Department of Electrical Engineering

New Course Structure for M. Tech. 2019-21 batch onwards

FIRST SEMESTER

A. **Departmental Core Papers (Papers–I, II, III),** May differ for different specializations;

Paper	Subject code	Subject Name	Class Load/Week			Total load(h)	Credit	Marks
			L	T	P			
I	EE510X		3	0	0	3	3	100
II	EE510X		3	0	0	3	3	100
III	EE510X		3	0	0	3	3	100

Note: Class load /Week is normally kept at 3. But it is 4 in some cases with 1 additional tutorial (T) class. However, the credit is kept at 3 for all the subjects.

B. Departmental Elective Paper (Paper–IV) Any one to be opted from the dept. pool;

Sl. No	Subject code	Subject Name	Class Load/Week			Total load(h)	Credit	Marks
			L	T	P			
1	EE512X		3	0	0	3	3	100

C. **Open Elective Paper (Paper–V)** Any one to be opted from other dept. (institute pool)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load(h)	Credit	Marks
			L	T	P			
1	WW516X		3	0	0	3	3	100

D. **Departmental Labs/Mini Projects (Lab–I, II, III)** may differ for different specializations;

Lab	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
I	EE517X		0	0	3	3	2	100
II	EE517X		0	0	3	3	2	100
III	EE517X		0	0	3	3	2	100

Total Credits for 1st Semester: **21**

Department of Electrical Engineering

New Course Structure for M. Tech. 2019-21 batch onwards

SECOND SEMESTER

A. Departmental Core Papers (Papers–VI, VII, VIII), May differ for different specializations;

Paper	Subject code	Subject Name	Class Load/Week			Total load(h)	Credit	Marks
			L	T	P			
I	EE520X		3	0	0	3	3	100
II	EE520X		3	0	0	3	3	100
III	EE520X		3	0	0	3	3	100

B. Departmental Elective Paper (Paper–IX) Any one to be opted from the dept. pool;

Sl. No	Subject code	Subject Name	Class Load/Week			Total load(h)	Credit	Marks
			L	T	P			
1	EE522X		3	0	0	3	3	100

C. Open Elective Paper (Paper–X) Any one to be opted from other dept. (institute pool)

Sl. No	Subject code	Subject Name	Class Load/Week			Total load(h)	Credit	Marks
			L	T	P			
1	WW526X		3	0	0	3	3	100

D. M. Tech Project Part - I : Individual project for each student;

Sl. No	Subject code	Subject Name	Total load(h)	Credit	Marks
1	EE5291	M. Tech Thesis Part - I (Term Paper)	8	4	200
2	EE5292	Term Paper Seminar & Viva-voce		2	100

Total Credits for 2nd Semester: **21**

Department of Electrical Engineering

New Course Structure for M. Tech. 2019-21 batch onwards

THIRD SEMESTER

M. Tech Project Part - II

Sl. No	Subject code	Subject Name	Total load(h)	Credit	Marks
1	EE6191	M. Tech Thesis Part - II (Progress Report)	24	12	300
2	EE6192	Progress Report Seminar & Viva-voce		6	100

Total Credits for 3rd Semester: **18**

FOURTH SEMESTER

M. Tech Project Part - III

Sl. No	Subject code	Subject Name	Total load(h)	Credit	Marks
1	EE6291	M. Tech Final thesis	30	22	400
2	EE6292	Thesis Seminar& Viva-voce		8	200

Total Credits for 4th Semester: **30**

Total Credits in 4 semesters: 21 + 21 + 18 + 30 = **90**

Department of Electrical Engineering

Subjects offered for M. Tech. course 2019-21 batch onwards

FIRST SEMESTER

A. Departmental Core Papers (Papers–I, II, III), May differ for different specializations;

Specializations →	Control System & Instrumentation **(CSI)**	Power & Energy Systems **(PES)**	Power Electronics, Machines and Drives **(PEMD)**
Paper-I	EE5101: Modelling and Control of Physical Systems	EE5104: Advanced Power System Analysis	EE5107: Advanced Power Electronics
Paper-II	EE5102: Theory of Discrete and Digital Systems	EE5105: Power System Operation and Control	EE5108: Generalized Theory of Electrical Machines
Paper-III	EE5103: Advanced Process Control & Instrumentation*	EE5106: Power Transmission and Power Quality	EE5101: Modeling and Control of Physical Systems

*** Subject of 3 credit but (3L+1T) classes/week**

B. Departmental Elective Paper (Paper–IV)

Any one to be opted from the following pool of subjects/ or as may be offered by the department from time to time:

1. EE5121: Advanced Microcontroller Technology
2. EE5122: Advanced Computational Methods in Electrical Engineering
3. EE5123: Application of Soft Computing Techniques in Electrical Engineering
4. EE5124: Power Quality studies in Electrical systems

C. Open Elective Paper (Paper–V) Any one to be opted from other dept. (institute pool)

Open elective offered by EE Dept. for other dept. students:

1. EE5161: Illumination Science, Engineering and Design**

**** Subject of 3 credit but (3L+1T) classes/week**

D. Departmental Labs/Mini Projects(Lab–I,II,III)

Specializations →	Control System & Instrumentation **(CSI)**	Power & Energy Systems **(PES)**	Power Electronics, Machines and Drives **(PEMD)**
Lab-I	EE5171: **Lab on** Modeling and Control of Physical Systems	EE5174: **Lab on** Advanced Power System Analysis	EE5177: **Lab on** Advanced Power Electronics
Lab-II	EE5172: **Mini Project I**: Related to Theory of Discrete and Digital Systems	EE5175: **Mini project I**: on Power System Operation and Control	EE5178: **Mini Project on** Generalized Theory of Electrical Machines
Lab-III	EE5173: **Lab on** Advanced Process Control & Instrumentation	EE5176: **Mini project II**: on Power Transmission and Power Quality	EE5171: **Lab on** Modeling and Control of Physical Systems

Department of Electrical Engineering

Subjects offered for M. Tech. course 2019-21 batch onwards

SECOND SEMESTER

A. Departmental Core Papers (Papers–VI, VII, VIII), May differ for different specializations;

Specializations →	Control System & Instrumentation **(CSI)**	Power & Energy Systems **(PES)**	Power Electronics, Machines and Drives **(PEMD)**
Paper-VI	EE5201: Optimal & Robust Control Theory	EE5204: Advanced Power System Protection	EE5207: Advanced Electrical Drives
Paper-VII	EE5202: Signal and Image Processing for Instrumentation and Control	EE5205: Power System Stability, Security and High Voltage Engineering	EE5208: Special Topics in Power Electronics
Paper-VIII	EE5203: Optimal Filtering & Stochastic Processes	EE5206: Smart Grid Technologies and Energy Informatics	EE5209: Selected Machines for Electric Vehicle and Wind Power Applications

B. Departmental Elective Paper (Paper–IX)

Any one to be opted from the following pool of subjects/ or as may be offered by the department from time to time:

1. EE5221: Intelligent Control systems
2. EE5222: Nonlinear Control Theory
3. EE5223: Condition Monitoring of Electrical Equipment
4. EE5224: Power system Reliability and load forecasting techniques
5. EE5225: Special Electrical Machines
6. EE5226: Power Electronic Converters for Bulk Power Conditioning

C. Open Elective Paper (Paper–X) Any one to be opted from other dept. (institute pool)

Open elective offered by EE Dept. for other dept. students:

1. EE5261: Energy Informatics
2. EE5262: Power supplies for Electrical Equipment

Modelling and Control of Physical Systems

(EE 5101)

Prerequisites: Signals and Systems basics, Control System basics, Advanced Engineering Mathematics

Weekly contact: 3 - 0 - 0 (L- T- P) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Recapitulation:** State Space Modelling of SISO and MIMO systems (Assignments**)**. Examples-Power Systems Applications, Power Electronic Applications and Nonlinear Systems (Assignments). Solution to State Equations, State Transition Matrix, Time response, BIBO and Zero Input Stability, Diagonalisation, Block Jordan Form.	10L
02	**Synthesis of Linear State Variable Feedback (LSVF) Controllers (SISO, LTI):** Controllability, Observability, Canonical Forms, Arbitrary Pole Placement, Design of Controllers – Case Studies- Examples form Power Systems, Power Electronics etc. Linearisation of Nonlinear State Equations. Controller design for linearised system. **Advanced Topics**: Integral LSVF Controller design with examples, MIMO Controller design.	7L
03	**Synthesis:** Implementation of LSVF Controllers, Design of Observers, Estimation Error, Separation Principle, Numerical Examples. **Advanced Topics:** Design of Reduced Order Observers, Implementation, Examples.	4L
06	**Introduction to Optimal Control:** Performance Index (PI) in Classical Control, Linear Optimal Control, Related Mathematics, Numerical Examples.	4L
07	**Introduction to Artificial Neural Networks:** Basic Definitions, Activation Functions, Mathematical Model of a Neuron, Network Architectures, Basic Idea of Control with Neural Networks	4L
08	**Introduction to Robust Control:** Basic Definitions, Robust Control Problems and Solutions. Other advanced Topics	4L
09	**Case Studies:** Examples from Power Systems; Power Electronics; and other systems from Electrical Engineering	6L
	Total:	**39L**

