POWER CONTROL AND MANAGEMENT Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1 Identify the necessity of reactive power compensation
CO2 Understand the objective and specification of the load compensation.
CO3 Know the steady state and transient state reactive power compensation in transmission line.
CO4 Understand the reactive power coordination.
CO5 Characterize distribution side and utility side reactive power management.
CO6 Use of reactive power management in electric traction systems and arc furnaces.

Module 1: Introduction: (6 Hrs)

Power mismatching, reactive power characteristics, inductive and capacitive approximate biasing, load compensator as a voltage regulator, phase balancing and power factor correction of unsymmetrical loads.

Module 2: Reactive Power Coordination: (8 Hrs)

Objective, mathematical modeling, operation planning, transmission benefits, basic concepts of quality of power supply, disturbances, steady state variations, effects of under voltages , frequency, harmonics, radio frequency and electromagnetic interferences.

Module 3: Reactive Power Compensation in Transmission line: (8 Hrs)

Uncompensated line, types of compensation, passive shunt and series and dynamic shunt compensation, Characteristic time periods, passive shunt compensation, static compensations, series capacitor compensation, compensation using synchronous condensers.

Module 4: Distribution side reactive power planning and management: (14 Hrs)

Distribution side reactive power management, System losses, loss reduction methods, reactive power planning, economics planning capacitor placement, retrofitting of capacitor banks, kVAR requirements for domestic appliances, distribution transformers, electric arc furnaces, basic operations, furnaces transformer, filter requirements, remedial measures, power factor of an arc furnace.

Text Books:

1. Reactive power control in Electric power systems by T. J. E. Miller, John Wiley and Sons, 1982.
2. Reactive power Management by D. M.Tagare, Tata McGraw Hill, 2004.

Reference Books:

1. Reactive Power Management: Reactive Power Control for greater efficiency by Rafael Barreto, Create Space Independent, 2014.
2. Reactive Power Control in AC Power Systems by Mahdavi Tabatabaei, Jafari Aghbolaghi, Blaabjerg, Springer, 2017.

EE 6111 CONTROL TECHNIQUES IN POWER ELECTRONICS Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Recognize different control techniques and design of compensators, controllers and observers.
CO2 Model and analyse various closed loop controllers.
CO3 Apply voltage mode control and current.
CO4 Design controllers for rectifiers and inverters.
CO5 Model and design of various controllers for BLDC and Reluctance motors.
CO6 Design controller for photovoltaic (PV) connected converters.

Module 1: Review of basic control theory: **(5 Hrs)**

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.

Module 2: Control of DC-DC converters. **(12 Hrs)**

Mathematical switched model and general framework, bilinear form, classical state space average modelling of basic buck, boost and buck-boost converter. Voltage mode control, Current mode control, two loop cascaded control structure of DC-DC converter, converters with non-minimum phase behavior, pole placement technique. Introduction of state feedback controllers and sliding mode controllers.

Module 3: Control of rectifiers and Inverters. **(9 Hrs)**

State space modeling of single phase and three phase rectifiers and inverters. Control in rotating d-q frame (Example of grid connected single phase DC-AC converter). Resonant controller-necessity and design method (Example of Three phase inverter and three phase active rectifier).

Module 4: Modelling of Brushless DC motors and its speed regulations **(5 Hrs)**

State space model, sensor less speed control of BLDC motor. Modelling and control of switched reluctance motor.

Module 5: Modeling of multi input DC-DC converters **(5 Hrs)**

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.

Text Books:

1. V.Ramnarayanan "Course Material on Switched Mode Power Conversion", IISC Bangalore, December 2, 2007.
2. Bacha, Seddik, Munteanu, Iulian, Bratcu, Antoneta Iuliana, "Power Electronics converters modelling and control", Spinger Nature, 2014 edition.
3. Bimal Bose, 'Power electronics and motor drives', Elsevier, 2006.

Reference Books:

1. Siew-Chong Tan, Yuk-Ming Lai, Chi Kong Tse, 'Sliding mode control of switching Power Converters', CRC Press, 2011.

2. Sira -Ramirez, R. Silva Ortigoza, 'Control Design Techniques in Power Electronics Devices', Springer, 2006.
3. Ion Boldea and S.A Nasar, 'Electric drives', CRC Press, 2005.

EE 6130 Nonlinear Control Theory Cr-3

(Department Level Common Subject)

Course Outcomes: At the end of the course, students will be able to:

CO1	Understand and model physical systems using state vectors.
CO2	Check controllability and observability of the physical system.
CO3	Design state feedback controllers and observers.
CO4	Understand and analyze non-linear systems.
CO5	Study the nonlinear system's behavior by phase plane and describing function method.
CO6	Inspect the stability of non-linear systems by Lyapunov's stability analysis.

Module 1: State Space Analysis and Design: (9Hrs)

Introduction, State space representation of physical systems, State representation using canonical variables, Characteristics equation, eigen values and eigen vectors, Evaluation of State Transition Matrix (STM), Similarity transformation and invariance of system properties due to similarity transformations, feedback control, Controllability and Controllable canonical form, Obsevability and Observable canonical form, Principle of duality .

Module 2 : Pole Placement Techniques: (9Hrs)

Introduction, State observers: Concept of state observer, Full order state observer, Determination of matrix K, Necessary and sufficient condition for state observation, determination of state observer gain matrix. Necessary and sufficient condition for arbitrary pole placement, Dual problem.

Module 3: Nonlinear Control Systems: (12 Hrs)

Introduction, Properties of Nonlinear systems, Classification of nonlinear systems, Phase plane analysis: Basic concept of phase plane, singular points, Limit cycle and jump resonance, stability of nonlinear systems, construction of phase trajectory, Describing function method: Describing function of common nonlinearities, Stability analysis by describing function method.

Module 4: Stability Analysis for Nonlinear Control Systems: (6 Hrs)

Introduction, Stability in the sense of Lyapunov, second method, stability theorem, Lyapunov function for linear and nonlinear system.

Text Books:

1. Advanced Control System, by B. N. Sarkar, PHI Learning, 2013.
2. Digital Control and State Variable Methods, M. Gopal, TMH Publication,2012.

Reference Books:

1. Modern Control Engg. by K. Ogata PHI Publication, 2010.
2. Control System Engg, by I.J. Nagrath and M Gopal, New age international publication,2007.
3. Automatic Control Systems by Benjamin C Kuo, Prentice-Hall, 1991.

4. Non Linear Systems Analysis by M Vidyasagar, Prentice Hall NJ, USA.
5. Nonlinear Systems by H.K Khalil, Prentice Hall, NJ,USA.

RENEWABLE POWER GENERATION TECHNOLOGIES Cr-3

EE 6208

Course Outcomes (CO): At the end of the course, the students will be able to

CO1	Understand various dynamic energy conversion technologies
CO2	Know the operation and principle of wind turbine
CO3	Understand various static energy conversion technologies
CO4	Apply the conversion of biomass from solid - liquid gas
CO5	Know basic configuration of energy storage technology
CO6	Design plugin hybrid vehicles

Module 1: Dynamic Energy Conversion Technologies (12Hrs)

Introduction to different conventional and nonconventional dynamic generation technologies, gas and micro turbines, hydro generation technologies, Feasibility of small, mini and micro hydel plants scheme layout economics. Tidal and wave energy, Geothermal and Ocean-thermal energy conversion (OTEC) systems schemes, feasibility and viability, Wind speed and power relation, power extracted from wind, wind distribution and wind speed predictions. Wind power systems : System components, Types of Turbine, Turbine rating Choice of generators, turbine rating, electrical load matching, Variable speed operation, maximum power operation.

Module 2: Static Energy Conversion Technologies (14Hrs)

Introduction to different conventional and nonconventional static generation technologies, Availability and limitations of solar energy – Measuring techniques and estimation of solar radiation – Solar thermal collectors – General description and characteristics – Flat plate collectors – Heat transfer processes – Short term and long term collector performance –Solar concentrators – Design, analysis and performance evaluation of solar energy technologies, photovoltaic based generators, Biomass - Conversion of biomass in other form of energy - solid, liquid and gases, Gasifiers, Biomass fired boilers, Cofiring, Generation from municipal solid waste, Issues in harnessing these sources.

Module 3: Energy Storage configurations: (10Hrs)

Energy storage: Battery - types, equivalent circuit, performance characteristics, battery design, charging and charge regulators. Battery management. fly wheel energy relations, components, benefits over battery. Fuel Cell energy storage systems. Ultra Capacitors, plug-in-hybrid vehicles

Text Books

1. Renewable Energy Resources, Second Edition, John Twidell& Tony Weir, Tailer& Fracis-2008
2. Non-Conventional Energy Resources, B.H. Khan,TMH, 2nd Edition-2009

Reference Books

1. Wind and Solar Systems by Mukund Patel, CRC Press, 2011.
2. Grid Integration, from: IEEE Journals (Transaction)

ENERGY AUDITING AND MANAGEMENT Cr - 3

EE 6206

Course Outcomes: At the end of the course, the students will be able to:

CO 1: Learn and apply various data analysis methodologies.
CO 2: Understand the concept of energy conservation and audit.
CO 3: Apply the energy policies and understand its impact.
CO 4: Analyze Combined Heating and Power system.
CO 5: Analyze various applications and types of energy audit.
CO 6: Create a report of energy audit of a system.

Module 1:General Aspects (10 Hrs)
Definitions of Energy Efficiencies, Estimation of Energy efficiencies in supply side and demand side, definition of energy conservation, management and audit, similarities and dissimilarities in financial audit and energy audit, approach, data collection and data analysis methodologies, demand and supply matching methodologies, optimization methodologies in input and output.

Module 2: Energy Utilization and Conversion System (12 Hrs)
Classification of furnace, controlled atmosphere in furnace, furnace fuels, efficiency of energy in furnace, thermal efficiency, Heat losses, reducing heat losses in hydraulic power systems compressed air, heat recovery, drying and leak, operating conditions, steam turbine as alternatives to electric motors combined power and heating systems.

Module 3 Applications of Energy Audit (14 Hrs)
Definition of energy audit, need for energy audit, energy audit and reporting format, financial audit. Peak load, average load, firm power, dump power, secondary power, load curve, load distribution curve, plant capacity factor, energy index, cost index, budgeting and standard costing, representation of energy consumption, energy economics.

Text Books:

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy,'Guide to Energy Management',5th Edition, The Fairmont Press, Inc., 2006.

Reference Books:

1. Amit K. Tyagi, 'Handbook on Energy Audits and Management', The Energy and Resources Institute, 2003.
2. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.
3. +

EE6154 FLEXIBLE AC TRANSMISSION SYSTEMS Cr: 3

Course Outcomes: At the end of the course, students will be able to

CO1 Know types of FACTS controllers
CO2 Understand static VAR compensators and their applications
CO3 Know the importance of compensator to manage active and reactive power
CO4 Design the Shunt and Series Compensators
CO5 Compare among GCSC, TSSC and TCSC
CO6 Implement the Unified Power Flow Controller (UPFC) for Power Quality Improvement

Module 1: Introduction: (10Hrs)

Definition of FACTS, Flow of power in an ac system- dynamic stability consideration- types of FACTS controllers- static shunt compensator, SVC & STATCOM, objectives of shunt compensation, methods of controllable VAR generation, switching converter type VAR generators, basic operating principle and control approaches.

Module 2: Shunt Compensation: (10Hrs)

Active and reactive power related to sending and receiving end, active and reactive power related to compensator, FACTS based shunt compensators: TCR, TSC (Analysis-waveforms, Effective reactance, Compensator Current and Reactive power, VI characteristics), STATCOM – (Analysis - phasor diagram, Compensator Current and Reactive power, VI characteristics).

Module 3: Series Compensation: (10Hrs)

Active and reactive power related to sending and receiving end, active and reactive power related to compensator. FACTS based series compensators: GCSC, TSSC and TCSC (Analysis-waveforms, Effective reactance, Compensator voltage and Reactive power).

Module 4: Combined Compensator: (6Hrs)

Combined Series –shunt Compensator: Unified Power Flow Controller (UPFC).

TEXT BOOKS:

1. K.R.Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International(P) Limited, Publishers, New Delhi, 2008.
2. N.G. Hingorani and L.Gyugyi "Understanding FACTS" Standard Publishers, Distributors, New Delhi.

REFERENCE BOOKS:

1. V.K.Sood,"HVDC and FACTS controllers – Applications of Static Converters in Power System" Kluwer Academic Publishers, 2004.
2. Xiao – Ping Zang, Christian Rehtanz and Bikash Pal, "Flexible AC Transmission System: Modelling and Control" Springer, 2012.

EE 6142 SOFT-COMPUTING TECHNIQUES Cr-3

Course Outcomes (CO): At the end of the course, the students will be able to

CO1. Know the soft computing techniques, paradigms for building intelligent systems.
CO2. Understand the concept of supervisory neural network and apply to real word problem by supervisory neural network .
CO3. Know the concept of unsupervisory neural network and apply it to real word problem.
CO4. Understand the concepts of fuzzy sets, knowledge representation using fuzzy rules
CO5. Apply Evolutionary algorithms to optimization problems.
CO6. Evaluate solutions by various soft computing approaches for a given problem.

Module-1: Introduction (10 Hrs)

Difference between Hard and Soft computing, fundamental concepts, Biological neural networks, Artificial neuron, activation functions, setting of weights, typical architectures, biases and thresholds, learning/training laws and algorithms, Hebbian learning, error correction learning, competitive learning, Boltzman learning, supervised learning, unsupervised learning, Perceptron, linear separability- XOR function.

ANN Paradigms (6 Hrs)

Multi-layer perceptron using back propagation algorithm (BPA), self organizing map (SOM), radial basis function network, functional link network (FLN), Hopfield Network.

Module-2: Fuzzy Logic (8 Hrs)

Introduction, fuzzy versus crisp, fuzzy sets, membership function, basic fuzzy set operations, properties of fuzzy sets, fuzzy Cartesian product, operations on fuzzy relations, fuzzyfication, fuzzy quantifiers, fuzzy inference, fuzzy rule based system, defuzzification methods.

Module-3: Genetic Algorithms (6 Hrs)

Introduction, encoding, fitness function, reproduction operators, genetic modeling, genetic operators, crossover, single site crossover. two point crossover, multi point crossover, uniform crossover, matrix crossover, crossover rate, inversion & deletion, mutation operator, mutation, mutation rate, bit–wise operators, generational cycle, convergence of genetic algorithm.

Module-4 Applications of AI Techniques (6 Hrs)

Load forecasting, load flow studies, economic load dispatch, load frequency control, single area system and two area system, small signal stability (dynamic stability), reactive power control, speed control of DC and AC motors.

Text Books:

1. S. Rajasekaran and G. A. V. Pai, Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi, 2003.
2. D. E. Goldberg, Genetic Algorithm in search, optimization and machine learning, Addition Wesley Publication, NY.

Reference Books:

1. Zimmermann H. J., "Fuzzy Set Theory and Its Applications", Allied Publishers Ltd., 1999.
2. Klir G. J., Folger T., "Fuzzy Sets, Uncertainty and Information", Prentice Hall of India, 5th. Indian reprint, 2002.
3. Zurada J. M., "Introduction to Artificial Neural Systems", Jaico Publishing House, 2006.