Suggested readings

1. Linear System Theory and Design, C. T. Chen, 3rd Edition, 1999.
2. Modern Control Theory, M. Gopal, Second Edition, 2005.
3. Automatic Control Systems, B.C. Kuo and F. Golnaraghi, 9th Edition, 2014.
4. Control Systems: Principles and Design: Gopal, Second Edition, 2002.
5. Digital Control and State Variable Methods: M. Gopal, Second Edition, 2003.
6. Optimal Control: Linear Quadratic Methods, Anderson and Moore, Dover Edition, 1990.
7. An Introduction to Neural Networks for beginners – Andy Thomas (https://adventuresinmachinelearning.com/wp-content/uploads/2017/07/An-introduction-to-neural-networks-for-beginners.pdf)
8. Multivariable Feedback Control: Analysis and Synthesis, Skogestad and Postlewaite, Second Edition, 2005.
9. Feedback Control Theory- Doyle, Francis and Tannenbaum, 1990.

Theory of Discrete and Digital Control Systems

(EE-5102)

Prerequisites: Signals and Systems, Control Systems and Discrete Time Systems

Weekly contact: 3 - 0 - 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Recapitulation of Discrete signals and Systems**: Discrete-time and sampled data system; Time invariant system response, Recursive solution; Discrete convolution; Digital simulation of analog system.	2L
02	**Sampling and Reconstruction of signals**: Impulse sampling; Frequency domain consideration; zero-order and first-order holds; Shanon's sampling theorem.	3L
03	**Z-transform and its application**: Z-transform analysis of sampled data system; Obtaining z-transform by convolution integral; Inverse z-transform; Mapping between s-plane and z-plane; Discrete-time transfer function; signal flow graph; Pulse transfer function using convolution sum; System with dead time/transportation lag; Modified z-transform; Bilinear transformation; Frequency pre-warping.	4L
04	**Design of Discrete-time controller**: Time-domain specifications; Error constants for different discrete control configurations; Digital PID controller; Relationship with analog and digital controller parameters: Frequency responses; Realization of position and velocity form of discrete-time PID controller.	5L
05	**Stability Analysis**: Jury's stability criterion; Schur-Cohn criterion; Routh's stability criterion; State variable representation of discrete time systems; controllability and observability. Canonical forms.	6L
06	**Multirate and Skip sampling**: Skip sampled components; Transfer function of complex system with mixed sampling rates.	4L
07	**Realization of discrete time systems**: Direct and Standard programming; Series, Parallel and ladder programming; errors in realization.	6L
08	**Discrete and Truncated Fourier series**: Discrete and First Fourier Transforms; Digital Data transmission and digital modulation systems; Error control codes.	4L
	Total:	**39L**

Suggested Readings:

1. **K. Ogata**- Discrete Time Control Systems, Prentice Hall Inc., 2e, © 2001.
2. **M. Gopal** - Modern Control System Theory, TMH, 2e, © 2005.
3. **B. C. Kuo** - Digital control systems, Oxford, 2e, © 2012.
4. **Landau, IoanDoré, Zito**, **Gianluca** - Digital Control Systems - Design, Identification and Implementation, Springer, © 2006.

Advanced Process Control & Instrumentation

(EE5103)

Prerequisite: Fundamentals of Control System and Instrumentation

Weekly contact: 3 - 1 - 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and topics	No. of Lecture-Hrs.
01	**Some terminologies related to a process:** (i) Balanced Condition ii) Self regulation iii) Time Lag iv) Process disturbance v) Process reaction Curve	3L
02	**Realisation of Control Actions**: Applying pneumatic, hydraulic and electronic principles	6L
03	**Special Control Techniques** : Feed forward, cascade and ratio control	3L
04	**Fluidics:** Fluidic devices, Fluidic devices, Coanda Action, Fluidic Oscillator, Bistable amplifier, Proportional amplifier	3L
05	**Actuator and Control valves:** Operation and types of Actuator, Types of control valves and their working principles, Valve Characteristics, Rangeability and Turn down, Selection of valve for different process variables	6L
06	**Special Sensors:** pH, flow sensor etc. Piezoelectric transducers	7L
07	**Programmable Logic Controller:** Relay Ladder Diagram, PLC programming	7L
08	**Industrial Buses:** Field bus, Profibus and Device Net systems	3L
09	**Computer aided process control:** Distributed Control System, SCADA	4L
10	**Thermal Power plant:** Instrumentation and Control	5L
11	**Probable Research Direction based on the above topic:** Process Parameter Optimization Algorithm, Data-driven fault diagnosis and process Monitoring, Data mining in monitoring and knowledge discovery	5L
	Total:	**52L**

Suggested Readings:

1. S. Bhanot – Process Controls : Principles and Applications ; Oxford Higher Educations, 2008
2. B. G. Liptak – Instrumentation Handbook.CRC Press,4th Edition, 2003
3. D. M. Considine – Instrumentation Handbook. 1993
4. D. Patranabis – Sensors and Transducers; PHI Learning Private Limited, 2013
5. J. W. Webb & R. A. Reis – Programmable Logic Controllers; Prentice Hall India. 2003
6. J Park, S. Mackay & E Wright – Data Communication for Instrumentation & Control; Newnes 2003

Advanced Power System Analysis

(EE5104)

Prerequisite: Power Systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and topics	No. of Lecture-Hr.
01	**Introduction:** Incidence Matrix and Loop Matrix	3L
02	**Formation of Y-bus and Z-bus matrix:** Y-bus matrix without and with transformer, Y-bus matrix modification with addition and deletion of branch, Y-bus for large network, Z-bus matrix, Addition of a branch or link, Modification of Z-bus, Direct building of Z-bus, Power invariant transformation, Application of computer methods (Gaussian Elimination,	6L
03	**Network Modeling:** Balanced and Unbalanced excitation, Modeling of network elements, Transformation matrices, Diagonalization	4L
04	**Short Circuit Studies:** Fault current and voltages, Short Circuit calculations for balanced network using Z-bus, Fault analysis (3-phase, L-G, L-L, L-L-G) using Z-bus algorithm	7L
05	**Load Flow Studies:** Review of Load Flow Methods (GSLF, NRLF, DCLF and FDLF), Sparsity and near optimal ordering, Sparse matrix storage techniques, Matrix Decomposition	7L
06	**Contingency Analysis:** Addition and deletion of transmission lines, generators and loads. Current Injection Distribution Factor (CIDF) and Line Outage Distribution Factor (LODF), Single and multiple contingencies	6L
07	**State Estimation and Load Forecasting:** Fundamental concept, Basic methods of State Estimation, External system equivalencing, Bad data detection and suppression, Observability, Load Forecasting Techniques	4L
08	**Current Topics:** Restructuring of power system, distributed generation, open access market	2L
	Total:	**39L**

Suggested Reading:

1. Grainger J.J. and Stevenson W.D., Power System Analysis, McGraw Hill Education, 2003
2. Kothari D.P. and Nagrath I.J., Modern Power System Analysis, McGraw Hill, Education, 2003
3. Singh L.P., Advanced Power System Analysis, Wiley Eastern, India
4. Chakrabarti A. and Haldar S., Power System Analysis, Operation and Control, PHI India.
5. Stagg and El-Abiad,Computer Methods in Power System Analysis, McGraw Hill. 1968

Power System Operation and Control
(EE5105)

Prerequisite: Power Systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and topics	No. of Lecture-Hr.
01	**Introduction:** Structure and Representation of a Power System, Necessity of Control and Control Methods, Types of Control, Common Operating Problems, Operating States, Use of Computer Control and Modern Methods in Power System Operation and Control, SCADA system	5L
02	**Economic Operation and Unit Commitment:** Input/Output characteristics of unit, Incremental cost curves , Constraints in economic operation, Analytical approach to determine economic operation criterion with and without network losses for thermal plants, thermal plant scheduling, Transmission loss allocation and penalty factor, Hydrothermal scheduling (Long Range and Short Range with and without network losses), Scheduling of hydraulically coupled unit, Scheduling of pumped storage plants, Concept of unit commitment and solution methods, Computer application in economic dispatch	11L
03	**Automatic Generation Control:** Types of exciter, AVR loop and its static and dynamic performance, Automatic Load Frequency Control (ALFC), Primary ALFC loop and secondary ALFC loop model, Static and dynamic performance of ALFC Loop, Two area control, Optimal control concept in ALFC, Optimal Line Regulator (OLR) design	10L
04	**Sub Synchronous Resonance (SSR):** Introduction to SSR, Torsional interaction, Eigen value analysis, Modern topics	3L
05	**Power System Compensation and FACTS Devices:** Operation of transmission line during no-load and heavy loading condition, Voltage regulation and Maximum Power Transfer in uncompensated line, Concept of SIL and Line Loadability, Passive compensators, FACTS devices	7L
06	**Power System Economics:** Tariffs, Concept of Deregulation, Power Pool and Service Operator, Network Restructuring, Congestion Management and Electricity Pricing	3L
	Total:	**39L**

Suggested Reading:

1. Wood A.J., Woolenberg, Power Generation Operation and Control, John Wiley and Sons Inc, USA.
2. Chakrabarti A. and Haldar S., Power System Analysis, Operation and Control, PHI India
3. Kothari D.P. and J.S. Dhillon, Power System Optimization, PHI, New Delhi
4. Mahalanabis A.K., Kothari D.P. and Ahson S.I., Computer Aided Power System Analysis and Control, McGraw Hill, India

Power Transmission and Power Quality
(EE5106)

Prerequisite: Power Systems & Power Electronics

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and topics	No. of Lecture-Hr.
01	**EHVAC Transmission**: Review of Basic Concepts, Surge Impedance loading of EHV Lines and its implication, operation of EHV Line during no-load and heavy loading condition, Maximum Power Transfer, Line Loadability, Implication of Voltage Regulation, Stability aspects and line length limitation, Line Congestion. Protection Sub- systems(ATP).	6L
02	**Reactive Power Compensation in EHVAC lines**: Shunt inductive and Capacitive compensation, series compensation, Comparison between shunt and series compensation, role of location of series capacitor and effect of capacitor busing arrangement, synchronous condenser, Fundamentals of FACTS Devices, Classification, Types of Series FACTS controllers (SSSC, TCSC and TCSR), Types of Shunt FACTS controllers (SVC, SSG, STATCOM), Combined Shunt- Series FACTS Controllers (SPS, UPFC), Advantages of FACTS devices.	10L
03	**Power Electronic Converters and HVDC Transmission:** Review of Concept of Controlled Rectification, 3- Phase Controlled Rectifiers, Thyristor Protection Devices, Poly-phase Converter Expressions, 6-Pulse and 12-Pulse Configurations, Effect of Source Inductance, Rectifier Transformer Rating, Principle of Inversion, Necessity of Filters, IGBT Converters, Advantages and Disadvantages of HVDC Transmission, HVDC System Configuration, HVDC Control (Basic requirements, control characteristics, selection of controls), HVDC line and line reactors, HVDC Terminal Equipments, HVDC System Protection, Modeling of HVDC systems, MTDC System, Current Topics	8L
04	**Power Quality:** Concept of Quality of Power in utility industries, Role of harmonics in Power Quality, Representation and Characteristics of Harmonics in Power Systems, Computation of Harmonic Distortion, Sources of Harmonics in Transformers, Rotating Machines, Power Systems, Role of Power Electronic Converters in generation of harmonics, Implication of harmonic distortion on Thermal losses, Core losses, and dielectric losses, Effect of harmonics on Power system equipments, Power Quality Measurement, Power system harmonics mitigation, Current Topics	15L
	Total:	**39L**

Suggested Reading:

1. Adamson and Hingorani, High Voltage Direct Current Power Transmission, Garraway, London
2. Arrillaga J., HVDC Transmission, Peter Peregrinus, London
3. Gonen T., Electric Power Transmission System Engineering, John Wiley
4. Chakrabarti A., Power System Dynamics and Simulation, PHI
5. Heydt. G.T., Electric Power Quality, Circle Publications
6. Ghosh A and G. Ledwich, Power Quality Enhancement Using Custom Power Devices, Kluwer Academics“

Advanced Power Electronics

(EE5107)

Prerequisite: The course on basic power electronics

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction:** Review of existing solid state power devices. Quadrant operation of devices. Modern solid state devices (GaN and SiC), special driver circuits, SOA and switching trajectory, losses in power electronic devices, pulse transformer.	8L
02	**DC-DC converters:** Discontinuous conduction, 2-quadrant and 4-quadrant DC-DC converters. Forward, flyback, push-pull, half-bridge and full-bridge topologies and their open-loop control. Dynamic modeling of DC-DC converters and closed loop control, efficiency issues of DC-DC converters.	9L
03	**AC-DC converters:** Review of diode based and thyristor based rectifiers, discontinuous conduction, effect of source inductance, effect on AC side, efficiency issues of rectifiers..	3L
04	**DC-AC conversion:** Single phase and three phase inverters, concept of space vectors, analysis of 2-level inverters with Sine-PWM and Space vector pulse width modulation. Concept of current source inverters, efficiency issues of inverters. .	8L
05	**AC-AC conversion:** Review of cycloconverters, matrix converters.	6L
06	**Passive components:** Magnetics and capacitors for PE applications, design of heat sink for dissipation of losses	5L
	TOTAL	**39L**

Suggested Readings:

1. N. Mohan, T. M. Undeland and W.P. Robbins, "Power Electronics: Converters, Applications and Design", John Wiley & Sons, 2007.
2. C. W. Lander, "Power Electronics", McGraw Hill Book Co, 1987.
3. R. W. Erickson and D. Maksimovic, "Fundamentals of Power Electronics, 2nd Edition", Kluwer Academic Publishers, New York, 2001.
4. M. H. Rashid, "Power Electronics - Circuits, Devices and Applications", Prentice Hall, Pearson Education, 2014.
5. G. K. Dubey, S. R. Doradla, A. W. Joshi, R. M. K. Sinha, "Thyristorised Power Controllers", Wiley, 1986.
6. A. I. Pressman, K. Billings, T. Morey, "Switching Power Supply Design", 3rd Edition, McGraw-Hill, 2009.
7. Modern research literatures

Generalized Theory of Electrical Machines

(EE5108)

Prerequisites: Courses on electrical machines and basic power electronics

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction:** Review of coupled circuits, electro-mechanical energy conversion basics, energy and co-energy, concept of virtual work and electromagnetic torque production, origin of reluctance torque.	4L
02	**Generalized machine theory and reference frame theory:** Assumptions behind the theory, Park's transformation, Clarke's transformation.	4L
03	**Transformations:** Different types of d-q transformation used in modern research literatures, stationary, rotor, synchronously rotating and arbitrarily rotating reference frame, mathematical relationships existing between above reference frames, torque and motional impedance matrices.	5L
04	**Application of the theory on induction machines:** Transient and steady state modeling and analysis of 3-phase induction machine in terms of above reference frames, case studies showing applications, equivalent circuits.	6L
05	**Application of the theory on synchronous machines:** Transient and steady state modeling and analysis of 3-phase wound-field synchronous machine in terms of above reference frames, case studies showing applications, equivalent circuits, steady state and transient/sub-transient operations of synchronous machines	7L
06	**Generalized theory applied to D.C. and cross field machines:** **a) Introduction:** Adaptability of the theory, transformations, equation for small changes, short circuit studies on D.C. separately excited generator, rototrol, shunt generator, block diagrams. **b) Analysis with emphasis on saturation:** Expressions of voltage build up, effect of saturation, Froelich & Rudenburg graphical analysis, measurement of parameters. **c) Control applications of D.C. machines**: Ward Leonard method, cross field machines, rotating amplifiers.	5L 4L 4L
	TOTAL	**39L**

Suggested Readings:

1. Denis O'Kelley, S. Simmons, "Introduction to generalized electrical machine theory", McGraw-Hill, 1968.
2. Paul Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven Pekarek, "Analysis of Electric Machinery and Drive Systems", 3rd Edtion, IEEE Press, 2013.
3. B. Adkins and R. G. Harley, "The General Theory of Alternating Current Machines: Applications to Practical Problems", Springer Science and Business Media, B. V, 1978.
4. Modern research literatures

Advanced Microcontroller Technology

(EE5121)