4. Mohammad H. Hassoun, "Fundamentals of Neural Networks", Prentice Hall of India, 2002.

EE 6144 ANALYSIS AND DESIGN OF POWER CONVERTERS Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Learn the design of power electronics converters for different applications
CO2 Interpret the design of High Frequency transformers and Inductors
CO3 Analyse the working and application of inverters
CO4 Apply the operation of resonant converter and SMPS in various industries.
CO5 Understand the power quality improvement strategies using power electronic converters.
CO6 Design the gate driver circuit for different semiconductor devices.

Prerequisites: Power Converters (EE 6105)

Module 1: AC – DC Converters (5 Hrs)

Single phase Rectifier Circuit: *L* and *C* filter design, performance parameters, Concept of Heat Sinks.

Module 2: DC to DC Converters (7 Hrs)

Non-isolated dc-dc converters: Design and operation of buck-boost, Cuk, SEPIC, Zeta in DCM and CCM.

Module 3: Switch Mode Power Supply (6 Hrs)

Isolated dc-dc converters: Operation of Flyback Converter, Forward Converter andpush-pull Converters in CCM.Current Mode Control; Magnetic Materials suitable for high frequency transformers.

Module-4: Resonant Converters (7 Hrs)

Introduction to Soft switching, difference between hard and soft switching, basic resonant circuit concept; ZCS and ZVS resonant converters; Electronic Ballasts.

Module 5: Inverters (8 Hrs)

Review of Inverter circuits. Modulation Strategies: Bipolar and Unipolar switching scheme; Performance parameters of 3 phase Sinusoidal PWM Inverters; Harmonic reduction techniques, Multi-level inverters, advantages, configurations: Diode clamped, flying capacitor and cascade multi-level inverters, applications.

Module-6: Gate drive Circuits: (3 Hrs)

Gate drive circuits for Thyristor, MOSFET, IGBT, BJT, GTO

Text Books:

1. Power Electronics By M.H. Rashid Pearson Education , 3rd Edition,2009.
2. Power Electronics , Converters , Applications and Design, by N . Mohan, Underland and Robbins , John Wiely and Sons, 3rd Edition,2011.

Reference Books:

1.Power Electronics By M.D . Singh and K.B. Khanchandani, Tata McGraw - Hill publishers, 2nd edition,2008.
2. Modern Power Electronics, by P.C Sen, Wheeler publishing Co, First Edition,2009.

3. Elements of Power Electronics, by Philip T. Krein, Oxford University Press,25 Sept 1997.

EE 6322 Distributed Generation Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Understand the importance of DG and its current scenario.
CO2 Know different types of interfaces for Grid integration of DGs.
CO3 Understand the technical impacts of DGs penetration in transmission and distribution systems.
CO4 Compare the various control techniques of different DG sources.
CO5 Know protection related issues in micro-grids and transient.
CO6 Understand the planning and operational issues related to DG and Micro- grids.

Module 1: Importance of Distributed generation (DG) (4hrs)
Introduction, current scenario in Distributed Generation, Renewable sources in distributed generation, Planning of DGs – Siting and sizing of DGs.

Module 2: Grid integration of DGs (10hrs)
Different types of interfaces and control - 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, optimal placement of DG sources in distribution systems. De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems.

Module 3: Economic and control aspects of DGs (10hrs)
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.

Module 4: Introduction to micro-grids (12hrs)
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.

Text 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.

Reference Books:

1. 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.
2. Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson 'Facility Microgrids', Subcontract report, May 2005.

EE 6306 DIGITAL PROTECTION IN POWER SYSTEM Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Know basics of Static Relays and Protection scheme of transmission line
CO2 Understand the applications of static relay
CO3 Know the operational of numerical relay
CO4 Understand on digital protection of transmission line
CO5 Know digital protection of synchronous generator
CO6 Know digital protection of power transformer

Module 1: Static Relay: (8 Hrs)

General Introduction to Static Relays, Comparator and Associated Elements, Solid State Power Supply Circuit, Timer Relays and Voltage Relays, Differential Relays, Distance relay and Microprocessor Applications to Protection.

Module 2: Numerical Protection: (8 Hrs)

Introduction, block diagram of numerical relay, sampling theorem, correlation with a reference wave, least error squared (LES) technique, digital filtering, and numerical over current protection.

Module 3: Digital Protection of Transmission Line: (8 Hrs)

Introduction, Protection scheme of transmission line, distance relays, traveling wave relays, digital protection scheme based upon fundamental signal, hardware design, software design, digital protection of EHV/UHV transmission line based upon traveling wave phenomenon, new relaying scheme using amplitude comparison.

Module 4: Digital protection of Synchronous Generator: (6 Hrs)

Introduction, faults in synchronous generator, protection schemes for synchronous generator, digital protection of synchronous generator.

Module 5: Digital Protection of Power Transformer: (6 Hrs)

Introduction, faults in a transformer, schemes used for transformer protection, digital protection of transformer.

Text Books:

1. Digital Protection, L. P. Singh, (New Age International (P) Limited Publishers, New Delhi, 2nd Edition).
2. Power System Protection; Static Relays with Microprocessor Applications, 2nd Edition, T.S.Madhava Rao, Tata Mc Graw Hill.

Reference Books

1. Transmission Network Protection Paithankar (Marcel&Dekker, New York)
2. Digital Relay / Numerical relays – T.S.M. Rao, Tata Mc Graw Hill, New Delhi.
3. Fundamentals of Power System Protection Paithankar&Bhide (Prentice Hall of India Pvt Ltd., New Delhi)
4. Protective Relaying for Power System II Stanley Horowitz (IEEE press , New York)

EE 6132 SOLAR POWER ENGINEERING Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Analysis limiting parameters and its applications for Solar PV cell
CO2 Comprehend the construction and working principle of different solar PV cell
CO3 Identify the field of application of Solar Electric Power.
CO4 Realize power conditioning and MPPT operation.
CO5 Understand the design and sizing of Solar power plant.
CO6 Know about present and future scope of solar energy and its storage system.

Prerequisites: Nil

Module 1: Design of Solar Cells: (6Hrs)
Limits of cell parameter, losses in solar cell, solar cell design, Analytical techniques.

Module 2: Solar Cell Technologies: (6Hrs)
Production of Si, Growth of solar PV industry and Si requirements, Production of MGS and EGS, Si wafer based solar cell technology, Thin film solar cell technologies, Concentrator PV cells and Systems, Emerging solar cell technologies and concepts.

Module 3: Solar PV Application (8Hrs)
Solar radiation, Sun tracking, estimating solar Radiation Empirically, Measurement of solar Radiation, Solar PV modules, Mismatch in series and parallel connection, Design and structure of PV Modules, power output.

Module 4:Balance of Solar PV Systems: (8Hrs)
Basic of electrochemical cell, Factors affecting the battery performance, Batteries for PV systems, Algorithm of MPPT, Charge controller.

Module 5: Photovoltaic System Design: (8Hrs)
Introduction to Solar PV systems, Stand alone PV system configurations, Design methodology PV systems, Wire sizing in PV system, Precise sizing of PV systems , Hybrid PV systems, Grid connected PV systems, Simple payback period, Life cycle costing(LCC).

Text Books:

1. Solar Photovoltaic's Fundamentals, Technologies and Applications by Chetan Singh Solanki, PHIPublication 2nd Edition 2011.

2. Wind and solar systems by Mukund Patel, CRC Press,2006

Reference Book

1. Terrestrial Solar photovoltaic's by Tapan Bhattacharya, Narosa Publishing House 2010.

2. Energy Technology – S. Rao, and B.B. Parulkar,2009.

3. Non-conventional Energy Resources, by N K Bansal, Vikash publisher, 1st edition-2013

EE 6136 **WIND POWER ENGINEERING** **Cr-3**

Course Outcomes:

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

CO1 Understand operating principle of power generation
CO2 Know wind power control strategies
CO3 Study major power electronics components in wind power plants
CO4 Analysis Economics aspects of Wind Power Plants
CO5 Develop the concept of grid integration with wind power plant
CO6 Know the operation and maintenance issues of wind power plants

Module 1: Wind Power : **(6 Hrs)**

Wind Power in India, IEC Standards for Wind Turbines, State Government Policy for Wind Power Project Investment.Wind Characteristics:Power in the wind: Conversion of Wind to Electric Energy.

Module 2: Wind Power Plant **(8 Hrs)**

Types of Wind Power Plant:Components of Wind Power Plants:Working of Wind Power Plants: Aerodynamic Power Regulation of Wind Power Plants:Specifications of Wind Power Plants: Electrical Power Control Strategies.

Module 3: Major Power Electronics Components in Wind Power Plants **(10 Hrs)**

Power Electronics Wind Power Plants: Type-A WPP with Squirrel cage Induction generator: Type-B WPP with Wound Rotor Induction generator: Type-C WPP with Doubly-fed Induction generator: Type-D WPP with Wound Rotor Synchronous generator: Type-D WPP with Permanent Magnet Synchronous generator.

Module 4: Economics of Wind Power Plants **(6 Hrs)**

Wind Power Quality and Electrical Generators: Grid Integration of Wind Power Plants:Wind resource Assessment: Siting Of Wind Power Plants: Economics of Wind Power Plants: Choice of Wind Turbines: Wind Power Project development.

Module 5: Maintenance of Wind Power Plant components **(6 Hrs)**

Wind Power Policy:Wind Power and the Environment:Wind Power Planning:Public Perception and Acceptance:Operation and Maintenance Issues of Wind power Plants: Maintenance of Wind Power Plant components.

Text Books

1. Wind Power Plants and Project Development by Joshua Earnest , Tore Wizelius, PHI Publication.
2. Wind Energy Technology – Njenkins, John Wiley & Sons.

Reference Books

1. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley

EE 6328 DEREGULATED POWER SYSTEM Cr 3

Course Outcomes: At the end of course, students will be able to:

CO1 Understand the Entities involved in restructuring in power system.
CO2 Realize the salient features of Electricity act 2003 and reforms in Indian power sector
CO3 Know the fundamentals of economics and the philosophy of market models
CO4 Understand the transmission congestion management
CO5 Realize ancillary service management
CO6 Know the market power and generators bidding

Module 1: Introduction: (4Hrs)

Introduction, Reasons for restructuring / deregulation of power industry, Entities involved, The levels of competition, The market place mechanisms, Sector-wise major changes required), Introduction to issues involved in deregulation, Reasons and objectives of deregulation of various power systems across the world (The US, The UK, The Nordic Pool, The developing countries).

Module 2: Reforms in Indian power sector and The Electricity Act 2003 (6Hrs)

Introduction, Framework of Indian power sector, Operational Demarcation of the Power System, National and Transnational Grids, Reform initiatives during 1990-1995-The Independent Power Plants, Orissa Reform Model, Accelerated Power Development and Reforms Program (APDRP), Public-Private Partnership, Other Developments, The availability based tariff (ABT) - The Mechanism, Working of the mechanism, Effects of ABT, Intra-state ABT, The Electricity Act 2003-Provisions in the generation sector, Provisions in the transmission sector, Provisions in the distribution sector, Power trading, Other important changes; Open Access issues-Operational Practices, Transmission pricing, Loss allocation, Reservation of Transmission Capacity and Congestion Management, Reactive power support, Explanation of practices using illustrative example; Power exchange-The auction, The congestion management.

Module 3: Fundamentals of Economics (4Hrs)

Introduction, Consumer behavior-Total utility and marginal utility, Law of diminishing marginal utility, Consumer surplus, Consumer equilibrium, Market demand curve, Demand elasticity; Supplier behavior -Law of diminishing marginal product, Supply functions, Supplier equilibrium, Supplier surplus, Supplier elasticity; Market equilibrium-Global welfare, Deadweight loss; Short-run and Long-run costs, Various costs of production-Total cost (TC), Average fixed cost (AFC), Average variable cost (AVC), Average cost (AC), Marginal cost (MC)), Relationship between short-run and long-run average costs, Perfectly competitive market.

Module 4: The Philosophy of Market Models (6Hrs)

Introduction, Market models based on contractual arrangements-Monopoly model, Single buyer model, Wholesale competition model, Retail competition model; Comparison of various market models, Electricity vis-à-vis other commodities -Distinguishing features of electricity as a commodity, Four pillars of market design (Imbalance, Scheduling and Dispatch, Congestion Management, Ancillary Services; Market architecture-Timeline for various energy markets, Bilateral / forward contracts; The spot market -Discriminatory or non-discriminatory pricing?, Simple bids or complex bids, Day-ahead and real-time market; Models for trading arrangements-Integrated or centralized model, Decentralized model, Comparison between trading arrangement models, ISO or TSO model.

Module 5: Transmission Congestion Management (6Hrs)

Definition of congestion, Reasons for transfer capability limitation, Importance of congestion management in deregulated environment, Effects of congestion, Desired features of congestion management schemes, Classification of congestion management methods-Basis for classification, Non-market methods,. Market methods; Calculation of ATC, Definition of various terms-ATC, TTC, TRM, CBM; ATC calculation using PTDF and LODF based on DC model - DC Load flow model, Power Transfer Distribution Factor (PTDF), Calculation of PTDF using DC model, ATC calculation using PTDF, Line Outage Distribution Factor (LODF), ATC calculation using PTDF and LODF, Calculation of ATC using AC model; Non-market methods - Capacity allocation on first come first served basis, Capacity allocation based on pro-rata methods, Capacity allocation based on type of contract, Market based methods-Explicit auctioning, Coordinated auctioning, Nodal pricing; OPF based congestion management -DC OPF, OPF with load elasticity, AC OPF, Interpretation of Lagrange multipliers, Implications of nodal pricing; Inter-zonal Intra-zonal congestion management, Price area congestion management -Algorithm, Illustrative example), Capacity alleviation method-Re-dispatching, Counter-trade, Curtailment, Comparison

Module 6: Ancillary Service Management (4Hrs)

Introduction to ancillary services, Types of ancillary services, Classification of ancillary services, Load-generation balancing related services-Frequency regulation, Load following, Spinning reserve services; Voltage control and reactive power support services-Different sources of reactive power-Generators, Synchronous condensers, Capacitors and inductors, SVCs, STATCOMs; Comparison between different sources of reactive power, Issues in reactive power management, Black start capability service, How to obtain ancillary services?, Mandatory provision of ancillary services, Markets for ancillary services, Co-optimization of energy and reserve services.

Module 7: Market power and generators bidding (6Hrs)

Attributes of a perfectly competitive market, The firm's supply decision under perfect competition, Imperfect competition-Monopoly, Oligopoly, Cournot model, Bertrand model, Electricity markets under imperfect competition; Market power-Sources of market power, Effect of market power; Identifying market power, HHI Index, Entropy coefficient, Lerner index; Market power mitigation-Effects of contract for differences, Role of demand side bidding; Financial markets associated with electricity markets-Forwards, Futures, Options, Swaps; Introduction to optimal bidding by a generator company-Bidding in real markets; Optimal bidding methods-Game theory, Markov decision process, Genetic algorithm, Equilibrium analysis, Conjectural variation, Bayesian analysis, Summary

Text Books:

1. Kankar Bhattacharya, Math H.J. Boller, Jaap E.Daalder, 'Operation of Restructured Power System' Klumer Academic Publisher,2010.
2. S.K.Gupta, "Power System Operation Control and Restructuring" I.K.International Publishing House Pvt. Ltd, New Delhi, 2015.

Reference Books:

1. Loi Lei Lai; "Power system Restructuring and Deregulation", Jhon Wiley & Sons Ltd., England.
2. Know Your Power", A citizens Primer On the Electricity Sector, Prayas Energy Group, Pune.
3. Sally Hunt, "Making Competition Work in Electricity", 2002, John Wiley Inc.

POWER ELECTRONICS AND DRIVES

RS 6001 FUNDAMENTALS OF RESEARCH METHODOLOGY Cr-3

Course Outcomes: At the end of the course, the students will be able to:

CO1 Conduct review of literature effectively
CO2 Formulate a viable research problem
CO3 Effectively write a technical paper based on research findings
CO4 Analyze and interpret research data
CO5 Develop awareness on IPR and allied issues
CO6 Follow ethical practices in research

Module 1: Introduction: (8 Hrs)

Types of research, Literature review, Research gap, Motivation, Research objectives and specifications, Formulation of research questions, Research approach, Research hypothesis.

Module 2: Research Writing: (8 Hrs)

Methodology to write a technical paper/short communication/research proposal/monograph, Abstract writing, Report or presentation of results, Bibliography.

Module 3: Data Analysis: (8 Hrs)

Classification of data, Methods of data collection, Statistical techniques, Design of experiments and choosing an appropriate statistical technique, Introduction to mathematical modeling (regression, model fitting), Hypothesis testing, Statistical inference.

Module 4: Intellectual Property: (8 Hrs)

Intellectual property, Patent, Trademark, GI, Copyright and related rights, Research Incentives, PCT and WIPO.

Plagiarism: Definition, Plagiarism and consequences, IPR Violation and Detection.

Module 5: Research Ethics: (4 Hrs)

Professional ethics in research, Ethical issues, Definition and importance, Ethical guidelines, Peer review, Research misconduct, Conflicts of interest.

Text Books:

3. C. R. Kothari, Research Methodology, New Age International, 2004.
4. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.

Reference Books:

1. J. W. Bames, Statistical Analysis for Engineers and Scientists, Tata McGraw-Hill, New York.
2. Donald Cooper, Business Research Methods, Tata McGraw-Hill, New Delhi.

3. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.
4. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
5. Manna, Chakraborti, Values and Ethics in Business Profession, Prentice Hall of India, New Delhi, 2012.
6. R. Subramanian, Professional Ethics, Oxford University Press, 2013.

EE 6105 POWER CONVERTERS CR-3

Course Outcomes: At the end of the course, students will be able to

CO1 Learn the characteristics and operation of power semiconductor devices.
CO2 Analyze the operation of Ac-DC converters.
CO3 Derive DC-DC converters for wider applicability
CO4 Conceptualize of DC-AC conversion techniques
CO5 Realize the operation of AC-AC converters
CO6 Design and apply the converters in various fields of application.

Module 1: Power Semiconductor Devices (5 Hrs)

Review of power semiconductor switching devices, Thyristors, MOSFET, IGBT and modern devices, characteristics and Applications, Introduction to Turn-ON/Turn-OFF mechanism of switching devices, Gate-drive circuits, Switching-aid circuits, protection, Heat sink design.

Module 2: AC-DC Conversion Techniques (8 Hrs)

Line- commutated rectifiers, single and three-phase rectifiers (controlled/ uncontrolled), performance analysis, harmonics, Ripple reduction techniques, Introduction to multi-pulse converters, applications.

Module 3: DC-DC Conversion Techniques (10 Hrs)

Switch-mode DC-DC Converters, pulse width modulation, Nonisolated and isolated Topologies, design of transformer for switch-mode power converters, continuous and discontinuous modes of operations, steady-state analysis, impact of voltage and current stress on the switches and reduction techniques, energy storage elements design, higher-order topologies, applications.

Module 4: DC-AC Conversion techniques (8 Hrs)

Inverters, single and three-phase inverter configurations, voltage and current source inverters and their operating modes, voltage control in inverters and harmonic reduction using PWM strategies, Introduction to Multi-level Inverters, applications.

Module 5: AC-AC Conversion Techniques (5 Hrs)

AC-AC voltage controllers, configurations, performance analysis, harmonics, Cyclo-converters, introduction to Matrix converters and their applications.

Text Books:

4. V. Ramanarayanan Course Material on Switched Mode Power Conversion, Department of Electrical Engineering, Indian Institute of Science, Bangalore 560012.

5. Elements of Power Electronics, by Philip T. Krein, Oxford University Press,25 Sept 1997.
6. Power Electronics By M. H. Rashid, Pearson Education, 3rd Edition, 2009.

Reference Book:

3. Power Electronics, Converters, Applications and Design N. Mohan, Undeland and Robbins, John WileyandSons , 3rd Edition ,2009.
4. Modern Power Electronics by P. C Sen, S Chand Publisher- 2013

EE 6107 POWER ELECTRONIC DRIVES CR-3

Course Outcomes: At the end of the course, students will be able to

CO1: Learn the stability criterion and importance of flywheel in electric drives
CO2: Analyze the motor selection for Industrial needs.
CO3: Modelling of DC machine and speed control through power electronics
CO4: Analyze the transient behaviour of any machine through closed loop control
CO5: Realize the speed control of induction motor drive
CO6: Modelling of inverter for control of AC.Machines

Module 1: DYNAMICS OF ELECTRICAL DRIVES (10 Hrs)

Basic Parameters of Electric Drive, Types of load, Equivalent values of drive parameters , Multi quadrant operation , steady state stability, Calculation of time and energy losses transient operation.

Module 2: PHASE CONTROLLED DC MOTORS DRIVES (8 Hrs)

Principle of DC motor speed control, Four quadrant operation, phase controlled DC drive (Single phase and three phase) , Steady state analysis of three phase control DC motor drive. Closed loop control , Transfer functioning of DC motor load.

Module 3: CHOPPER CONTROLLER DC DRIVE (8 Hrs)

Principle of operation of the chopper in four quadrants, steady state analysis of chopper control DC motor drives.

Module 4: INDUCTION MOTOR DRIVE: (10 Hrs)

Torque- speed characteristics of 3-phase induction motor drive, Equivalent circuit diagram, Variable- voltage, constant frequency operation, Constant Volt/Hz operation. Drive operating region. Variable stator current operation. The effects of harmonics torque pulsation. Stator voltage control steady state analysis. Voltage –source inverter driven induction motor drive and control strategies and its implementation. Current source induction motor drives and its implementation, Slip energy recovery scheme.

Text Book:

1. Fundamentals of Electric drives by G.K. Dubey Narosa publishing House, 3rd Edition, 2002

Reference Books:

1. Electric Motor Drives Modeling Analysis and Control by R Krishnan PHI 2nd edition 2002

2. Electric Drives by M. Chilkin Mir Publishers Moscow, 2nd Edition, 1997
3. Fundamentals of Electric Drives by Mohammad A. EI-Sharkawi, Thomson Asia Pvt Ltd, Singapore, 2007
4. Electric drives concept and application by Vedam Subrahmanyam, TMH, 2012
5. A first course of electrical drives by S K Pilai New age International Publisher, revised Edition 2013

EE 6109 POWER QUALITY ISSUES AND MITIGATION Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Know importance of power quality, terms and definitions of power quality.
CO2 Understand flickers and transients in power system.
CO3 Know Voltage Sag, Swells, Interruptions and its impact on power system.
CO4 Analyze the waveform distortion, harmonics effect in measuring power quality.
CO5 Know the impact of harmonics on power system.
CO6 Know different power quality monitoring techniques.

Modue-1: Introduction (6 Hrs)

Importance of power quality, terms and definitions of power quality as per IEEE std. 1159. such as transients, short and long duration voltage variations, interruptions, short and long voltage fluctuations, imbalance, flickers and transients. Symptoms of poor power quality.

Modue-2: Flickers & Transient Voltages: (8 Hrs)

RMS voltage variations in power system and voltage regulation per unit system, complex power. Principles of voltage regulation. Basic power flow and voltage drop. Various devices used for voltage regulation and impact of reactive power management. Various causes of voltage flicker and their effects. Short term and long term flickers. Various means to reduce flickers. Transient over voltages, sources, impulsive transients, switching transients, Effect of surge impedance and line termination, control of transient voltages.

Modue-3: Voltage Sag, Swells and Interruptions: (8 Hrs)

Voltage sags versus interruptions. Economic impact of voltage sag. Major causes and consequences. characteristics. assessment. Influence of fault location and fault level on voltage sag. Areas of vulnerability. Assessment of equipment sensitivity to voltage sags, CBEMA, ITIC, SEMI F 42 curves. Representation of the results of voltage sags analysis. Voltage sag indices. Mitigation measures for voltage sags, such as UPS, DVR, SMEs, CVT etc.

Modue-4: Waveform Distortion: (8 Hrs)

Definition of harmonics, Causes and effect of harmonics. Voltage versus current distortion. Harmonic indices. A.C. quantities under non-sinusoidal conditions. Triplen harmonics, characteristics and non characteristics harmonics. Harmonics series and parallel resonances. Consequences of harmonic resonance. Principles for controlling harmonics. Reducing harmonic currents in loads. Harmonic study procedure. Computer tools for harmonic analysis. Locating sources of harmonics.

Modue-5: Power Quality Monitoring (6 Hrs)

Need of power quality monitoring and approaches followed in power quality monitoring. Power quality monitoring objectives and requirements. Initial site survey. Power quality Instrumentation. Selection of power quality monitors, selection of monitoring location and period. Setting thresholds on monitors, data collection and analysis. Transient monitoring, event recording and flicker monitoring.

Text Books:

3. Electrical Power System Quality , by R C Dugan, M.F Mcgranaghan, S. Santoso& H W Beaty, 2nd Edition TMH publication- 2008.
4. Electric Power Quality by Heydt, G T, Stars in a circle publications, Indiana 2nd edition-1994

Reference Books:

3. Arrillaga J and Watson RN, Chen S, Power system Quality Assessment, Wiley New York-2000.
4. Bollen M H J, Understanding Power Quality Problems,: Voltage Sag and interruptions, IEEE press NY-2000.

EE 6111 CONTROL TECHNIQUES IN POWER ELECTRONICS Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Recognize different control techniques and design of compensators, controllers and observers.
CO2 Model and analyse various closed loop controllers.
CO3 Apply voltage mode control and current.
CO4 Design controllers for rectifiers and inverters.
CO5 Model and design of various controllers for BLDC and Reluctance motors.
CO6 Design controller for photovoltaic (PV) connected converters.

Module 1: Review of basic control theory: **(5 Hrs)**

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.

Module 2: Control of DC-DC converters. **(12 Hrs)**

Mathematical switched model and general framework, bilinear form, classical state space average modelling of basic buck, boost and buck-boost converter. Voltage mode control, Current mode control, two loop cascaded control structure of DC-DC converter, converters with non-minimum phase behavior, pole placement technique. Introduction of state feedback controllers and sliding mode controllers.

Module 3: Control of rectifiers and Inverters. **(9 Hrs)**

State space modeling of single phase and three phase rectifiers and inverters. Control in rotating d-q frame (Example of grid connected single phase DC-AC converter). Resonant controller-necessity and design method (Example of Three phase inverter and three phase active rectifier).

Module 4: Modelling of Brushless DC motors and its speed regulations (5 Hrs)

State space model, sensor less speed control of BLDC motor. Modelling and control of switched reluctance motor.

Module 5: Modeling of multi input DC-DC converters (5 Hrs)

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.

Text Books:

4. V.Ramnarayanan "Course Material on Switched Mode Power Conversion", IISC Bangalore, December 2, 2007.
5. Bacha, Seddik, Munteanu, Iulian, Bratcu, Antoneta Iuliana, "Power Electronics converters modelling and control", Spinger Nature, 2014 edition.
6. Bimal Bose, 'Power electronics and motor drives', Elsevier, 2006.

Reference Books:

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

EE 6303 COMPUTER ANALYSIS IN POWER SYSTEM Cr-3

Course Outcomes (CO) : At the end of the course, the students will be able to

CO1 formulate Bus admittance matrix during load flow study.
CO2 model for power system components using graph theory.
CO3 formulate incidence and network matrix of 3-phase networks.
CO4 formulate the Bus impedance matrix using Bus impedance building algorithm.
CO5 analyze the different fault study of 3-phase network using Z_{bus}.
CO6 know the transient stability analysis.

Module-1

Load Flow Study using Computer Techniques: (11 Hrs)

Formation of Y_{bus} with regulating transformer, Network matrices, Reference frame, Network graph, Tree, branch, Basic loop and Cut sets, Basic Incidence matrices, Augmented matrices, Primitive networks, Network matrices by Singular and Non-singular transformation with different Reference frame.

Module-2

Studies of Three Phase Networks: (17 Hrs)

Elements in impedance and admittance form, Balance and Un-balance excitation, Transformation matrices for symmetrical components, Incidence and network matrix for 3-phase elements, Formation of Z_{bus} through Bus impedance building algorithm, Short circuit study and analysis of symmetrical and un-symmetrical fault of balanced network using Z_{bus}.

Module-3

Transient stability Analysis: (8 Hrs)

Load representation, Network performance equation, Swing equation, Machine equation, Solution techniques in transient stability study using Eulers and Runge Kutta 4^{th} order method.

Text Books:

3.Computer Methods in Power System Analysis by Glenn W. Stagg, Ahmed H. El-Abiad, McGraw-Hill Book Company, International Editions, 2009.

4.Advanced Power System Analysis and Dynamics by L. P. Singh, New Age International (P) Limited, Publishers, Revised 4th Edition, 2011.

Reference Books:

5.Power System Analysis by N.V.Ramana, Pearson Publication,2011

6.Computer application techniques in Power System by M.A.Pai, TMH, 2006.

7.Computer Aided Power System Analysis, by George L. Kusic, PHI, 2005

8.Power System Analysis by John J. Grainger and William D.Stevenson, McGraw-Hill, 2016.

EE6211 INTEGRATION AND CONTROL OF RENEWABLES Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1 Understand the effects of renewable energy penetration into the grid

CO2 Know various MPPT control techniques for solar PV system

CO3 Understand different synchronization techniques.

CO4 Control real and reactive power fed to the grid

CO5 Study of integration of different Energy Conversion Technologies

CO6 Analyze grid connected and islanding mode of operations

Module-1: Introduction (8Hrs)

Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements

Module 2: MPPT control techniques in solar PV system: (8Hrs)

MPPT Control approach, Perturb and Observe (P&O) Method, Incremental Conductance Method (INCond.), Open-Circuit Voltage Method, Short-Circuit Current Method, Fuzzy Logic Controller, Other MPPT algorithms

Module-3: Real and reactive power control (10Hrs)

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

Module-4: Integration of different Energy Conversion Technologies (10Hrs)

Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus

Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

Text Books:

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

Reference Book:

1. Quing-Chang Zhong, "Control of Power Inverters in Renewable Energy and Smart Grid Integration", Wiley, IEEE Press

EE 6141 MICROCONTROLLER APPLICATIONS Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1 Know low cost microcontroller architecture.
CO2 Understand the Pin configuration of 8051 and ATMEL 89C51
CO3 Know AVR programming for ATMEGA 328.
CO4 Apply different programming techniques like shifting , branching in AVR.
CO5 Design interface circuit for stepper motor control using ATMEGA 328.
CO6 Generate PWM signals for single phase voltage source Inverter.