Prerequisites: : A basic course on Microprocessors and Microcontrollers

Weekly contact: 3 - 0 - 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introductory concepts**: Programmers model of processor, processor architecture; Microcontroller architecture; Types of Memory & memory interfacing; Instruction set, modular assembly programming using subroutines, macros etc.; Concept of interrupts: hardware & software interrupts, Interrupt handling techniques, Interrupt controllers; Programmable Peripheral devices and I/O Interfacing ; DMA controller and its interfacing.	6L
02	**Introduction to Intel 8051 Microcontroller**: Basic architecture, Addressing modes and port structures, Timers, Interrupts, Serial Interface, Instruction Set and programming.	7L
03	**Introduction to PIC Microcontroller**: Basic architecture, I/O ports, Timers, CCP Module, ADC Module, Synchronous Serial Port, Instruction Set and programming.	7L
04	**Introduction to ARM Microcontroller**: Basic architecture and pipeline structures, Programming modes and instruction set, ARM Coprocessor interface, Cache and Memory management, Timer, ADC/DAC, Interrupts, I^2C, SPI, PWM Interfaces.	7L
05	**Introduction to ADSP Microcontroller:** Basic architecture, Instruction Set and programming methodology.	7L
06	**Typical applications of microcontrollers**: Typical examples of applications in drives, power grid control, electric utility or any other suitable examples, highlighting development of system hardware/software (in assembly language/high level language), debugging and troubleshooting.	5L
	Total:	**39L**

Suggested readings:

1. 'PIC- Fundamentals of Microcontrollers and applications in Embedded Systems' by Ramesh S. Gaonkar; Penram Intl. Publishing(India)Pvt. Ltd., 2010
2. DSP Microcontroller- ADSP-2100_ User's_Manual, 1993
3. 'The 8051 Microcontroller' (3rd ed.) by Kenneth J. Ayala, Delmar Cengage Learning, 2005
4. 'ARM Assembly Language Programming & Architecture' (2nd ed.) by Mazidi & Naimi et al., 2016

Advanced Computational Methods and Programming for Electrical Engineering (EE-5122)

Prerequisite: Programming in C

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction:** Review of number representation, error associated with numerical computation and solution and their minimization	2L
02	**Matrices:** Matrix manipulation, Inverse, Eigen value and Eigen vector problems. Solution of Simultaneous Algebraic Equations: Gauss Elimination, Gauss-Jordan Elimination, Method of Factorization, Iterative methods: Jacobi's method, Gauss-Seidel method.	3L
03	**Interpolation and Curve Fitting:** Divided and finite difference interpolation formula, Fittings of curves over discrete sets of points, Least square curve-fitting.	4L
04	**Numerical Integration:** Trapezoidal rule, Simpson's rule. Numerical Solution of ordinary differential equations: Solution of initial value problem by Tailor's series method, Euler's method, Runge Kutta Gill's Formula, 2^{nd} order and 4^{th} order Runge-Kutta methods.	6L
05	Review of Computing Systems, Operating Systems, Programming Environment and tools Editor, Compiler, Debugger, Profiling and Revision Control System/Concurrent Version Control	10L
06	C/C++/Python language and its programming utilities including structure, symbols, separators, Operators, data types heading and declaration part, identifiers, assign statements and expression, procedures and functions. input output statements, simple and structural statements, blocks, locality, array, record, object, set, file, pointer, units	10L
07	An Introduction to Parallel Computation and High Performance Computation using Message Passing Interface	4L
	Total:	**39L**

Suggested Reading:

1. Introductory Methods of Numerical Analysis by S. S. Sastry; Prentice Hall India, 2012
2. Applied Numerical methods with MATLAB for Engineers and Scientists by Chapra, Tata McGraw-Hill, India, 3rd Edition, 2012
3. Numerical Methods using MATLAB by Lindfield, Penny; Academic Press. 2018

4. The C++ Programming Language - BjarneStroustru; PHI, 4th Ed, 2013
5. Numerical Methods in Science and Engineering by S. Rajasekaran; S. Chand, 2003
6. Numerical Methods in Engineering and Science by B. S. Grewal, Khanna Publisher, 2013
7. The C Programming language -Dennis Ritchie, Brian Kernighan, PHI, 2nd Ed. 1988
8. The Unix Programming Environment - Brian Kernighan and Rob Pike, PHI, 1987
9. Beginning Linux Programming - Neil Matthew and Richard Stones, Wrox, 2017
10. An Introduction to Parallel Programming - Peter S. Pacheco, Morgan Kaufmann, 2011

Application of Soft Computing Techniques in Electrical Engineering (EE5123)

Prerequisite: Engineering Mathematics

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01.	**Introduction to Soft Computing**: Inspiration behind soft computing, difference between hard and soft computing, computational intelligence, machine learning and computer vision	3L
02.	**Artificial Neural Network (ANN)**: Introduction to Neural Computing (NC) & Artificial Neural Network, comparison between biological and artificial neural network, major types of variants of ANN, neural network training, supervised and unsupervised learning algorithms	8L
03.	**Typical Applications of ANN:** *Applications of Supervised Learning*: Enhancement of Voltage Stability in Multi-Bus Power Systems by Network Reconfiguration assisted by ANN, Load forecasting using MLP with Back Propagation algorithm, Fault diagnosis of electrical machines and drives, *Applications of Unsupervised Learning*: Kohonen's SOM based Differential Relay for Protection of Synchronous Generators, Fault Diagnosis in Transformer Winding Insulation using SOM	6L
04.	**Fuzzy Logic and Fuzzy:** System: Basic concepts of Fuzzy logic approaches, linguistic variables, membership functions, basic operation, Fuzzy relations, different de-Fuzzification techniques, Fuzzy rule based model, type-2 Fuzzy system	5L
05.	**Typical Applications of Fuzzy Logic:**fuzzy logic controllers, neuro-fuzzy model in load forecasting, Fuzzy and neuro fuzzy techniques in fault detection	4L
06.	**Genetic algorithms (GA)**: Introduction to search optimization method, evolutionary algorithms (EA), biological inspiration behind GA, working principles, encoding, crossover and mutation, basic GA algorithm	4L
07.	**Typical Applications of Genetic Algorithm** Optimal sizing and placement of Capacitor bank in power network using GA, Economic load dispatch and optimal allocation of resources using GA, Optimization of distribution network for economic operation using GA	3L
08.	**Recent Trend inMachine Learning:** Recurring Neural Networks (RNN)**,** Deep Learning**,** "Big data Analysis", Time series prediction and other current issues	6L
	TOTAL	**39L**

Suggested Readings:

1. Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis And Applications, By S. Rajasekaran and G. A. VijayalakshmiPai, PHI Learning Ltd, 2003
2. Soft Computing : Techniques and is Applications in Electrical Engineering, By D. K. Chaturvedi, Springer 2008
3. Tutorial on Fuzzy Logic Applications in Power System, IEEE –PES winter meeting in Singapore, January, 2000
4. Neural Network Applications in Power Electronics and Motor Drives- An Introduction and Perspective, B. K. Bose, IEEE Transaction on Industrial Electronics, 2007
5. Genetic Algorithm in Applications, Edited by Dr. RustemPopa, March 2012

Power Quality Studies in Electrical Systems

(EE5124)

Prerequisites: Network theory, analog and digital electronics, Fourier analysis, electrical machine, power system and power electronics.

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Power Quality terms and standards:** Power quality definition, different type of poor power quality events: voltage sag, voltage swell, impulsive transient, oscillatory transient, interruption, harmonic/inter-harmonic distortion, notching and voltage fluctuation(flicker), familiarization with different standards.	6L
02	**Power and its component:** Definition of various power components for non-sinusoidal voltage and current, single phase and three phase balanced and unbalanced circuits.	6L
03	**Harmonic/inter-harmonic distortion:** Voltage and current distortion, harmonic indices, power factor with harmonics/inter-harmonics, displacement factor, harmonic sources from commercial and industrial loads, locating harmonic sources; power system response characteristics, resonance, harmonic distortion evaluation, devices for controlling harmonic distortion, passive filters, active filters, power factor correction equipment, IEEE and IEC standards.	9L
04	**Load voltage regulation:** Causes of sags and interruptions, mitigation of voltage sags: active series compensators, static transfer switches and fast transfer switches. Sources of transient over voltages (swells): capacitor switching, lightning, ferro-resonance; mitigation of voltage swells: Introduction to custom power devices (DSTATCOM, DVR) and their applications in power system.	9L
05	**Noises:** Common mode noises, EMIs, mitigation, cable shielding, isolation.	2L
06	**Wiring and grounding:** Familiarization with ANSI/IEEE Standard 1100-1992, IEEE Standard 518, reasons for grounding, wiring and grounding problems, solutions, grounding techniques for signal reference, grounding for sensitive equipment.	3L
07	**Power quality measurement equipment:** Power analyzer, harmonic / spectrum analyzer, flicker meters, disturbance analyzer, analysis tools.	2L

08	**PQ Audit and Benchmarking:** Preparation of report, the different components of the report, comparison with acceptable PQ indices	2L
	TOTAL	**39L**

Suggested Readings:

1. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, and H. Wayne Beaty, "Electrical Power Systems Quality", McGraw Hill, 2012.
2. C. Sankaran , "Power Quality", CRC press, 2017.
3. Alexander Kusko and Mark T. Thompson, "Power quality in Electrical Systems", McGraw Hill, 2007.
4. Ewald F. Fuchs and Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines", Academic Press (Elsivier), 2008.
5. Jos Arrilaga, "Power System Harmonic Analysis", John Wiley and Sons Limited, 1997.