Module-1: 8051 and ATMEL 89C51 Microcontrollers: (12 Hrs)

Introduction, over view of 8051 family. Architecture of 8051 MC, Addressing modes, Instruction sets, timers & counters, simple programming. ATMEL 89C51 microcontroller: feature, description, pin configuration, pin descriptions, programming the flash and programming interface.

Module-2: AVR Microcontrollers: (14 Hrs)

Overview of AVR family, AVR microcontroller architecture, Register, ATMEGA 328 pin configuration & function of each pin, addressing modes of AVR, AVR status register, rotate and shift, branch and call instructions, AVR data types and assembler directives, AVR I/O port programming, AVR programming in assembly language and C, AVR development boards.

Module-3: Applications of Microcontrollers: (10 Hrs)

Microcontroller based DC and stepper motor control system, ADC and DAC interfacing with microcontrollers, PWM signal generation for single phase inverter, digital PID controller implementation using microcontroller, sensor interfacing with microcontrollers.

Text Books:

3. Desmukh, "Microcontrollers - Theory and Applications" 1st edition TMH publications, 2005

4. Muhammad Ali Mazidi, Sepehr Naimi, "Sarmad Naimithe AVR controller and embedded systems using assembly and C" Pearson Education Inc, 2017

Reference Books:

5. M.A. Mazidi, "The 8051 microcontroller and embedded systems" Pearson, 2nd edition, 2011
6. Md. Rafiquzzaman, "Microprocessors & Microcomputers based System Design" -UBS, 2nd edition, 1995
7. Udayashankara and M Mallikarjunaswamy, "8051 microcontroller-Hardware, software and applications, THM, 1st edition, 2009.
8. S. K. Venkat Rama, "Advanced microprocessors and microcontrollers" Laxmi publications, 1st edition, 2004.

EE 6235 DISCRETE AND DIGITAL SIGNAL PROCESSING Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Understand the basics of discrete-time signals, systems and Z-Transform.
CO2 Perform discrete-time Fourier Transform and Fast Fourier Transform of Discrete Signals.
CO3 Design various Digital Filters using Estimation and Prediction Techniques.
CO4 Understand the basic architecture of Digital Signal Processors.
CO5 Design and Implement various Discrete/ Digital Systems.
CO6 Design DSP system architecture using VHDL programming.

Module-1: Introduction (5 Hrs)

Review of Discrete – Time Signal & System, Mathematical description of change of sampling rate– Interpolation and Decimation, Transformation of Discrete- time Signal, representation in Z-domain, Inverse Z-Transform &Properties

Module-2: Discrete- Time Fourier Transform and Fast Fourier Transform (8 Hrs)

Sampling in Fourier domain - Discrete Fourier Transform and its properties – Linear filtering using DFT – Resolution of DFT - FFT Algorithm – Radix-2 FFT Algorithm - DIT & DIF Structures - Higher Radix schemes, Filter implementation for sampling rate conversion – direct form FIRstructures, DTFT, FFT, Wavelet transform and filter bank implementation ofwavelet expansion of signals.

Module-3: Estimation and Prediction Techniques (8 Hrs)

Discrete Random Processes – Ensemble averages, Stationary processes,Autocorrelation and Auto covariance matrices, Parseval's Theorem, Wiener-Khintchine Relation, Power Spectral DensityAR, MA, ARMA model basedspectral estimation, Parameter Estimation, Linear prediction, Forward andbackward predictions, Least mean squared error criterion, Wiener filter forfiltering and prediction, Discrete Kalman filter.

Module-4: Digital Signal Processor (7 Hrs)

Basic Architecture – Computational building blocks,MAC, Bus Architecture andmemory, Data Addressing, Parallelism and pipelining, Parallel I/O interface,Memory Interface, Interrupt, DMA.

Module-5:Application of DSP (5 Hrs)

Design of Decimation and Interpolation Filter, PID Controller,Application for Serial Interfacing, DSP based PowerMeter, Position control

Module-6:VLSI Implementation (3 Hrs)

Basics on DSP system architecture design using VHDLprogramming, Mapping ofDSP algorithm onto hardware, Realisation of MAC & Filter structure.

Text Books:

1. Monson H. Hayes, "Statistical Digital Signal Processing and Modelling", JohnWiley and Sons, Inc.
2. John G. Proaks, Dimitris G. Manolakis, "DigitalSignal Processing", PearsonEducation 2002.

Reference Books:

1. BernardWidrow, Samuel D. Stearns, Adaptive Signal Processing", Pearson Education, third edition, 2004.
2. Dionitris G. Manolakis, Vinay K. Ingle, Stepen M. Kogon,"Statistical & Adaptive signal processing, spectral estimation, signal modeling, Adaptivefiltering& Array processing", McGraw-Hill International edition 2000.
3. S. Salivahanan, A. Vallavaraj and C. Gnanapriya"Digital Signal Processing",TMH,2000.
4. Avatar Sing, S. Srinivasan, "Digital Signal Processing- Implementation using DSP Microprocessors with Examples from TMS320C54xx", Thomson India,2004.
5. Lars Wanhammer, "DSP Integrated Circuits", Academic press, 1999,New York.
6. Ashok Ambardar,"Digital Signal Processing: A Modern Introduction",Thomson India edition, 2007.
7. Lars Wanhammer, "DSP Integrated Circuits", Academic press, 1999,NewYork.

2nd Semester

EE 6130 NONLINEAR CONTROL THEORY Cr-3

(Department Level Common Subject)

Course Outcomes: At the end of the course, the students will be able to:

CO1. Understand and model physical systems using state vectors.

CO2. Check controllability and observability of the physical system.

CO3. Design state feedback controllers and observers.

CO4. Understand and analyze non-linear systems.

CO5. Study the nonlinear system's behavior by phase plane and describing function method.

CO6. Inspect the stability of non-linear systems by Lyapunov's stability analysis.

Module 1: State Space Analysis and Design: (9 Hrs)

Introduction, State space representation of physical systems, State representation using canonical variables, Characteristics equation, eigen values and eigen vectors, Evaluation of State Transition Matrix (STM), Similarity transformation and invariance of system properties due to similarity transformations, feedback control, Controllability and Controllable canonical form, Obsevability and Observable canonical form, Principle of duality .

Module 2 : Pole Placement Techniques: (9 Hrs)

Introduction, State observers: Concept of state observer, Full order state observer, Determination of matrix K, Necessary and sufficient condition for state observation, determination of state

observer gain matrix. Necessary and sufficient condition for arbitrary pole placement, Dual problem.

Module 3: Nonlinear Control Systems: (12 Hrs)

Introduction, Properties of Nonlinear systems, Classification of nonlinear systems, Phase plane analysis: Basic concept of phase plane, singular points, Limit cycle and jump resonance, stability of nonlinear systems, construction of phase trajectory, Describing function method: Describing function of common nonlinearities, Stability analysis by describing function method.

Module 4: Stability Analysis for Nonlinear Control Systems: (6 Hrs)

Introduction, Stability in the sense of Lyapunov, second method, stability theorem, Lyapunov function for linear and nonlinear system.

Text Books:

3. Advanced Control System, by B. N. Sarkar, PHI Learning, 2013.
4. Digital Control and State Variable Methods, M. Gopal, TMH Publication,2012.

Reference Books:

6. Modern Control Engg. by K. Ogata PHI Publication, 2010.
7. Control System Engg, by I.J. Nagrath and M Gopal, New age international publication,2007.
8. Automatic Control Systems by Benjamin C Kuo, Prentice-Hall, 1991.
9. Non Linear Systems Analysis by M Vidyasagar, Prentice Hall NJ, USA.
10. Nonlinear Systems by H.K Khalil, Prentice Hall, NJ,USA.

EE 6110 DESIGN OF SMPS AND PWM CONVERTERS Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Know Different PWM Techniques of Inverters.
CO2 Design Multilevel voltage source Inverters.
CO3 Understand the operation of resonant DC-DC converters.
CO4 Analyze soft switching technique of converters.
CO5 Know the design aspects of isolated DC-DC converters.
CO6 Design and control switched mode power supply.

Prerequisites: Power Converters (EE 6105)

Module 1: Inverters: (10 Hrs)

VSI, CSI, PWM techniques for inverters. Multi level Inverters (NPC, Cascaded, Switched Capacitor) and control technique.

Module 2: Resonant Converters: (12 Hrs)

Classification of resonant converters, Basic resonant circuit concepts, Series Resonant Inverters, half bridge and full bridge. Series loaded resonant converters , Parallel loaded resonant

converters. Class E resonant converters. Quasi Resonant converters: ZCS & ZVS resonant switch converters. ZVS buck converter.

Module 3: Switch Mode Power Supply: (14 Hrs)

Overview, DC – DC converters with isolation. Fly Back Converters. Forward Converters. Design of Filter Inductor for Switching Regulators. Design of Transformer for Fly Back and Forward converters. Design of Filter Capacitor for fly back converter. Push – Pull Converter, Half Bridge & Full Bridge Converters. Control of SMPS.

Text Books:

1. Power Electronics, Converters, Applications &Design N. Mohan, Undeland& Robbins, Wiley publication, 4th edition 2014.
2. Course Material on Switched Mode Power Conversion, V.Ramnarayanan ,IISC Bangalore, December 2, 2007.

Reference Book :

1. Power Electronics Circuits, Devices, Applications (3rd Edition) By M.H. Rashid , 12th Edition, PHI publication, 2016.

EE6108 VECTOR CONTROL OF ELECTRIC DRIVES Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1	Learn the conversion principles of any phase to two phase system
CO2	Analyze the importance of field oriented control of induction motor drive
CO3	Analyze the implementation of sensorless vector control
CO4	Conceptualize of different types of synchronous motor drive and brush less drive.
CO5	Realize the control operation of synchronous motor drive
CO6	Modelling and apply the reluctance motor drive

Prerequisites: Power Electronic Drives (EE 6107)

Module-1:Vector Controller Induction Motor Drive (10 Hrs)

Dynamic d-q model of 3 phase induction motor d-q equivalent circuit(stator, rotor, synchronously rotating reference frames model), equation of flux linkage, small signal equations of induction motor, dynamic model state space equations, Principles of vector control, direct vector control, implementation with voltage source, Derivation of indirect vector control scheme.

Module-2: Parameter Compensation (10 Hrs)

Parameter sensitivity of the indirect vector controller induction motor drive, Parameter Sensitivity compensation, Speed- Controller design for an indirect vector controller induction motor drive, Sensorless vector control.

Module-3: Permanent- Magnet Synchronous Motor Drives (8 Hrs)

Permanent magnet – Synchronous and Brush less DC motor drive: Equivalent circuits of synchronous machines, Developed torque dynamic d-q machine model of synchronous machine, synchronous reluctance machine, permanent magnet machine, permanent magnet materials and

characteristics, sinusoidal interior magnet machine trapezoidal surface magnet machine, variable reluctance machine.

Module-4: Vector Control Synchronous Motor Drives (8 Hrs)

Vector control of PM synchronous machine, control strategies (constant torque angle control, unit power factor control, constant flux linkage control, optimum torque per ampere control). Flux weakening operation, Speed – controller design, Sensor less control, PM Brush less DC motor(PMBDCM), Modeling of PM Brush less DC motor. Synchronous reluctance- Machine drives. Current vector control of synchronous reluctance motor drive. Switched Reluctance motor drives.

Text Books:

1. Electric Motor Drives Modeling , Analysis and Control by R. Krishnan , PHI, 2010
2. Modern Power Electronics & AC Drives by Bimal Kumar Bose(Pearson Education), 2009

Reference Books :

1. Vector control dynamics of AC drives T W Novotony T A Lipo , Oxford science Publication , 2012
2. Neural and Fuzzy logic control of drives and power system, M N Cirstea, A. Dinu, J G Khor, M Mcormic, Elsiever, 2011

EE6154 FLEXIBLE AC TRANSMISSION SYSTEMS Cr. 3

Course Outcomes: At the end of the course, students will be able to

CO1 Know types of FACTS controllers
CO2 Understand static VAR compensators and their applications
CO3 Know the importance of compensator to manage active and reactive power
CO4 Design the Shunt and Series Compensators
CO5 Compare among GCSC, TSSC and TCSC
CO6 Implement the Unified Power Flow Controller (UPFC) for Power Quality Improvement

Module 1: Introduction: (10Hrs)

Definition of FACTS, Flow of power in an ac system- dynamic stability consideration- types of FACTS controllers- static shunt compensator, SVC & STATCOM, objectives of shunt compensation, methods of controllable VAR generation, switching converter type VAR generators, basic operating principle and control approaches.

Module 2: Shunt Compensation: (10Hrs)

Active and reactive power related to sending and receiving end, active and reactive power related to compensator, FACTS based shunt compensators: TCR, TSC (Analysis-waveforms, Effective reactance, Compensator Current and Reactive power, VI characteristics), STATCOM – (Analysis - phasor diagram, Compensator Current and Reactive power, VI characteristics).

Module 3: Series Compensation: (10Hrs)

Active and reactive power related to sending and receiving end, active and reactive power related to compensator. FACTS based series compensators: GCSC, TSSC and TCSC (Analysis-waveforms, Effective reactance, Compensator voltage and Reactive power).

Module 4: Combined Compensator: (6Hrs)

Combined Series –shunt Compensator: Unified Power Flow Controller (UPFC).

Text Books:

1. K.R.Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International(P) Limited, Publishers, New Delhi, 2008.
2. N.G. Hingorani and L.Gyugyi "Understanding FACTS" Standard Publishers, Distributors, New Delhi.

Reference Books:

3. V.K.Sood,"HVDC and FACTS controllers – Applications of Static Converters in Power System" Kluwer Academic Publishers, 2004.
4. Xiao – Ping Zang, Christian Rehtanz and Bikash Pal, "Flexible AC Transmission System: Modelling and Control" Springer, 2012.

EE 6142 SOFT-COMPUTING TECHNIQUES Cr-3

Course Outcomes (CO): At the end of the course, the students will be able to

CO1 Know the soft computing techniques, paradigms for building intelligent systems.
CO2 Understand the concept of supervisory neural network and apply to real word problem by supervisory neural network .
CO3 Know the concept of unsupervisory neural network and apply it to real word problem.
CO4 Understand the concepts of fuzzy sets, knowledge representation using fuzzy rules
CO5 Apply Evolutionary algorithms to optimization problems.
CO6 Evaluate solutions by various soft computing approaches for a given problem.

Module-1: Introduction: (10 Hrs)

Difference between Hard and Soft computing, fundamental concepts, Biological neural networks, Artificial neuron, activation functions, setting of weights, typical architectures, biases and thresholds, learning/training laws and algorithms, Hebbian learning, error correction learning, competitive learning, Boltzman learning, supervised learning, unsupervised learning, Perceptron, linear separability- XOR function.

ANN Paradigms: (6 Hrs)

Multi-layer perceptron using back propagation algorithm (BPA), self organizing map (SOM), radial basis function network, functional link network (FLN), Hopfield Network.

Module-2 Fuzzy Logic: (8 Hrs)

Introduction, fuzzy versus crisp, fuzzy sets, membership function, basic fuzzy set operations, properties of fuzzy sets, fuzzy Cartesian product, operations on fuzzy relations, fuzzyfication, fuzzy quantifiers, fuzzy inference, fuzzy rule based system, defuzzification methods.

Module-3 Genetic Algorithms: (6 Hrs)

Introduction, encoding, fitness function, reproduction operators, genetic modeling, genetic operators, crossover, single site crossover. two point crossover, multi point crossover, uniform crossover, matrix crossover, crossover rate, inversion & deletion, mutation operator, mutation, mutation rate, bit–wise operators, generational cycle, convergence of genetic algorithm.

Module-4 Applications of AI Techniques: (6 Hrs)

Load forecasting, load flow studies, economic load dispatch, load frequency control, single area system and two area system, small signal stability (dynamic stability), reactive power control, speed control of DC and AC motors.

Text Books:

3. S. Rajasekaran and G. A. V. Pai, Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi, 2003.
4. D. E. Goldberg, Genetic Algorithm in search, optimization and machine learning, Addition Wesley Publication, NY.

Reference Books:

5. Zimmermann H. J., "Fuzzy Set Theory and Its Applications", Allied Publishers Ltd., 1999.
6. Klir G. J., Folger T., "Fuzzy Sets, Uncertainty and Information", Prentice Hall of India, 5th. Indian reprint, 2002.
7. Zurada J. M., "Introduction to Artificial Neural Systems", Jaico Publishing House, 2006.
8. Mohammad H. Hassoun, "Fundamentals of Neural Networks", Prentice Hall of India, 2002.

EE 6206 ENERGY AUDITING AND MANAGEMENT Cr - 3

Course Outcomes: At the end of the course, the students will be able to:

CO 1: Learn and apply various data analysis methodologies.
CO 2: Understand the concept of energy conservation and audit.
CO 3: Apply the energy policies and understand its impact.
CO 4: Analyze Combined Heating and Power system.
CO 5: Analyze various applications and types of energy audit.
CO 6: Create a report of energy audit of a system.

Module 1:General Aspects (10 Hrs)

Definitions of Energy Efficiencies, Estimation of Energy efficiencies in supply side and demand side, definition of energy conservation, management and audit, similarities and dissimilarities in financial audit and energy audit, approach, data collection and data analysis methodologies, demand and supply matching methodologies, optimization methodologies in input and output.

Module 2: Energy Utilization and Conversion System (12 Hrs)

Classification of furnace, controlled atmosphere in furnace, furnace fuels, efficiency of energy in furnace, thermal efficiency, Heat losses, reducing heat losses in hydraulic power systems compressed air, heat recovery, drying and leak, operating conditions, steam turbine as alternatives to electric motors combined power and heating systems.

Module 3 Applications of Energy Audit (14 Hrs)

Definition of energy audit, need for energy audit, energy audit and reporting format, financial audit. Peak load, average load, firm power, dump power, secondary power, load curve, load distribution curve, plant capacity factor, energy index, cost index, budgeting and standard costing, representation of energy consumption, energy economics.

Text Book:

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, 'Guide to Energy Management',5th Edition, The Fairmont Press, Inc., 2006

Reference Books:

1. Amit K. Tyagi, 'Handbook on Energy Audits and Management', The Energy and Resources Institute, 2003
2. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.

EE 6144 ANALYSIS AND DESIGN OF POWER CONVERTERS Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1 Learn the design of power electronics converters for different applications
CO2 Interpret the design of High Frequency transformers and Inductors
CO3 Analyse the working and application of inverters
CO4 Apply the operation of resonant converter and SMPS in various industries.
CO5 Understand the power quality improvement strategies using power electronic converters.
CO6 Design the gate driver circuit for different semiconductor devices.

Prerequisites: Power Converters (EE 6105)

Module 1: AC – DC Converters (5 Hrs)

Single phase Rectifier Circuit: *L* and *C* filter design, performance parameters, Concept of Heat Sinks.

Module 2: DC to DC Converters (7 Hrs)

Non-isolated dc-dc converters: Design and operation of buck-boost, Cuk, SEPIC, Zeta in DCM and CCM.

Module 3: Switch Mode Power Supply (6 Hrs)

Isolated dc-dc converters: Operation of Flyback Converter, Forward Converter andpush-pull

Converters in CCM.Current Mode Control; Magnetic Materials suitable for high frequency transformers.

Module-4: Resonant Converters (7 Hrs)

Introduction to Soft switching, difference between hard and soft switching, basic resonant circuit concept; ZCS and ZVS resonant converters; Electronic Ballasts.

Module 5: Inverters (8 Hrs)

Review of Inverter circuits. Modulation Strategies: Bipolar and Unipolar switching scheme; Performance parameters of 3 phase Sinusoidal PWM Inverters; Harmonic reduction techniques, Multi-level inverters, advantages, configurations: Diode clamped, flying capacitor and cascade multi-level inverters, applications.

Module-6: Gate drive Circuits: (3 Hrs)

Gate drive circuits for Thyristor, MOSFET, IGBT, BJT, GTO

Text Books:

1. Power Electronics By M.H. Rashid Pearson Education , 3rd Edition,2009.
2. Power Electronics , Converters , Applications and Design, by N . Mohan, Underland and Robbins , John Wiely and Sons, 3rd Edition,2011.

Reference Books:

1.Power Electronics By M.D . Singh and K.B. Khanchandani, Tata McGraw - Hill publishers, 2nd edition,2008.
2. Modern Power Electronics, by P.C Sen, Wheeler publishing Co, First Edition,2009.
3. Elements of Power Electronics, by Philip T. Krein, Oxford University Press,25 Sept 1997.

EE 6146 ELECTRIC HYBRID VEHICLES Cr-3

Course Outcomes (CO) : At the end of the course, the students will be able to

CO1. Understand the modeling of Electric Vehicles and Hybrid Electric Vehicles
CO2. Analyze and investigate propulsion drive system
CO3. Realize the controlling of output voltage and current of Traction Inverter
CO4. Control the speed of traction motor
CO5. Realize the energy storage system and energy flow management
CO6. Design the Hybrid and Electric Vehicle

Prerequisites: Power Converter (EE6105)

Module 1: Introduction (5 Hrs)

History of hybrid and Electric vehicles, social and environmental importance of hybrid and electric vehicles.

Module 2: Hybrid Electric Drive-trains (5 Hrs)

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

Module 3: Electric Drive-trains (5 Hrs)

Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis. Demonstration of EV vs Conventional Vehicle with suitable schematic.

Module 4: Electric Propulsion unit (8 Hrs)

Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, and Switch Reluctance Motor drives, drive system efficiency. Types of hybrid electric vehicle drive train with the suitable schematic of power flow arrangement.

Module 5: Energy Storage (7 Hrs)

Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems

Types of energy storage systems with their specific application, Discuss merits and demerits, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis

Module 6: Energy Management Strategies (6 Hrs)

Introduction to energy management strategies used in hybrid and electric vehicles, Classification of different energy management strategies, Comparison of different energy management strategies. Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV). Modeling and design of a HEV using multiple sources of Energy.

Text Books:

1. Electric and Hybrid Vehicles: Design Fundamentals, Iqbal Husain (2nd Edition 2010) CRC Press.
2. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, Second Edition , MehrdadEhsani, YiminGao, Ali Emadi, CRC Press, December 2017.

Reference Book:

1. Electric Vehicle Technology Explained, James Larminie, Wiley-Blackwell publication (21 October 2003).

EE 6148 HARMONICS ELIMINATION IN POWER SYSTEM Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1 Understand the various terms related to harmonics and their standards.

CO2 Learn the harmonic generation from electrical loads.

CO3 Apply the signal processing techniques for assessment of harmonics.

CO4 Analyse the effects of harmonics on different electrical components and systems.

CO5 Identify the nature of harmonics with different techniques.

CO6 Design filters for elimination of harmonics.

Prerequisites: POWER QUALITY ISSUES AND MITIGATION (EE 6109)

Module 1: Introduction (7 Hrs)

Definition- RMS value, average power, True power factor, K factor, Phase Shift, Phase Sequence, Standards- factors influencing the development of standards, existing harmonic standards (IEC, IEEE), General harmonics indices.

Module-2: Causes of Harmonics (7 Hrs)

Transformer magnetization, machines, Power electronics loads such as line- commutated converters- typical current waveforms and THD, Switched mode power supplies- typical current waveforms and THD, Uncharacteristic and inter-harmonics.

Module 3:Effect of Harmonics (7 Hrs)

Resonance, nuisance tripping, blown capacitor fuses and capacitor cells, degradation of internal capacitance, digital clocks motor overheating, overloading neutrals, telephone interference.

Module-4: Investigation of Harmonics (7 Hrs)

Field measurements, requirements, harmonics phase angle displacement, harmonic symmetrical components, transducers, harmonic instrumentation.

Module 5: Harmonics Elimination: (8 Hrs)

Passive filter definitions, conventional design criteria, tuned filters, automatically tuned filters with an example, damped filter- design, conventional six – pulse design with an example.

Text Books:

1. Arrillaga J. and Waston N.R., "Power System harmonics", Wiley Second Edition, U.S.A., 2003.
2. Prof. Mack Grady , " Understanding Power System harmonics"; Dept of Electrical & Computer Engineering University of Texas at Austin , U.S.A., 2012.

Reference Books:

1. "Power Systems Harmonics" by George J. Wakileh, Springer, 2001.
2. F. Z. Peng, "Harmonic sources and filtering approaches," *IEEE Ind. Appl. Mag.,* vol. 7, pp. 18–25, 2001.

EE 6150 SWITCH MODE POWER CONVERSION Cr-3

Course Outcomes (CO) : At the end of the course, the students will be able to

CO1. Understand the basic characteristics of different power electronics devices.

CO2. Design the various reactive elements in power electronic systems.

CO3. Analyze the various versatile dc to dc converters.

CO4. Understand the working of various isolated dc to dc converters

CO5. Know the average modeling and state space modeling of various converters.

CO6. Evaluate the performance of various resonant switch converters.

Pre-requisites: Power Converter (EE6105)

Module 1: **(8 Hrs)**

Power Switching Devices: Diodes, Controlled Switches.

Reactive Elements in Power Electronic Systems: Design of inductor, design of transformer, capacitor for power electronic application, types of capacitors

Module 2: **(14 Hrs)**

DC-TO-DC Converters:

Overview, Versatile Power Converters: Buck Converter, Boost Converter, Buck-Boost Converter, DC – DC converters with isolation. Fly Back Converters. Forward Converters. Push – Pull Converter, Half Bridge & Full Bridge Converters, Averaged Model of the Converter**,** Generalised State Space Model of the Converter.

Module 3: Resonant Switch Converters: (**14 Hrs)**

Classification of resonant converters, Basic resonant circuit concepts, Series Resonant Inverters, half bridge and full bridge. Series loaded resonant converters, Class E resonant converters. Quasi Resonant converters: ZCS & ZVS resonant switch converters. ZVS buck converter.

Text Books:

1. V. Ramanarayanan Course Material on Switched Mode Power Conversion, Department of Electrical Engineering, Indian Institute of Science, Bangalore 560012.

2. Elements of Power Electronics, by Philip T. Krein, Oxford University Press,25 Sept 1997.

3. Power Electronics By M. H. Rashid, Pearson Education, 3rd Edition, 2009.

Reference Books:

1. Power Electronics, Converters, Applications and Design N. Mohan, Undeland and Robbins, John WileyandSons , 3rd Edition ,2009.

2. Modern Power Electronics by P. C Sen, S Chand Publisher- 2013.

3. Power Electronics K.R.Varmah and Chikku Abraham, Cengage Publications- 2014.

4. Power Electronics By M. D. Singh and K.B. Khanchandani, Tata McGraw - Hill publishers, 2nd edition,2008.

5.Power Electronics, by P S Bhimbra, Khanna Publishers, 5th Edition, 2011.

EE 6152 DC- AC CONVERSION SYSTEMS Cr- 3

Course Outcomes: At the end of the course, the students will be able to

CO1. Understand the concept of PWM, PWM inverters and the applications of PWM inverters

CO2. Realize the concept of multilevel inverters and operating principle of conventional multilevel inverters.

CO3. Know the different control strategies for multilevel inverters.

CO4. Understand the emerging multilevel inverter topologies and research scope in this field.

CO5. Learn the different control strategies for Z- source inverters.

CO6. Apply the concept of DC to AC conversion systems in different field of applications.

Prerequisites: Power Converters (EE 6105)

Module 1:Pulse Width Modulated (PWM) inverter (**10 Hrs**)

Introduction, parameters used in PWM operation: modulation ratios and harmonic parameters, single phase full bridge voltage source inverter (VSI), three phase full bridge VSI, multistage PWM inverters: unipolar PWM VSI, multicell PWM VSI, industrial applications of PWM VSI.

Module 2: Multilevel Inverters (**10 Hrs**)

Introduction; Diode-Clamped Multilevel Inverters; Capacitor-Clamped Multilevel Inverters; Multilevel Inverters Using H-Bridges (HBs) Converters- Cascaded Equal Voltage Multilevel Inverters (CEMI), Binary Hybrid Multilevel Inverter (BHMI), Trinary Hybrid Multilevel Inverter (THMI); Best Switching angles to obtain Lowest THD for Multilevel DC/AC Inverters- Methods for determination of switching angle, main switching angles, equal-phase (EP) method, half-equal-phase (HEP) method, half-height (HH) method, Industrial applications of multilevel inverters.

Module 3: Emerging Inverters (**8 Hrs**)

Introduction; Z-source inverters: classifications of different ZSIs, modulation strategy, boosting factor; Switched capacitor MLIs: basic cell, operating principle, modulation strategy, capacitor selection procedure; Reduced device count MLIs.

Module 4: Applications of Inverters (**8 Hrs**)

Motor drives application of inverters, renewable energy conversion systems: Photovoltaic systems, wind energy conversion systems, STATCOM applications, automotive application: EV and HEV.

Text Books:

1. F. L. Luo and H. Ye, "Advanced DC/AC inverters application in renewable energy", Boca Raton, FL: CRC press: Taylor and Francis, 1st edition, 2013.

2. N. Mohan, Underland and Robbins, "Power Electronics , Converters , Applications and Design", John Wiely and Sons, 3rd Edition,2011.

Reference Books:

1. L Umanand, "Power Electronics: Essentials and Applications" Willey, 1st edition, 2009.

Muhammad H. Rashid, " Electric Renewable Energy Systems" - Academic Press, 1st edition, 2016.

2. William shepherd and Li Zhang, "Power Converter Circuits", Marcel Dekker Inc., 1st edition, 2004.

3. L. G. Franquelo; J. Rodriguez, J. I. Leon, S. Kouro, R. Portillo, and M. A. M. Prats, "The age of multilevel converters arrives," IEEE Ind. Electron. Mag., vol. 2, no. 2, pp. 28–39, Jun. 2008.

4. H. Abu-Rub, J. Holtz, J. Rodriguez, and G. Baoming, "Medium-voltage multilevel converters; state of the art, challenges, and requirements in industrial applications," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2581–2596, Aug. 2010.

Power System Engineering

RS 6001 FUNDAMENTALS OF RESEARCH METHODOLOGY Cr-3

Course Outcomes: At the end of the course, the students will be able to:

CO1. Conduct review of literature effectively
CO2. Formulate a viable research problem
CO3. Effectively write a technical paper based on research findings
CO4. Analyze and interpret research data
CO5. Develop awareness on IPR and allied issues
CO6. Follow ethical practices in research

Module1: Introduction (8 Hrs)

Types of research, Literature review, Research gap, Motivation, Research objectives and specifications, Formulation of research questions, Research approach, Research hypothesis.