Illumination Science, Engineering and Design

(EE5161)

Prerequisite: Physics

Weekly contact: 3 +1+0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Sources of light**: Day light, artificial light source; energy radiation, visible spectrum of radiation, black body radiation and full radiator.	6L
02	Incandescence, dependence of light o/p on temperature. Theory of gas discharge and production of light.	6L
03	**Perception of light and colour**: optical system of human eye, eye as visual processor. Reflection, refraction and other behaviors of light.	6L
04	**Measurement of light**: radiometric and photometric quantities and their units of measurement. Standardization, measurement of light distribution, direct & diffused reflection, fundamental concept of colorimeters and measurement of colour.	9L
05	**Types of lamps**: GLS Tungsten —halogen, Discharge, low pressure sodium vapour, high pressure sodium mercury vapour, fluorescent, Metal-halide IR and UV lamps, their construction , filament material , theory of operation , life , characteristics and application Xenon Lamps, LED lamps, Fibre Optic and Laser Lighting	8L
06	Design objectives and specification of lighting & system design of luminaire, their electrical circuits and auxiliaries. Basic Lighting Design Considerations and Lighting parameters for interior lighting, exterior lighting and day lighting	6L
07	Energy efficiency in Design and Installation of Lighting Systems, the physiological effects of lighting, Mesopic Photometry	7L
08	A Case Study with Lighting design Software to learn an optimized design approach	4L
	TOTAL	**52L**

Suggested Reading:

1. Architectural Lighting: Designing with Light and Space - Cecilia Ramos and HervéDescottes
2. Designing With Light: The Art, Science and Practice of Architectural Lighting Design- Jason Livingston
3. Illuminating Engineering: From Edison's Lamp to the LED - Joseph B. Murdoch
4. *Applied Illumination Engineering - Jack L. Lindsey*
5. Human Factors in Lighting, Third Edition - Peter Robert Boyce
6. Road Lighting Fundamentals, Technology and Application - van Bommel, Wout

7. Lamps and Lighting 4th Edition - M.A. Cayless (Author), J R Coaton (Editor), A. M. Marsden (Editor)
8. Light Pollution Caused by Building Façade Lighting and Signs Attached to Buildings -Chung-yun Juan Lo
9. Daylighting: Architecture and Lighting Design - Peter Tregenza, Michael Wilson
10. How to Design and Install Outdoor LightingBy William H. W. Wilson
11. Designing With Light: The Art, Science and Practice of Architectural by Jason Livingston
12. Architectural Lighting Design by Gary Steffy
13. Lighting Control: Technology and Applications by Robert Simpson
14. Lighting Controls Handbook by Craig DiLouie
15. e-bookstore of **IESNA [www.iesna.org]** and **CIE[www.cie.co.at]** lighting design guidelines/ recommendation etc.

Optimal And Robust Control Theory

(EE5201)

Prerequisites: EE 5101, Matrices, Linear Algebra, Integration, Ordinary Differential Equations

Weekly contact: 3 - 0 - 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction to Calculus of Variations:** Euler's Equation. Legendre's Condition, Conditional Extremum Problems; Examples. **Advanced topics**: Transversality Conditions, Sufficient Conditions for an extremum.	**10L**
02	**Quadratic Forms:** Solution to Lyapunov Equation, Stability of unforced linear state equations	**4L**
02	**Linear Optimal Control:** Linear Quadratic Regulator Problem; State Feedback Solution; LTI Infinite Horizon problem; Algebraic Riccati Equation (ARE); Hamiltonian Matrix; Numerical Design Examples.	**7L**
03	**Robust Control:** Robust Control Problems; H_2 Control; H_∞ Optimization; Standard Problem; Different configurations; Solution; Numerical Examples.	**7L**
04	**Linear Matrix Inequalities:** Definition of Convexity, Convex Optimization, LMIs; Formulation of standard optimization problems as LMIs; Numerical Examples.	**6L**
06	**Case Studies:** Study of standard benchmark problems; Design Examples..	**5L**
	Total:	**39L**

Suggested Readings:

1. Variational Methods in Optimum Control Theory – I. Petrov, 2012.
2. Optimal Control: Linear Quadratic Methods, Anderson and Moore, Dover Edition, 1990.
3. Robust Control Systems: Theory and Case Studies – U. Mackenroth, 2004.
4. Feedback Control Theory – J. C. Doyle, B. Francis and A. Tannenbaum, 1990.
5. Multivariable Feedback Control: Analysis and Synthesis, Skogestad and Postlewaite, Second Edition, 2005.
6. Linear Matrix Inequalities in System and Control Theory – Boyd, El Ghaoui, Feron and Balakrishnan
   (https://web.stanford.edu/~boyd/lmibook/lmibook.pdf)
7. A Course in Robust Control Theory: A Convex Approach – G. E. Dullerud and F. Paganini, 2000.
8. Linear Matrix Inequalities in Control – C. Scherer and S. Weiland

9. (http://www.eeci-institute.eu/pdf/M012/lec1.pdf)
10. Essential of Robust Control – K. Zhou and J. C. Doyle, 1999.

Signal and Image Processing for Instrumentation and Control

(EE 5202)

Prerequisite: Engineering Mathematics

Weekly contact: 3 - 0 - 0 (L- T- P) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Signal Transforms:** Ortho-normal vector and functional space, Fourier transform, Fourier series, Generalized Fourier transform property and convolution theorem Hilbert Transform, Hilbert-Huang Transform,Discrete Cosine Transform (DCT), Discrete Sine Transform (DST), Short Time Fourier Transform (STFT)	12L
02	**Wavelet Transform:** Method , Different variety Properties, Applications to Instrumentation and control	7L
03	**Mathematical Preliminaries of signal processing**: Spectral Representation and Analysis, Sparse Signal Processing, Blind Signal Processing	5L
04	**Image processing fundamentals:** Steps in Image processing, Components of an image processing system, Image sampling and quantization, Image representation, Image description. Noise models, Color image processing.	7L
05	**Image Processing Applications:** Image enhancement in spatial domain, Image enhancement in frequency domain, Image restoration, Image compression, Morphological image processing, Image segmentation	8L
	Total	**39L**

Suggested Readings:

1. Truong Nguyen & Gilbert Strang, - Wavelets and Filter Banks, Wellesley-Cambridge Press. 1996

2. K. R. Rao and P. Yip- Discrete Cosine Transform: Algorithms, Advantages, Applications, Academic Press, 1990

3. Khalid Sayood- Introduction to Data Compression, Elsevier, 2006

4. Gilbert Strang, Nelson Engineering-Linear Algebra and Its Applications, 1986

5. Rafael C Gonzalez, Richard E Woods-Digital Image Processing, Pearson Education, 2008

6. A.K. Jain- Fundamentals of Digital Image Processing, PHI, 2004

7. R.C. Gonzalez, R.E. Woods, and S. L. Eddins- Digital Image Processing using MATLAB, Pearson Prentice-Hall, 2009

8. J. R. Parker, Wiley and Sons-Algorithms for Image Processing and Computer Vision,2011

Optimal Filtering and Stochastic Processes

(EE5203)