Module 2: Research Writing (8 Hrs)

Methodology to write a technical paper/short communication/research proposal/monograph, Abstract writing, Report or presentation of results, Bibliography.

Module 3: Data Analysis (8 Hrs)

Classification of data, Methods of data collection, Statistical techniques, Design of experiments and choosing an appropriate statistical technique, Introduction to mathematical modeling (regression, model fitting), Hypothesis testing, Statistical inference.

Module 4: Intellectual Property (8 Hrs)

Intellectual property, Patent, Trademark, GI, Copyright and related rights, Research Incentives, PCT and WIPO.

Plagiarism: Definition, Plagiarism and consequences, IPR Violation and Detection.

Module 5: Research Ethics (4 Hrs)

Professional ethics in research, Ethical issues, Definition and importance, Ethical guidelines, Peer review, Research misconduct, Conflicts of interest.

Text Books:

5. C. R. Kothari, Research Methodology, New Age International, 2004.
6. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.

Reference Books:

7. J. W. Barnes, Statistical Analysis for Engineers and Scientists, Tata McGraw-Hill, New York.
8. Donald Cooper, Business Research Methods, Tata McGraw-Hill, New Delhi.
9. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.

10. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
11. Manna, Chakraborti, Values and Ethics in Business Profession, Prentice Hall of India, New Delhi, 2012.
12. R. Subramanian, Professional Ethics, Oxford University Press, 2013.

EE 6301 POWER SYSTEM STABILITY AND CONTROL Cr-3

Course Outcomes: At the end of the course, the students will be able to:

CO1. Understand the concept of Rotor angle and frequency stability.
CO2. Develop skills to model control devices that can be incorporated in power system simulation.
CO3. Analyze the performance of single and multi - machine systems, under steady state and dynamic conditions.
CO4. Understand the conception of transient stability and methods to imp rove it.
CO5. Analyze voltage stability and phenomena of voltage collapse.
CO6. Analyze dynamic behavior of power control systems subject to various disturbance.

Module1: Introduction to power system stability problem (8 Hrs)

Definition of stability, classification of stability, Rotor angle stability, frequency stability, voltage stability, mid - term and long term stability, classical representation of synchronous machine in a single machine infinite bus system (SMIB).

Module 2: Modeling of power system components for stability analysis (8 Hrs)

Synchronous machine modeling: sub- transient model, two axis model, one axis (flux decay) model, classical model. Excitation systems modeling: DC excitation, AC excitation and static excitation. Prime mover and energy supply systems modeling. Transmission line modeling, load modeling. Methods of representing synchronous machines in stability analysis.

Module 3: Small signal stability (10 Hrs)

Fundamental concepts, state space representation, Modal analysis: eigen properties, participation factors, stability assessment. Effects of excitation system on stability, power system stabilizer and its design, Dynamic stability of SMIB system, Angle and voltage stability of multi - machine power systems and phenomenon of sub synchronous resonance.

Module 4: Transient stability (5 Hrs)

Fundamentals of transient stability, numerical solutions, direct method of transient stability, transient energy function method, Methods of improving transient stability

Module 5: Voltage stability (5 Hrs)

Classification of voltage stability, modeling requirements, voltage stability analysis: static and dynamic, sensitivity analysis, modal analysis, , prevention of voltage collapse.

Text Books:

1. Prabha Kundur: Power Systems stability and Control, McGraw – Hill Inc. New York, 1994.

EE 6303 COMPUTER ANALYSIS IN POWER SYSTEM Cr-3

Course Outcomes (CO) : At the end of the course, the students will be able to

CO1. Formulate Bus admittance matrix during load flow study.
CO2. Model for power system components using graph theory.
CO3. Formulate incidence and network matrix of 3-phase networks.
CO4. Formulate the Bus impedance matrix using Bus impedance building algorithm.
CO5. Analyze the different fault study of 3-phase network using Z_{bus}.
CO6. Know the transient stability analysis.

Module-1:Load Flow Study using Computer Techniques (11 Hrs)

Formation of Y_{bus} with regulating transformer, Network matrices, Reference frame, Network graph, Tree, branch, Basic loop and Cut sets, Basic Incidence matrices, Augmented matrices, Primitive networks, Network matrices by Singular and Non-singular transformation with different Reference frame.

Module-2: Studies of Three Phase Networks (17 Hrs)

Elements in impedance and admittance form, Balance and Un-balance excitation, Transformation matrices for symmetrical components, Incidence and network matrix for 3-phase elements, Formation of Z_{bus} through Bus impedance building algorithm, Short circuit study and analysis of symmetrical and un-symmetrical fault of balanced network using Z_{bus}.

Module-3: Transient stability Analysis: (8 Hrs)

Load representation, Network performance equation, Swing equation, Machine equation, Solution techniques in transient stability study using Eulers and Runge Kutta 4^{th} order method.

Text Books:

5.Computer Methods in Power System Analysis by Glenn W. Stagg, Ahmed H. El-Abiad, McGraw-Hill Book Company, International Editions, 2009.
6.Advanced Power System Analysis and Dynamics by L. P. Singh, New Age International (P) Limited, Publishers, Revised 4th Edition, 2011.

Reference Books:

9.Power System Analysis by N. V. Ramana, Pearson Publication,2011
10. Computer application techniques in Power System by M. A. Pai, TMH, 2006.
11. Computer Aided Power System Analysis, by George L. Kusic, PHI, 2005
12. Power System Analysis by John J. Grainger and William D. Stevenson, McGraw-Hill, 2016.

EE 6313 REACTIVE POWER CONTROL AND MANAGEMENT Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Identify the necessity of reactive power compensation**.**

CO2. Understand the objective and specification of the load compensation.

CO3. Know the steady state and transient state reactive power compensation in transmission line.

CO4. Understand the reactive power coordination.

CO5. Characterize distribution side and utility side reactive power management.

CO6. Use of reactive power management in electric traction systems and arc furnaces.

Module 1: Introduction (6 Hrs)

Power mismatching, reactive power characteristics, inductive and capacitive approximate biasing, load compensator as a voltage regulator, phase balancing and power factor correction of unsymmetrical loads.

Module 2: Reactive Power Coordination (8 Hrs)

Objective, mathematical modeling, operation planning, transmission benefits, basic concepts of quality of power supply, disturbances, steady state variations, effects of under voltages , frequency, harmonics, radio frequency and electromagnetic interferences.

Module 3: Reactive Power Compensation in Transmission line (8 Hrs)

Uncompensated line, types of compensation, passive shunt and series and dynamic shunt compensation, Characteristic time periods, passive shunt compensation, static compensations, series capacitor compensation, compensation using synchronous condensers.

Module 4: Distribution side reactive power planning and management (14 Hrs)

Distribution side reactive power management, System losses, loss reduction methods, reactive power planning, economics planning capacitor placement, retrofitting of capacitor banks, kVAR requirements for domestic appliances, distribution transformers, electric arc furnaces, basic operations, furnaces transformer, filter requirements, remedial measures, power factor of an arc furnace.

Text Books:

1. Reactive power control in Electric power systems by T. J. E. Miller, John Wiley and Sons, 1982.

2. Reactive power Management by D. M.Tagare, Tata McGraw Hill, 2004.

Reference Books:

1. Reactive Power Management: Reactive Power Control for greater efficiency by Rafael Barreto, Create Space Independent, 2014.

2. Reactive Power Control in AC Power Systems by Mahdavi Tabatabaei, Jafari Aghbolaghi, Blaabjerg, Springer, 2017.

EE 6305 PLANNING AND AUTOMATION OF DISTRIBUTED SYSTEM Cr - 3

Course Outcomes (CO): At the end of the course, the students will be able to:

CO1. Understand and distinguish characteristics of distribution systems from transmission systems
CO2. To design, analyze and evaluate distribution system based on forecasted data
CO3. Identify and select appropriate sub–station location
CO4. Design and evaluate a distribution system for a given geographical service area from alternate design alternatives
CO5. Know distribution system automation
CO6. Understand different methods of grounding

Module-1:

Distribution System Planning (2Hrs)

Planning and forecasting techniques – Present and future – Role of computers.

Load Characteristics: (3 Hrs)

Definitions – Load forecasting – methods of forecast – regression analysis – correlation analysis and time series analysis – Load management – tariffs and metering of energy.

Distribution Transformers: (3 Hrs)

Types – Three phase and single phase transformers – connections – Dry type and self- protected type transformers – regulation and efficiency.

Sub Transmission Lines And Distribution Sub–Stations: (2 Hrs)

Distribution substations –Bus schemes –description and comparison of switching schemes Substation location and rating.

Primary Systems: (2 Hrs)

Types of feeders – voltage levels – radial type feeders.

Voltage Drop And Power Loss Calculations: (3 Hrs)

Three phase primary lines – Copper loss – Distribution feeder costs – Loss reduction and Voltage improvement in rural networks.

Capacitors in Distribution Systems: (3 Hrs)

Effects of series and shunt capacitors – justification for capacitors – Procedure to determine optimum capacitor size and location.

Distribution System Protection: (3 Hrs)

Basic definitions – types of over current protection devices. Objective of distribution system protection.

Module-2: **Distribution System Automation** **(12 Hrs)**

Reforms in power sector – Methods of improvement – Reconfiguration – Reinforcement – Automation – Communication systems – Sensors – Automation systems – Basic architecture of Distribution automation system – software and open architecture – RTU and Data communication – SCADA requirement and application functions – GIS/GPS based mapping of Distribution networks– Communication protocols for Distribution systems – Integrated sub– station metering system – Revenue improvement – issues in multi–year tariff and availability based tariff.

Module-3: **Grounding** **(3 Hrs)**

Grounding system – earth and safety – nature and sizes of earth electrodes – design – earthing schemes.

Text Books:

1. Turan Gonen : Electric Power Distribution Engg., Mc-GrawHill,1986.
2. A. S. PABLA : Electric Power Distribution,TMH,2000.

Reference Books:

1. Planning of Electric Power Distribution Networks with Reliability Criteria, Agapios N. Platis, Vassilis P. Koutras
2. Control and Automation of Electrical Power Distribution Systems (Power Engineering) 1st Edition by James Northcote-Green(Author, Editor), Robert G. Wilson (Author, Editor)

EE 6211 INTEGRATION AND CONTROL OF RENEWABLES Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Understand the effects of renewable energy penetration into the grid
CO2. Know various MPPT control techniques for solar PV system
CO3. Understand different synchronization techniques.
CO4. Control real and reactive power fed to the grid
CO5. Study of integration of different Energy Conversion Technologies
CO6. Analyze grid connected and islanding mode of operations

Module-1: Introduction **(8 Hrs)**

Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements

Module 2: MPPT control techniques in solar PV system: **(8 Hrs)**

MPPT Control approach, Perturb and Observe (P&O) Method, Incremental Conductance Method (INCond.), Open-Circuit Voltage Method, Short-Circuit Current Method, Fuzzy Logic Controller, Other MPPT algorithms

Module-3: Real and reactive power control **(10 Hrs)**

Control issues and challenges in Diesel, PV, wind and fuel cell based generators, PLL, Modulation Techniques, Dimensioning of filters, Linear and nonlinear controllers, predictive

controllers and adaptive controllers, Fault-ride through Capabilities, Load frequency and Voltage Control

Module-4: Integration of different Energy Conversion Technologies (10 Hrs)

Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

Text Books:

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

Reference Books:

2. Quing-Chang Zhong, "Control of Power Inverters in Renewable Energy and Smart Grid Integration", Wiley, IEEE Press

EE 6128 POWER SYSTEM TRANSIENTS Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Familiar on simple switching transients and damping
CO2. Understand abnormal switching transients
CO3. Solve transients in 3-phase Circuit
CO4. Solve transients in D.C Circuits and Conversion Equipments
CO5. Know important of electromagnetic effect for cryogenic systems
CO6. Realize travelling waves in a transmission lines

Simple Switching Transients:

Circuit closing transients, double frequency transients. **(2 Hrs)**

Damping:

Generalized damping curves, series R-L-C circuit, resistance switching, load switching, other form of damping.

(4 Hrs)

Abnormal Switching Transients:

Normal and abnormal switching, current suppression, capacitance switching, other restrtiking phenomena. Ferro resonance. **(4 Hrs)**

Transients in 3-phase Circuit:

Importance of the types of neutral connection, switching a 3-phase reactor with an isolated neutral, 3-phase capacitance switching, the symmetrical components method of solving 3- phase switching transients in star connected transformers, circuit reduction.

(6 Hrs)

Transients in D.C Circuits and Conversion Equipments:

Interruption of direct current and periodic functions. Characteristics of thyristor and communication transients. Current limiting static circuit breaker.
(4 Hrs)

Topics on Electromagnetic Phenomena:

A review of electromagnetic induction with respect to transients. Attenuatation of static field in to conductors under steady state and transients condition. Electromagnetic shielding. Important of electromagnetic effect for cryogenic systems. **(5 Hrs)**

Travelling Waves in A Transmission Lines:

circuit with distributed parameters, wave equation, reflection and restriction of travelling waves, behavior of travelling waves at line of termination. Lattice diagram. Attenuation and distortion of travelling waves. Multi conductor system and multi velocity waves. **(6 Hrs)**

Lighting Phenomena:

Scope of lighting problems, the physical phenomena of lighting, interaction of lighting with power system. Factors contribution to good line design.
(5 Hrs)

Text Books

1. Electric Transients in Power Systems by Allan Greenwood, Wiley-Blackwell; 2nd Edition edition,30 May 1991
2. Transients performance in electric power systems by R. Rudenberg, M.I.T. Press, 1967

EE 6109 POWER QUALITY ISSUES AND MITIGATION Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Know importance of power quality, terms and definitions of power quality.
CO2. Understand flickers and transients in power system.
CO3. Know Voltage Sag, Swells, Interruptions and its impact on power system.
CO4. Analyze the waveform distortion, harmonics effect in measuring power quality.
CO5. Know the impact of harmonics on power system.
CO6. Know different power quality monitoring techniques.

Modue-1: Introduction (6 Hrs)

Importance of power quality, terms and definitions of power quality as per IEEE std. 1159. such as transients, short and long duration voltage variations, interruptions, short and long voltage fluctuations, imbalance, flickers and transients. Symptoms of poor power quality.

Modue-2: Flickers & Transient Voltages: (8 Hrs)

RMS voltage variations in power system and voltage regulation per unit system, complex power. Principles of voltage regulation. Basic power flow and voltage drop. Various devices used for voltage regulation and impact of reactive power management. Various causes of voltage flicker and their effects. Short term and long term flickers. Various means to reduce flickers. Transient over voltages, sources, impulsive transients, switching transients, Effect of surge impedance and line termination, control of transient voltages.

Modue-3: Voltage Sag, Swells and Interruptions: (8 Hrs)

Voltage sags versus interruptions. Economic impact of voltage sag. Major causes and consequences. characteristics. assessment. Influence of fault location and fault level on voltage sag. Areas of vulnerability. Assessment of equipment sensitivity to voltage sags, CBEMA, ITIC, SEMI F 42 curves. Representation of the results of voltage sags analysis. Voltage sag indices. Mitigation measures for voltage sags, such as UPS, DVR, SMEs, CVT etc.

Modue-4: Waveform Distortion: (8 Hrs)

Definition of harmonics, Causes and effect of harmonics. Voltage versus current distortion. Harmonic indices. A.C. quantities under non-sinusoidal conditions. Triplen harmonics, characteristics and non characteristics harmonics. Harmonics series and parallel resonances. Consequences of harmonic resonance. Principles for controlling harmonics. Reducing harmonic currents in loads. Harmonic study procedure. Computer tools for harmonic analysis. Locating sources of harmonics.