Prerequisites: Control Systems, Statistics, Random Variables

Weekly contact: 3 - 0 - 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Basics of Stochastic Processes:**Langevian Equation, White noise process and Wiener noise process.	2L
02	**Probability and Random Variables:** Probability Distribution and Densities; Expectancy & Moment; Function of RV; Mean, Correlation, Covariance, Standard Deviation.	3L
03	**Random Processes and Sequences**: Brownian, Ergodic, Markov and Gaussian processes and sequences; Linear System model of Random Processes and sequences; Stochastic differential equations and stochastic integrals, Kolmogorov equations; Orthogonality principle	4L
04	**Estimation Techniques:** Least Square Estimation; Grammian Matrix &Observability: Weiner Filter;The AR and ARMA Model.	3L
05	**Kalman Filter:** Computational Origin, Description of Noise processes; Discrete-time Kalman Filter algorithms; Filter equations and their significances; Alternative form of Discrete Kalman algorithm; Deterministic Least Square Estimation and Kalman Filtering; Stability with Kalman Filter; Kalman-Bucy Filter.	7L
06	**Non-linear Application of Kalman Filter:** Linearized and Extended Kalman Filter Algorithms. Gaussian Sum estimation;Unscented Kalman Filter; General Optimal Filtering, FIR and IIR case.	6L
07	**Practical Implementation Considerations**: Predicted and unpredicted non-convergence problems and remedies; Bad-data problem. Round-off error etc.	2L
08	**Filtering, Prediction and Smoothing**: Fixed point, fixed lag and fixed interval smoothing: Maximum Likelihood Estimator, Particle Filter.	3L
09	**Control of Stochastic Processes**: LQ Theory, LQR Problem, LQG Problem, LQ estimator and LQ optimization of controller, Separation Principle, Discrete time LQG problem, LQG controller design for a regulator problem. Robustness of LQG controllers, Disturbance Modelling – Augmented model of systems.	7L
10	**Examples of Stochastic Processes:** Physiological System, Room	2L

	temperature control, Inventory Control, market economic process etc.	
	Total:	**39L**

Suggested Readings:

1. Grewal & Andrews, Kalman Filtering, Prentice Hall, 2e, © 1993.
2. Grewal & Andrews, Kalman Filtering: Theory and Practice with MATLAB, - Wiley, 4e, © 2015.
3. R. E. Kalman, "A New Approach to Linear Filtering and Prediction Problems", *Transactions of ASME – Journal of Basic Engg*., Vol 82, *pp*.35-45, March 1960.
4. R. E. Kalman and R. S. Bucy, "New Results in Linear Filtering and Prediction Theory", *Transactions of ASME – Journal of Basic Engg*., Vol 83, *pp*.95-107, December, 1961.
5. M. Athans, "The Role and Use of Stochastic Linear-Quadratic-Gaussian Problem in Control System Design"; IEEE *Transactions on Automatic Control, Special issue on LQG Problem,* Vol AC-16, No. 6, *pp*.529-552, December 1971.
6. B. D. O. Anderson and J. B. Moore; Optimal Control : Linear Quadratic Methods, PHI, New Delhi, © 2007.
7. T. Glad, L. Ljung; Control Theory: Multivariable and Nonlinear Methods, 1e, Taylor and Francis, © 2000.

Advanced Power System Protection

(EE5204)

Prerequisite: Power System Protection

Weekly contact:3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and topics	No. of Lecture-Hr.
01	**Circuit Breaker:** Review of concepts, Current chopping, Breaking of capacitive current, Rating, Testing and Selection of Circuit Breakers, HVDC Circuit breaker	3L
02	**Philosophy of Differential Protection:** Principles of Differential and Percentage Differential Relay, Pilot Relaying, Circulating Current and Opposed Voltage Type Relaying, Carrier Current and Microwave Pilot Relaying	3L
03	**Philosophy of Distance Protection:** Impedance Relay, Reactance and Admittance Relay - their characteristics and uses, Modified Distance Relays, Transmission Line Protection using Distance Relays	3L
04	**Generator Protection:** Circulating Current Differential Relay, Stator Earth Fault Relay, Restricted Earth Fault Relay, Rotor Earth Fault Relay, Loss of Excitation Relay, Reverse Power Relay, Negative Sequence Protection Relay, Back up Relaying.	4L
05	**Transformer Protection:** Circulating Current Differential Relay, Over Current and Earth Fault Protection, Over Fluxing Protection, Incipient Fault Protection	3L
06	**Bus bar Protection:** Differential and Back up Protection	2L
07	**Motor Protection (Large and Medium Size):** Differential Protection, Short Circuit and Overload Protection, Under Voltage Protection, Earth Fault Protection, Locked Rotor Protection, DC Motor Protection	3L
08	**Capacitor Bank and Reactor Protection:** Short Circuit, Over Current, Differential and Earth Fault Protection	2L
09	**System Protection Requirements:** Annunciation and Indication, Tripping and Control Circuit, Interlocking, Co-ordination of Protection Devices, Signal Derivation, Transient Characteristics, System Behaviour and Protection during Power Swing, Under Frequency and Islanding	3L
10	**Digital Protection and PMU Based Measurements:** Two and Multi-input	13L

	Comparator, Phase and Amplitude corrections, Types of Comparators, Practical Realization of Modern Relay Characteristics, Switched and Polarized Protection Systems, , Signal Processing Techniques for Digital Protection, Numerical Relays and Development of Relaying Algorithms ; Concept and Application of Adaptive Relaying, **Substation Automation**; Synchronized Phasor Measurement Unit and its Role in Wide Area Monitoring System for Enabling the Smart Grid.	
	TOTAL	**39L**

Suggested Reading:

1. Synchronized Phasor Measurements and Their Applications, A.Phadke, J Thorp, Springer Publishers ISBN: 9781441945631, 1441945636
2. Digital Protection for Power Systems A.T Johns, S.K. Salman, Publisher IET, 1997 ISBN-13:9780863413032
3. Digital Signal Processing in Power System Protection and Control, Waldemar Rebizant Janusz Szafran, Andrzej Wiszniewski, Springer-Verlag London Limited 2011.

Power System Stability, Security and High Voltage Engineering

(EE5205)

Prerequisite: Power Systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Review of Stability:** Steady State and Transient State Stability and Security, Stability Limits, Criterion for determination of Steady State and Transient Stability Limits, Swing Equation and Methods of Solution, Critical Clearing Time	4L
02	**Transient Stability:** Transient Stability Study in multi-machine power network, Development of Computer Algorithms in Transient Stability study, Modern Concepts	6L
03	**Small Signal Stability:** Nature of oscillations and modes, Concept of Small Signal Stability, Eigen properties of system matrix, Small Signal Stability modeling of a Single Machine Infinite Bus system (SMIB), State Space model, Role of Excitation systems, Application of Power System Stabilizer, Modern Topics	7L
04	**Voltage Stability and Security:**Role of Reactive power on Steady State Operation, Voltage to Reactive Power Sensitivity, Concept of Voltage Stability, Voltage Collapse and Voltage Security, Receiving end bus voltage and Critical Angle at Voltage Stability Limit, Fast Voltage Stability index, Line Voltage Stability Index, Line Quality Factor, Direct Indicator of Voltage Stability, L-Index, Global Voltage Stability Indicator, Modal Analysis in Voltage Stability, Modern Topics	9L
05	**High Voltage Engineering:** **a)** Dielectric Breakdown, Surface and Partial Discharges.Breakdown phenomena in Solid, Liquid and Gaseous dielectrics. Essential properties of dielectric materials for use in Power Equipment.	5L
06	**b) G**eneration of High AC, DC and Impulse Voltage for Dielectric Testing. High-voltage Testing transformer, Cascaded transformer, Resonant transformer, Marx generator.	5L
07	**c)** Over-voltage phenomena and Insulation-Coordination	3L
	TOTAL	**39L**

Suggested Reading:

1. Grainger and Stevenson, Power System Analysis, McGraw Hill, India.
2. Kothari and Nagrath, Modern Power System Analysis, McGraw Hill
3. Taylor C.W., Power System Voltage Stability (EPSR), McGraw Hill, USA.
4. Chakrabarti A., Kothari D.P., Mukhopadhyay A.K., De A., Reactive Power and Voltage Stability of EHV Power Transmission System, PHI
5. P. Kundur, Power System Control and Stability
6. E.Kuffel and W.S. Zaengl, J.Kuffel, "High Voltage Engineering Fundamentals", Newnes, Second Edition, Elsevier, 2005.
7. C. L. Wadhwa, "High voltage Engineering", New Age International Publishers, Third Edition, 2010
8. L. L. Alston, "High Voltage Technology", Oxford University Press, First Indian Edition 2011.
9. M. S. Naidu and V. Kamaraju, "High Voltage Engineering", 4thEdition, Tata McGraw-Hill Publishing Co. Ltd., New Delhi, 2009.