Modue-5: Power Quality Monitoring (6 Hrs)

Need of power quality monitoring and approaches followed in power quality monitoring. Power quality monitoring objectives and requirements. Initial site survey. Power quality Instrumentation. Selection of power quality monitors, selection of monitoring location and period. Setting thresholds on monitors, data collection and analysis. Transient monitoring, event recording and flicker monitoring.

Text Books:

5. Electrical Power System Quality , by R C Dugan, M.F Mcgranaghan, S. Santoso& H W Beaty, 2nd Edition TMH publication- 2008.
6. Electric Power Quality by Heydt, G T, Stars in a circle publications, Indiana 2nd edition-1994

Reference Books:

5. Arrillaga J and Watson RN, Chen S, Power system Quality Assessment, Wiley New York-2000.
6. Bollen M H J, Understanding Power Quality Problems,: Voltage Sag and interruptions, IEEE press NY-2000.

EE 6105 POWER CONVERTERS Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Learn the characteristics and operation of power semiconductor devices.
CO2. Analyze the operation of Ac-DC converters.
CO3. Derive DC-DC converters for wider applicability
CO4. Conceptualize of DC-AC conversion techniques
CO5. Realize the operation of AC-AC converters
CO6. Design and apply the converters in various fields of application.

Module 1: Power Semiconductor Devices (5 Hrs)

Review of power semiconductor switching devices, Thyristors, MOSFET, IGBT and modern devices, characteristics and Applications, Introduction to Turn-ON/Turn-OFF mechanism of

switching devices, Gate-drive circuits, Switching-aid circuits, protection, Heat sink design.

Module 2: AC-DC Conversion Techniques (8 Hrs)

Line- commutated rectifiers, single and three-phase rectifiers (controlled/ uncontrolled), performance analysis, harmonics, Ripple reduction techniques, Introduction to multi-pulse converters, applications.

Module 3: DC-DC Conversion Techniques (10 Hrs)

Switch-mode DC-DC Converters, pulse width modulation, Nonisolated and isolated Topologies, design of transformer for switch-mode power converters, continuous and discontinuous modes of operations, steady-state analysis, impact of voltage and current stress on the switches and reduction techniques, energy storage elements design, higher-order topologies, applications.

Module 4: DC-AC Conversion techniques (8 Hrs)

Inverters, single and three-phase inverter configurations, voltage and current source inverters and their operating modes, voltage control in inverters and harmonic reduction using PWM strategies, Introduction to Multi-level Inverters, applications.

Module 5: AC-AC Conversion Techniques (5 Hrs)

AC-AC voltage controllers, configurations, performance analysis, harmonics, Cyclo-converters, introduction to Matrix converters and their applications.

Text Books:

7. V. Ramanarayanan Course Material on Switched Mode Power Conversion, Department of Electrical Engineering, Indian Institute of Science, Bangalore 560012.
8. Elements of Power Electronics, by Philip T. Krein, Oxford University Press,25 Sept 1997.
9. Power Electronics By M. H. Rashid, Pearson Education, 3rd Edition, 2009.

Reference Books:

5. Power Electronics, Converters, Applications and Design N. Mohan, Undeland and Robbins, John WileyandSons , 3rd Edition ,2009.
6. Modern Power Electronics by P. C Sen, S Chand Publisher- 2013

2nd Semester

EE 6130 NONLINEAR CONTROL THEORY Cr-3

(Department Level Common Subject)

Course Outcomes: At the end of the course, the students will be able to:

CO1. Understand and model physical systems using state vectors.
CO2. Check controllability and observability of the physical system.
CO3. Design state feedback controllers and observers.
CO4. Understand and analyze non-linear systems.
CO5. Study the nonlinear system's behavior by phase plane and describing function method.
CO6. Inspect the stability of non-linear systems by Lyapunov's stability analysis.

Module 1: State Space Analysis and Design: (9 Hrs) Introduction, State space representation of physical systems, State representation using canonical variables, Characteristics equation, eigen values and eigen vectors, Evaluation of State Transition Matrix (STM), Similarity transformation and invariance of system properties due to

similarity transformations, feedback control, Controllability and Controllable canonical form, Obsevability and Observable canonical form, Principle of duality .

Module 2 : Pole Placement Techniques: (9 Hrs) Introduction, State observers: Concept of state observer, Full order state observer, Determination of matrix K, Necessary and sufficient condition for state observation, determination of state observer gain matrix. Necessary and sufficient condition for arbitrary pole placement, Dual problem.

Module 3: Nonlinear Control Systems: (12 Hrs)

Introduction, Properties of Nonlinear systems, Classification of nonlinear systems, Phase plane analysis: Basic concept of phase plane, singular points, Limit cycle and jump resonance, stability of nonlinear systems, construction of phase trajectory, Describing function method: Describing function of common nonlinearities, Stability analysis by describing function method.

Module 4: Stability Analysis for Nonlinear Control Systems: (6 Hrs)

Introduction, Stability in the sense of Lyapunov, second method, stability theorem, Lyapunov function for linear and nonlinear system.

Text Books:

1. Advanced Control System, by B. N. Sarkar, PHI Learning, 2013.
2. Digital Control and State Variable Methods, M. Gopal, TMH Publication,2012.

Reference Books:

1. Modern Control Engg. by K. Ogata PHI Publication, 2010.
2. Control System Engg, by I.J. Nagrath and M Gopal, New age international publication,2007.
3. Automatic Control Systems by Benjamin C Kuo, Prentice-Hall, 1991.
4. Non Linear Systems Analysis by M Vidyasagar, Prentice Hall NJ, USA.
5. Nonlinear Systems by H.K Khalil, Prentice Hall, NJ,USA.

EE 6308 HIGH VOLTAGE DC TRANSMISSION CR-3

Course Outcomes (CO): At the end of the course, the students will be able to:

CO1: Know the need for the HVDC transmission system.
CO2: Cite the applications of HVDC transmission system.
CO3: Understand the role of converters and controllers in HVDC transmission.
CO4: Analyse the effects of harmonics and its suppression using filters.
CO5: Model the faults of the converters.
CO6: Design the protection against the faults of the converters.

Module 1: HVDC Transmission (8 Hrs)

Introduction: Comparison of AC and HVDC, HVDC transmission analysis of HVDC converters, Pulse number, analysis with and without overlap, Converter bridge characteristics.

Module 2: HVDC System Control (12 Hrs)

Principles of dc link control, Starting and stopping of dc link, Power Control, Harmonics, Filters, Power flow analysis in ac/dc systems, General modeling of dc links, Solution of ac-dc power flow

Module 3: Reactive Power Control in HVDC (8 Hrs)

Reactive power requirements in steady state, Conventional control strategies, Alternate control strategies, Sources of reactive power, AC filters, Shunt capacitors, Synchronous condensers.

Module 4: Converter Fault & Protection (8 Hrs)

Converter faults, Protection against over current and over voltage in converter station, Surge arrestors, Smoothing reactors, DC breakers , Audible noise-space charge field, Corona effects on DC lines, Radio interference.

Text books:

1. K. R.Padiyar: HVDC Power Transmission System, New Age Intl.Co. 2002...
2. EHVAC and HVDC Transmission Engineering and Practice-S.Rao.

Reference books:

1. Mohamed E.El-Nawary (IEEE Press): Electrical Power Systems (Design & Analysis).
2. Electric Power System by C. L. Wadhwa
3. Kamakshaiah, V Kamaraju: HVDC Transmission, TMH Education Private Limited.
4. Power System Stability and Control by Prabha Kundur,TATA McGRAW-HILL,2010.

EE 6306 DIGITAL PROTECTION IN POWER SYSTEM Cr-3

Course Outcomes: At the end of the course, students will be able to

CO1. Know basics of Static Relays and Protection scheme of transmission line
CO2. Understand the applications of static relay
CO3. Know the operational of numerical relay
CO4. Understand on digital protection of transmission line
CO5. Know digital protection of synchronous generator
CO6. Know digital protection of power transformer

Module 1: Static Relay:

(8Hrs) General Introduction to Static Relays, Comparator and Associated Elements, Solid State Power Supply Circuit, Timer Relays and Voltage Relays, Differential Relays, Distance relay and Microprocessor Applications to Protection.

Module 2: Numerical Protection:

(8Hrs) Introduction, block diagram of numerical relay, sampling theorem, correlation with a reference wave, least error squared (LES) technique, digital filtering, and numerical over current protection.

Module 3: Digital Protection of Transmission Line:
(8Hrs) Introduction, Protection scheme of transmission line, distance relays, traveling wave relays, digital protection scheme based upon fundamental signal, hardware design, software design, digital protection of EHV/UHV transmission line based upon traveling wave phenomenon, new relaying scheme using amplitude comparison.

Module 4: Digital protection of Synchronous Generator:
(6Hrs) Introduction, faults in synchronous generator, protection schemes for synchronous generator, digital protection of synchronous generator.

Module 5: Digital Protection of Power Transformer:
(6Hrs)
Introduction, faults in a transformer, schemes used for transformer protection, digital protection of transformer.

Text Books:
1. Digital Protection, L. P. Singh, (New Age International (P) Limited Publishers, New Delhi, 2nd Edition).
2. Power System Protection; Static Relays with Microprocessor Applications, 2nd Edition, T.S.Madhava Rao, Tata Mc Graw Hill.

Reference Books:
1. Transmission Network Protection Paithankar (Marcel&Dekker, New York)
2. Digital Relay / Numerical relays – T.S.M. Rao, Tata Mc Graw Hill, New Delhi.
3. Fundamentals of Power System Protection Paithankar&Bhide (Prentice Hall of India Pvt Ltd., New Delhi)
4. Protective Relaying for Power System II Stanley Horowitz (IEEE press , New York)

EE 6154 FLEXIBLE AC TRANSMISSION SYSTEMS Cr. 3

Course Outcomes: At the end of the course, the students will be able to
CO1. Know types of FACTS controllers
CO2. Understand static VAR compensators and their applications
CO3. Know the importance of compensator to manage active and reactive power
CO4. Design the Shunt and Series Compensators
CO5. Compare among GCSC, TSSC and TCSC
CO6. Implement the Unified Power Flow Controller (UPFC) for Power Quality Improvement

Module 1: Introduction
(10Hrs)
Definition of FACTS, Flow of power in an ac system- dynamic stability consideration- types of FACTS controllers- static shunt compensator, SVC & STATCOM, objectives of shunt compensation, methods of controllable VAR generation, switching converter type VAR generators, basic operating principle and control approaches.

Module 2: Shunt Compensation (10Hrs)

Active and reactive power related to sending and receiving end, active and reactive power related to compensator, FACTS based shunt compensators: TCR, TSC (Analysis-waveforms, Effective reactance, Compensator Current and Reactive power, VI characteristics), STATCOM – (Analysis - phasor diagram, Compensator Current and Reactive power, VI characteristics).

Module 3: Series Compensation (10Hrs)

Active and reactive power related to sending and receiving end, active and reactive power related to compensator. FACTS based series compensators: GCSC, TSSC and TCSC (Analysis-waveforms, Effective reactance, Compensator voltage and Reactive power).

Module 4: Combined Compensator (6Hrs)

Combined Series –shunt Compensator: Unified Power Flow Controller (UPFC).

Text Books:

1. K.R.Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International(P) Limited, Publishers, New Delhi, 2008.
2. N.G. Hingorani and L.Gyugyi "Understanding FACTS" Standard Publishers, Distributors, New Delhi.

Reference Books:

5. V.K.Sood,"HVDC and FACTS controllers – Applications of Static Converters in Power System" Kluwer Academic Publishers, 2004.
6. Xiao – Ping Zang, Christian Rehtanz and Bikash Pal, "Flexible AC Transmission System: Modelling and Control" Springer, 2012.

EE 6142 SOFT-COMPUTING TECHNIQUES Cr-3

Course Outcomes (CO): At the end of the course, the students will be able to

CO1. Know the soft computing techniques, paradigms for building intelligent systems.
CO2. Understand the concept of supervisory neural network and apply to real word problem by supervisory neural network .
CO3. Know the concept of unsupervisory neural network and apply it to real word problem.
CO4. Understand the concepts of fuzzy sets, knowledge representation using fuzzy rules
CO5. Apply Evolutionary algorithms to optimization problems.
CO6. Evaluate solutions by various soft computing approaches for a given problem.

Module-1: Introduction (10 Hrs)

Difference between Hard and Soft computing, fundamental concepts, Biological neural networks, Artificial neuron, activation functions, setting of weights, typical architectures, biases and thresholds, learning/training laws and algorithms, Hebbian learning, error correction

learning, competitive learning, Boltzman learning, supervised learning, unsupervised learning, Perceptron, linear separability- XOR function.

ANN Paradigms (6 Hrs)

Multi-layer perceptron using back propagation algorithm (BPA), self organizing map (SOM), radial basis function network, functional link network (FLN), Hopfield Network.

Module-2: Fuzzy Logic (8 Hrs)

Introduction, fuzzy versus crisp, fuzzy sets, membership function, basic fuzzy set operations, properties of fuzzy sets, fuzzy Cartesian product, operations on fuzzy relations, fuzzyfication, fuzzy quantifiers, fuzzy inference, fuzzy rule based system, defuzzification methods.

Module-3: Genetic Algorithms (6 Hrs)

Introduction, encoding, fitness function, reproduction operators, genetic modeling, genetic operators, crossover, single site crossover. two point crossover, multi point crossover, uniform crossover, matrix crossover, crossover rate, inversion & deletion, mutation operator, mutation, mutation rate, bit–wise operators, generational cycle, convergence of genetic algorithm.

Module-4 Applications of AI Techniques (6 Hrs)

Load forecasting, load flow studies, economic load dispatch, load frequency control, single area system and two area system, small signal stability (dynamic stability), reactive power control, speed control of DC and AC motors.

Text Books:

5. S. Rajasekaran and G. A. V. Pai, Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi, 2003.
6. D. E. Goldberg, Genetic Algorithm in search, optimization and machine learning, Addition Wesley Publication, NY.

Reference Books:

9. Zimmermann H. J., "Fuzzy Set Theory and Its Applications", Allied Publishers Ltd., 1999.
10. Klir G. J., Folger T., "Fuzzy Sets, Uncertainty and Information", Prentice Hall of India, 5th. Indian reprint, 2002.
11. Zurada J. M., "Introduction to Artificial Neural Systems", Jaico Publishing House, 2006.
12. Mohammad H. Hassoun, "Fundamentals of Neural Networks", Prentice Hall of India, 2002.

EE 6206 ENERGY AUDITING AND MANAGEMENT Cr - 3

Course Outcomes: At the end of the course, the students will be able to:

CO 1: Learn and apply various data analysis methodologies.
CO 2: Understand the concept of energy conservation and audit.
CO 3: Apply the energy policies and understand its impact.
CO 4: Analyze Combined Heating and Power system.
CO 5: Analyze various applications and types of energy audit.
CO 6: Create a report of energy audit of a system.

Module 1:General Aspects **(10 Hrs)**

Definitions of Energy Efficiencies, Estimation of Energy efficiencies in supply side and demand side, definition of energy conservation, management and audit, similarities and dissimilarities in financial audit and energy audit, approach, data collection and data analysis methodologies, demand and supply matching methodologies, optimization methodologies in input and output.

Module 2: Energy Utilization and Conversion System **(12 Hrs)**

Classification of furnace, controlled atmosphere in furnace, furnace fuels, efficiency of energy in furnace, thermal efficiency, Heat losses, reducing heat losses in hydraulic power systems compressed air, heat recovery, drying and leak, operating conditions, steam turbine as alternatives to electric motors combined power and heating systems.

Module 3 Applications of Energy Audit **(14 Hrs)**

Definition of energy audit, need for energy audit, energy audit and reporting format, financial audit. Peak load, average load, firm power, dump power, secondary power, load curve, load distribution curve, plant capacity factor, energy index, cost index, budgeting and standard costing, representation of energy consumption, energy economics.

Text Books:

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, 'Guide to Energy Management',5th Edition, The Fairmont Press, Inc., 2006

Reference Books:

1. Amit K. Tyagi, 'Handbook on Energy Audits and Management', The Energy and Resources Institute, 2003
2. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.

EE 6322 DISTRIBUTED GENERATION Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Understand the importance of DG and its current scenario.
CO2. Know different types of interfaces for Grid integration of DGs.
CO3. Understand the technical impacts of DGs penetration in transmission and distribution systems.
CO4. Compare the various control techniques of different DG sources.
CO5. Know protection related issues in micro-grids and transient.
CO6. Understand the planning and operational issues related to DG and Micro- grids.

Module 1: Importance of Distributed generation (DG) (4 Hrs)

Introduction, current scenario in Distributed Generation, Renewable sources in distributed generation, Planning of DGs – Siting and sizing of DGs.

Module 2: Grid integration of DGs (10 Hrs)

Different types of interfaces and control - 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, optimal placement of DG sources in distribution systems. De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems.

Module 3: Economic and control aspects of DGs (10 Hrs)

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.

Module 4: Introduction to micro-grids (12 Hrs)

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.

Text Books:

4. H. Lee Willis, Walter G. Scott ,'Distributed Power Generation – Planning and Evaluation', Marcel Decker Press, 2000.
5. M.GodoySimoes, Felix A.Farret, 'Renewable Energy Systems – Design and Analysis with Induction Generators', CRC press.
6. Robert Lasseter, Paolo Piagi, ' Micro-grid: A Conceptual Solution', PESC 2004, June 2004.

Reference Books:

3. 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.
4. Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson 'Facility Microgrids', Subcontract report, May 2005.

EE6311 STATE ESTIMATION AND SECURITY ANALYSIS Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1. Develop mathematical models for analysis of linear and non–linear State Estimation.
CO2. Understand the observability and bad data detection techniques from a measurement.
CO3. Know the application of PMU in state estimation for bad data detection.
CO4. Understand the basics of contingency analysis of any practical Power System
CO5. Identify the most appropriate algorithm for security of a system.
CO6. Implement the computer control techniques through different software.

Module-1: State Estimation of Power Systems (12 Hrs)

Introduction to real time control of power system, Energy control center, security analysis and monitoring, Introduction to State Estimation (SE) in power systems: Maximum likelihood Weighted Least Square (WLS) Estimation SE. SE of AC networks. Types of measurements – linear WLS–SE theory – DC load flow based WLS–SE – linearized model of WLS–SE of non–linear AC power systems – sequential and non–sequential methods to process measurements.

Module-2: Network Observability and bad data detection (12 Hrs)

Network Observability and Pseudo–measurements, Observability analysis for branch variable formulation, observability by Graphical technique and Triangularisation approach, network topology processing, topological observability and its algorithm. Bad data detection in WLS method, chi square test, identification of bad data: method of normalized residual and test, application of PMU in state estimation, linear measurement model with PMU's, phasor measurements in dynamic state estimation, PMU placement to detect topology errors and bad data detection.

Module-3: Security Analysis of Power System (12 Hrs)

Concept of security, factors affecting power system security – contingency analysis for generator and line outages by fast decoupled inverse lemma–based approach – networks sensitivity factors. Contingency selection, concentric relaxation, Bounding area method. computer control of power systems: Need for real – time and computer control of power systems – operating states of a power system – Supervisory Control and Data Acquisition system (SCADA) – implementation considerations – energy control centers – software requirements for implementing the above functions.

Text Books:

1. Allen J. Wood and Bruce Woolenberg: Power System Generation, Operation and Control, John Wiley and Sons, 1996.
2. John J. Grainger and William D. Stevenson Jr.: Power System Analysis, McGraw Hill ISE, 1994.

Reference Book:

1. IEEE Proc. July 1974, Special Issue on Computer Control of Power Systems.

EE 6336 Smart Grid Cr-3

Course Outcome: At the end of the course, the students will be able to:

CO1 Understand the difference between conventional grid and smart grid
CO2 Understand the design of Smart Grid Architecture
CO3 Know the tools and different optimization techniques of smart grid
CO4 Understand the wide area monitoring system of smart grid
CO5 Understand the load flow analysis in micro grid
CO6 Know the voltage and reactive power control in smart grid

Pre-requisites: Power System Operation and Control(EE 3002),Renewable Energy Sources

Module-1: Introduction to Smart Grid: **(10 Hrs)**

Definition of smart grid, Components and architecture of smart grid design, Review of the proposed architectures for smart grid, The fundamental components of smart grid designs, Transmission automation, Distribution automation, Renewable integration, Demand side management, energy management system (EMS).

Module 2: Tools and Techniques for Smart Grid **(12 Hrs)**

Computational techniques, Static and dynamic optimization techniques, Computational intelligence techniques, Evolutionary algorithms, Artificial intelligence techniques, Distribution Generation Technologies

Communication Technologies and Smart Grid:

Introduction to communication technology, SynchroPhasor Measurement Units (PMUs).

Module 3: Control of Smart Power Grid System **(8 Hrs)** Load Frequency Control (LFC) in micro grid system, Voltage control in micro grid system, Reactive power control in smart grid, Case studies and test beds for the smart grids.

Module 4: Energy Storage configurations : **(6 Hrs)**

Energy storage: Battery - types, equivalent circuit, performance characteristics, battery design, charging and charge regulators. Battery management. fly wheel energy relations, components, benefits over battery. Fuel Cell energy storage systems. Ultra Capacitors, plug-in-hybrid vehicles

Text Books:

1. James Momoh, "SMART GRID, Fundamentals of Design and Analysis" IEEE press, 2013.
2. A. G. Phadke and J. S. Thorp, "Synchronized Phasor Measurements and their Applications", Springer Edition, 2010

Reference Books:

1. Gil Masters, "Renewable and Efficient Electric Power System", Wiley–IEEE Press, 2004.
2. T. Ackermann, "Wind Power in Power Systems", Hoboken, NJ, USA, John Wiley, 2005.
3. Clark W Gellings P.E. "The Smart Grid enabling energy efficiency and demand response", CRC Press, 2013.
4. Stuart Borlase, "Smart Grids, Infrastructure, Technology and Solutions", CRC Press, 2013.

EE 6328 DEREGULATED POWER SYSTEM Cr 3

Course Outcomes: At the end of course, students will be able to:

CO1 Understand the Entities involved in restructuring in power system.
CO2 Realize the salient features of Electricity act 2003 and reforms in Indian power sector
CO3 Know the fundamentals of economics and the philosophy of market models
CO4 Understand the transmission congestion management
CO5 Realize ancillary service management
CO6 Know the market power and generators bidding

Module 1: Introduction:
(4Hrs)

Introduction, Reasons for restructuring / deregulation of power industry, Entities involved, The levels of competition, The market place mechanisms, Sector-wise major changes required), Introduction to issues involved in deregulation, Reasons and objectives of deregulation of various power systems across the world (The US, The UK, The Nordic Pool, The developing countries).

Module 2: Reforms in Indian power sector and The Electricity Act 2003
(6Hrs)

Introduction, Framework of Indian power sector, Operational Demarcation of the Power System, National and Transnational Grids, Reform initiatives during 1990-1995-The Independent Power Plants, Orissa Reform Model, Accelerated Power Development and Reforms Program (APDRP), Public-Private Partnership, Other Developments, The availability based tariff (ABT) - The Mechanism, Working of the mechanism, Effects of ABT, Intra-state ABT, The Electricity Act 2003-Provisions in the generation sector, Provisions in the transmission sector, Provisions in the distribution sector, Power trading, Other important changes; Open Access issues-Operational Practices, Transmission pricing, Loss allocation, Reservation of Transmission Capacity and Congestion Management, Reactive power support, Explanation of practices using illustrative example; Power exchange-The auction, The congestion management.

Module 3: Fundamentals of Economics
(4Hrs)

Introduction, Consumer behavior-Total utility and marginal utility, Law of diminishing marginal utility, Consumer surplus, Consumer equilibrium, Market demand curve, Demand elasticity; Supplier behavior -Law of diminishing marginal product, Supply functions, Supplier equilibrium, Supplier surplus, Supplier elasticity; Market equilibrium-Global welfare, Deadweight loss; Short-run and Long-run costs, Various costs of production-Total cost (TC), Average fixed cost (AFC), Average variable cost (AVC), Average cost (AC), Marginal cost (MC)), Relationship between short-run and long-run average costs, Perfectly competitive market.

Module 4: The Philosophy of Market Models
(6Hrs)

Introduction, Market models based on contractual arrangements-Monopoly model, Single buyer model, Wholesale competition model, Retail competition model; Comparison of various market models, Electricity vis-à-vis other commodities -Distinguishing features of electricity as a commodity, Four pillars of market design (Imbalance, Scheduling and Dispatch, Congestion

Management, Ancillary Services; Market architecture-Timeline for various energy markets, Bilateral / forward contracts; The spot market -Discriminatory or non-discriminatory pricing?, Simple bids or complex bids, Day-ahead and real-time market; Models for trading arrangements-Integrated or centralized model, Decentralized model, Comparison between trading arrangement models, ISO or TSO model.

Module 5: Transmission Congestion Management
(6Hrs)

Definition of congestion, Reasons for transfer capability limitation, Importance of congestion management in deregulated environment, Effects of congestion, Desired features of congestion management schemes, Classification of congestion management methods-Basis for classification, Non-market methods,. Market methods; Calculation of ATC, Definition of various terms-ATC, TTC, TRM, CBM; ATC calculation using PTDF and LODF based on DC model - DC Load flow model, Power Transfer Distribution Factor (PTDF), Calculation of PTDF using DC model, ATC calculation using PTDF, Line Outage Distribution Factor (LODF), ATC calculation using PTDF and LODF, Calculation of ATC using AC model; Non-market methods - Capacity allocation on first come first served basis, Capacity allocation based on pro-rata methods, Capacity allocation based on type of contract, Market based methods-Explicit auctioning, Coordinated auctioning, Nodal pricing; OPF based congestion management -DC OPF, OPF with load elasticity, AC OPF, Interpretation of Lagrange multipliers, Implications of nodal pricing; Inter-zonal Intra-zonal congestion management, Price area congestion management -Algorithm, Illustrative example), Capacity alleviation method-Re-dispatching, Counter-trade, Curtailment, Comparison

Module 6: Ancillary Service Management
(4Hrs)

Introduction to ancillary services, Types of ancillary services, Classification of ancillary services, Load-generation balancing related services-Frequency regulation, Load following, Spinning reserve services; Voltage control and reactive power support services-Different sources of reactive power-Generators, Synchronous condensers, Capacitors and inductors, SVCs, STATCOMs; Comparison between different sources of reactive power, Issues in reactive power management, Black start capability service, How to obtain ancillary services?, Mandatory provision of ancillary services, Markets for ancillary services, Co-optimization of energy and reserve services.

Module 7: Market power and generators bidding
(6Hrs)

Attributes of a perfectly competitive market, The firm's supply decision under perfect competition, Imperfect competition-Monopoly, Oligopoly, Cournot model, Bertrand model, Electricity markets under imperfect competition; Market power-Sources of market power, Effect of market power; Identifying market power, HHI Index, Entropy coefficient, Lerner index; Market power mitigation-Effects of contract for differences, Role of demand side bidding; Financial markets associated with electricity markets-Forwards, Futures, Options, Swaps; Introduction to optimal bidding by a generator company-Bidding in real markets; Optimal bidding methods-Game theory, Markov decision process, Genetic algorithm, Equilibrium analysis, Conjectural variation, Bayesian analysis, Summary

Text Books:

1. Kankar Bhattacharya, Math H.J. Boller, Jaap E.Daalder, 'Operation of Restructured Power System' Klumer Academic Publisher,2010.
2. S.K.Gupta, "Power System Operation Control and Restructuring" I.K.International Publishing House Pvt. Ltd, New Delhi, 2015.

Reference Books:

4. Loi Lei Lai; "Power system Restructuring and Deregulation", Jhon Wiley & Sons Ltd., England.
5. Know Your Power", A citizens Primer On the Electricity Sector, Prayas Energy Group, Pune.
6. Sally Hunt, "Making Competition Work in Electricity", 2002, John Wiley Inc.
7. Mohammad Shahidehpour, and Muwaffaq alomoush, - "Restructured electrical Power systems" Marcel Dekker, Inc.,2009.

EE 6148 HARMONICS ELIMINATION IN POWER SYSTEM Cr-3

Course Outcomes: At the end of the course, the students will be able to

CO1 Understand the various terms related to harmonics and their standards.
CO2 Learn the harmonic generation from electrical loads.
CO3 Apply the signal processing techniques for assessment of harmonics.
CO4 Analyse the effects of harmonics on different electrical components and systems.
CO5 Identify the nature of harmonics with different techniques.
CO6 Design filters for elimination of harmonics.

Prerequisites: POWER QUALITY ISSUES AND MITIGATION (EE 6109)

Module 1: Introduction (7 Hrs)

Definition- RMS value, average power, True power factor, K factor, Phase Shift, Phase Sequence, Standards- factors influencing the development of standards, existing harmonic standards (IEC, IEEE), General harmonics indices.

Module-2: Causes of Harmonics (7 Hrs)

Transformer magnetization, machines, Power electronics loads such as line- commutated converters- typical current waveforms and THD, Switched mode power supplies- typical current waveforms and THD, Uncharacteristic and inter-harmonics.

Module 3:Effect of Harmonics (7 Hrs)

Resonance, nuisance tripping, blown capacitor fuses and capacitor cells, degradation of internal capacitance, digital clocks motor overheating, overloading neutrals, telephone interference.

Module-4: Investigation of Harmonics (7 Hrs)

Field measurements, requirements, harmonics phase angle displacement, harmonic symmetrical components, transducers, harmonic instrumentation.

Module 5: Harmonics Elimination: (8 Hrs)

Passive filter definitions, conventional design criteria, tuned filters, automatically tuned

filters with an example, damped filter- design, conventional six – pulse design with an example.

Text Books:

3. Arrillaga J. and Waston N.R., "Power System harmonics", Wiley Second Edition, U.S.A., 2003.
4. Prof. Mack Grady , " Understanding Power System harmonics"; Dept of Electrical & Computer Engineering University of Texas at Austin , U.S.A., 2012.

Reference Books:

3. "Power Systems Harmonics" by George J. Wakileh, Springer, 2001.
4. F. Z. Peng, "Harmonic sources and filtering approaches," IEEE Ind. Appl. Mag., vol. 7, pp. 18–25, 2001.