Smart Grid Technologies and Energy Informatics

(EE5206)

Prerequisite: Power Systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction to Smart Grids:** Definition, justification for smart grids, smart grid conceptual model, smart grid architectures, Interoperability, communication technologies, role of smart grids standards, intelligent grid initiative, national smart grid missions by Govt. of India	5L
02	**Smart Transmission Technologies:** Substation automation, Supervisory control and data acquisition (SCADA), energy management system (EMS), phasor measurement units (PMU), Wide area measurement systems (WAMS), role of Communication and Information Technology(ICT)	5 L
03	**Smart Distribution Technologies:** Distribution automation, outage management systems, automated meter reading (AMR), automated metering infrastructure (AMI), fault location isolation and service restoration, Outage Management Systems, Energy Storage, Renewable Integration	6L
04	**Distributed Generation and Smart Consumption:** Distributed energy resources, smart appliances, low voltage DC distribution in homes / buildings, home energy management system, Smart Metering, Building to Grid B2G, Vehicle to Grid V2G, Solar to Grid, Micro grid	6L
05	**Regulations and Market Models for Smart Grid:** Demand Response, Demand side Management, Tariff Design, Time of the day pricing, Critical Peak Pricing, Time of use pricing, Consumer privacy and data protection, consumer engagement.	4L
06	**Introduction to Energy Informatics:** Energy, sustainability and climate change, Green IT : policy and standards, Green IS , Energy efficiency design principles, Energy efficient logistics, farming, transportation, buildings , Energy system modelling	7L
07	**Data Driven Energy Management System:** Processing energy data streams :Big Data-driven smart Energy Management Systems, Data analytics for energy-cost efficient system operation.	6L
	TOTAL	**39L**

Suggested Reading:

1. Stuart Borlase. "Smart Grid: Infrastructure Technology Solutions" CRC Press, **2017**
2. Ali Keyhani, "Design of smart power grid renewable energy systems", Wiley IEEE,**2011**.
3. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press, **2009**.
4. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, "Smart Grid: Technology and Applications", Wiley **2012.**
5. A.G.Phadke , "Synchronized Phasor Measurement and their Applications", Springer, **2017**
6 .James Momoh, "Smart Grid: Fundamentals of Design and Analysis" – Wiley, IEEE Press, **2012.**
7. H. Lee Willis, Walter G. Scott, "Distributed Power Generation – Planning and Evaluation", Marcel Dekker Press, **2000**
8. India Smart Grid Knowledge Portal
9. Information Systems and Environmentally Sustainable Development : Energy Informatics and New Directions for the IS community, by R. T. Watson et al., MIS Quarterly, **2010**
10. Advances and New Trends in Environmental and Energy Informatics, by J. M. Gomez et. al., Springer,2014
11.Energy Informatics: Fundamentals and Standardizations, by B. Huang et al., ICT Express(Elsevier), **2017**

Advanced Electrical Drives

(EE 5207)

Prerequisite: Advanced Power Electronics (EE – 5107), Generalized Machine Theory (EE-5108), a basic course on electric drives

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction:** Review of two-loop control of adjustable speed DC drives, speed and current loop design, multi-quadrant control of DC drives	6L
02	**Induction motor (IM) drives:** Review of **s**olid state scalar V/f control of 3-phase induction motors (IM based VFD's). CSI-fed cage IM drives, comparison with VSI-fed drives, details of field-oriented control and direct torque control. Detailed analysis of wound rotor IM drives – chopper based control of rotor, Scherbius drives.	15L
03	**Wound-field Synchronous motor drives:** Synchronous motor as a variable speed motor – true-synchronous mode and self-synchronous modes of operation, soft-starting of large synchronous motor drives from weak grids,LCI-fed synchronous motor drive, its performance comparison with VFD-fed synchronous motor drive, vector control of synchronous motors. (PMSM machines and drives are discussed in the other core course, 'Selected Machines on Electric Vehicle and Wind Power Applications'.)	9L
04	**Switched reluctance motor drives**: Introduction, power converter circuits, control methodologies, analysis.	5L
05	**Sensorless AC motor drives:** Role of sensors in motor drives, sensorless operation of AC drives and techniques.	2L
06	**Special Industrial perspective of AC drives:** Energy efficiency of AC drives, effects of PWM switching on motors – issues related to dv/dt stress, effects of partial discharge and corona on machine insulation, effects of bearing currents, effects of vibration and noise, possible remedial measures	2L
	TOTAL	**39L**

Suggested Readings:

1. G. K. Dubey, "Fundamentals of Electric Drives", Narosa Publishing House, 2003.
2. G. K. Dubey, "Power Semiconductor Controlled Drives",Prentice Hall, 1989.
3. B. K. Bose, "Power Electronics and AC Drives", Prentice Hall, 1986.
4. J. Murphy and F. G. Turnbull, "Power Electronic Control of AC Motors",Pergamon Press, 1988.
5. Krishnan Ramu, "Switched Reluctance Motor Drives", CRC Press, 2001.
6. T.J.E Miller, "Switched Reluctance Motors and their control", Magna Physics Publishing, Oxford Science Publications, 1993.
7. Modern research literature

Special Topics in Power Electronics

(EE 5208)

Prerequisite: Advanced Power Electronics (EE 5107) and Generalized Theory of Electrical Machines (EE 5108)

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Digital signal based control of Power Electronic Installations**: For electrical machine drives and for applications – interfacing, generation and sequencing of trigger pulses, sensing issues, applications to different types of solid state power converters, monitoring and signaling, DSP and FPGA applications.	12L
02	**Soft-switched Converters:** Resonant converters, synchronous link converters, hybrid resonant link converters, quasi-resonant link inverters.	8L
03	**Special topics:** Multilevel inverters, Active filters, power electronic converters for induction heating and welding applications	8L
04	**Converters for electrical power systems:** STATCOM and UPQC	6L
05	**Converters for distributed generation:** Power Electronics-related issues in Wind energy applications, micro-hydel and PV-based power conditioning and grid integration.	5L
	TOTAL	**39L**

Suggested Readings:

1. Hamid Toliyat and S. G. Campbell, "DSP-based Electromechanical Motion Control", CRC Press, 2003.
2. N. Mohan. T. M. Undeland and W. P. Robbins, "Power Electronics – Converters, Applications and Design", 2nd Edition, John Wiley & Sons, 1995.
3. N. G. Hingorani, L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems" IEEE Press, 2013.
4. Gilbert M. Masters, "Renewable and Efficient Electric Power Systems", 2nd Edition, John Wiley & Sons, 2013.
5. Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", John Wiley & Sons, 2016.
6. S. Zinn& S. L. Semiatin, "Elements of Induction Heating: Design, Control, and Applications", ASM International & EPRI, 1988.

Selected Machines for Electric Vehicle and Wind Power Applications

(EE 5209)

Prerequisite: Generalized Theory of Electrical Machines (EE 5108)

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hrs.
A. Permanent Magnet Synchronous Machines for Electric Vehicle(EV) applications:		
01	Introduction, principle of operation, outline of Permanent Magnet (PM) materials	2L
02	Steady state and dynamic model and equivalent circuit of PMSMs, magnetic circuit.	3L
03	Construction, classification and types, comparison between PMSM and BLDC machines	2L
04	Special requirements of EV power-train components, review of DC series motors with their advantages and disadvantages, PMSM and BLDC motors and drives for EV applications, their similarities and differences, converters topologies.	4L
05	Drive Control strategies viz., vector control (VC), maximum torque per ampere (MTPA) control and direct torque control (DTC).	11L
06	Effects of these motor drives on the EV battery, battery power and energy density issues.	2L
B. Doubly-fed induction machines (DFIM) for wind power applications:		
01	Steady state operation – equivalent circuit in a-b-c frame, operating modes with respect to speed and power flows, active and reactive power exchanges, steady state characteristics, design requirements for the DFIM in wind energy generation applications.	4L
02	Dynamic modelling in α-β and d-q reference frames.	2L
03	Introduction to a wind energy generating system – Wind energy and wind turbine fundamentals, fixed speed wind energy conversion systems, variable speed wind energy conversion systems, Variable Speed Wind Energy Generation System based on DFIM, Maximum power point tracking for grid-connected DFIG.	4L
04	Drives for grid-connected DFIM, vector control of DFIM from rotor side, startup of the DFIM for grid-connected applications	5L
	TOTAL	**39L**

Suggested Readings:

1. P. C. Krause, O. Wasynczuk and S. D. Sudhoff, "Analysis of Electric Machinery and Drive Systems", 2nd Edition, Wiley, paperback, 2010.
2. K. Venkataratnam, "Special Electrical Machines", University Press (India) Pvt. Ltd., Hyderabad, India, 2009.
3. J. R. Hendershot Jr. and T. J. E. Miller, "Design of Brushless Permanent-Magnet Motors", Magna Physics Publishing and Clarendon Press, Oxford 1994.
4. R. Krishnan, "Permanent Magnet Synchronous and Brushless DC Motor Drives", CRC Press, Taylor and Francis Group, Boca Raton, USA, 2010.
5. Gonzalo Abad, Jesus Lopez, Miguel Rodriguez, Luis Marroyo, Grzegorz Iwanski, ",Doubly Fed Induction Machine: Modeling and Control for Wind Energy Generation", WILEY-IEEE Press, USA, 2011.
6. Modern research literatures

Intelligent Control Systems

(EE5221)

Prerequisites: Higher Engineering Mathematics

Weekly contact: 3 - 0 - 0 (L- T- P) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Optimization:** Convex, Linear Programming Problem (LPP), Constrained, Unconstrained Examples.	7L
02	**Introduction to Genetic Algorithms:** Basic Terminology, Working Principles, Simple GA, Examples and Case Studies, Assignments.	8L
03	**Fuzzy Logic:** Fuzzy Sets, Operations, Relations, Membership Functions, Fuzzification, Defuzzification, Fuzzy Logic, Systems, Examples, Assignments.	8L
04	**Introduction to Artificial Neural Networks:** Basic Definitions, Activation Functions, Mathematical Model of a Neuron, Network Architectures, Basic Idea of Control with Neural Networks, Examples, Assignments	8L
05	**Case Studies**: Examples of physical systems, Numerical Simulation.	8L
	Total:	**39L**

Suggested Readings:

1. Engineering Optimization – S. S. Rao, 4th Edition, 2009.
2. Digital Control and State Variable Methods: M. Gopal, Second Edition, 2003.
3. Fuzzy Logic with Engineering Applications – Timothy J. Ross, 3rd Edition, 2011.
4. Neural Networks – A classroom approach – Satish Kumar, 2009.
5. An Introduction to Genetic Algorithms – Melanie Mitchell, 1998.
6. Genetic Algorithms in Search, Optimization and Machine Learning, D. E. Goldberg
7. (https://pdfs.semanticscholar.org/2e62/d1345b340d5fda3b092c460264b9543bc4b5.pdf)"

Nonlinear Control System

(EE5222)

Prerequisite: Fundamentals of Control System and Engineering Mathematics

Weekly contact: 3 – 0 – 0 (L-T-S) **Full Marks- 100**

Module No.	Module Name and topics	No. of Lecture-Hr.
01	**Classification of Nonlinear Phenomena:** Saturation, Dead-zone, Backlash, Hysteresis, Limit Cycle, Multiple isolated equilibrium, Finite Escape Time, Sub harmonic /Harmonic Oscillations, Chaos and Bifurcation	4L
02	**Types of Systems:** Autonomous, Non autonomous, Time invariant and Time varying	1L
03	**State space Approach to Nonlinear System**: Inverted Pendulum and Orbiting Satellite Problem	4L
04	**Linearization Techniques:** Feedback Linearization, Input-Output Linearization, Full state Linearization	5L
05	**Describing Function methods:** Describing function of saturation, dead-zone, on-off non-linearity, backlash, hysteresis,Compensation and design of nonlinear system using describing function method	5L
06	**Phase-Plane analysis:** Phase portraits, Analysis of nonlinear systems using phase plane technique	4L
07	**Notions of Stability:** Absolute Stability, Lyapunov Stability, Zero-input and BIBO stability.	6L
08	**Nonlinear system dynamics:** Series Approximation method for small non-linearity	4L
09	**Concept of variable-structure controller and Sliding control**: Sliding Mode Control Design, Reaching condition and reaching mode, implementation of switching control laws. Reduction of chattering in sliding and steady state mode.	6L
	Total:	**39L**

Suggested Readings:

1. Nonlinear System, 3rd Edition, Hassan. K.Khalil, Pearson, 2015
2. Nonlinear Automatic Control, J.E.Gibson,1st Edition,1963
3. Nonlinear System Analysis, M.Vidyasagar, 2nd Edition,1993
4. Applied Nonlinear Control, Slotine and Li, 1991

Condition Monitoring of Electrical Equipment

(EE5223)

Prerequisite: Electrical Machines

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction to condition monitoring**: Need for Condition Monitoring, What and when to monitor, Root causes and failure of electrical equipment, Condition based maintenance, Life cycle costing, Asset management	5L
02	**Conventional techniques used in condition monitoring and diagnosis**: Electrical methods (voltage, current, flux, power monitoring), Mechanical methods (vibration and speed), Thermal methods (thermal imaging), Chemical methods (DGA, Furan Analysis)	7L
03	**Signal Processing requirements in Condition Monitoring**: Need for signal processing, Concept of Signal Processing tools like FFT, Wavelet analysis, Applications of Signal Processing techniques in fault diagnosis	7L
04	**Application of Artificial Intelligence (AI) in Condition Monitoring**: Introduction to various AI techniques like Expert system, ANN and Fuzzy Logic, Need for applications of AI in condition monitoring, Typical examples and current trend	7L
05	**Condition Monitoring of Rotating Electrical Machines**: Diagnosis of stator faults in insulation, winding and core; Diagnosis of Rotor Faults in broken rotor bars, eccentric rotor and bearing faults, Vibration and stator current based spectral analysis, Partial discharge analysis of large motors	6L
06	**Condition Monitoring of Power Transformers:** Failure statistics for Power Transformers, Monitoring and diagnostic requirements, monitoring of winding displacement and partial discharge. Impulse fault diagnosis in transformer - analysis of impulse current waveform, time and frequency domain analysis, transfer function method, tan delta method	7L
	TOTAL	**39L**

Suggested Reading:

1. Condition Monitoring of Rotating Electrical Machines, by P. J. Tavner, L. Ran, J. Penman and H. Sedding, IET, 2008

2. Review of Condition Monitoring of Rotating Electrical Machines, by P.J. Tavner, IET Electric Power Applications, 2007
3. Machinery Condition Monitoring,(Principles and Practices), A. R. Mohanty, CRC Press, Taylor and Francis Group, 2015
4. Condition Monitoring and Assessment of Power Transformer Using Computational Intelligence, By W. H. Tang, Q. H. Wu, Springer, 2011
5. Recent Trends in Condition Monitoring of Transformer (Theory, Implementation and Analysis), By S. Chakravorti, D. Dey, B. Chatterjee, Springer, 2013.

Power System Reliability and Load Forecasting Techniques

(EE5224)

Prerequisite: Probability Theory & Power systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Load Forecasting:**Objectives of power system load forecasting, load forecasting categories — long term, medium term and short term, Characteristics of loads, forecasting methodology, extrapolation technique to fit trend curves to basic historical data, simple regression and least square estimation, Different types of regression curves, scatter diagram, correlation and correlation coefficient, statistical definitions, time series, single and double exponential smoothing technique, ARIMA model.	9L
02	**Reliability analysis**: Definition of reliability, reliability indices, outage classification Reliability functions: Survivor function, cumulative failure distribution function, hazard rate, their relationships – exponential distribution – expected value and standard deviation of exponential distribution – Bath tub curve – reliability analysis of series parallel networks using exponential distribution – reliability measures MTTF, MTTR, MTBF.	4L
03	**Markov modelling**: Continuous Markov processes, evaluation of time dependent and limiting state probabilities for one component repairable system. **Network modelling and reliability analysis:** Analysis of Series, Parallel, Series-Parallel networks– decomposition method.	5L
04	**Frequency and duration techniques:** Frequency and duration concept – evaluation of frequency of encountering state, mean cycle time, for one, two component repairable models. Approximate system reliability evaluation for two component repairable series and parallel system.	5L

05	**Generating system reliability analysis:** Generation system model – capacity outage probability tables – Recursive relation for capacitymodel building – sequential addition method – unit removal – Evaluation of loss of load and energy indices, Frequency and Duration methods – Evaluation of equivalent transitional rates of identical andnon-identical units – Evaluation of cumulative probability and cumulative frequency of non-identicalgenerating units – 2- level daily load representation - merging generation and loadmodels.	6L
06	**Distribution system reliability analysis:** State space diagram, network reduction method of evaluating load point reliability index**.** Substations and Switching Stations: Effects of short-circuits - breaker operation – Open and Short-circuit failures – Active and Passive failures – switching after faults – circuit breaker model – preventive maintenance – exponential maintenance times. Bus bar failures, scheduled maintenance – temporary and transient failures – weather effects – common mode failures –Evaluation of various indices.	6L
07	**Reliability assessment of interconnected systems**: Probability array method – Two inter connected systems with independent loads – effects oflimited and unlimited tie capacity - imperfect tie – Two connected Systems with correlated loads –Expression for cumulative probability and cumulative frequency.	4L
	TOTAL	**39L**

Suggested Reading:

1. Reliability Evaluation of Power Systems by Roy Billinton and Roland Allan (Springer)-1996
2. Introduction to Time series Analysis and Forecasting by Douglas Montgomery, C.L. Jennings and M. Kulahci (Wiley) - 2008
3. Power System Planning by R.L. Sullivan (Tata McGraw Hill Publishing Company Ltd) -1977
4. Modern Power System Planning by X. Wang & J.R. McDonald (McGraw Hill Book Company)-1994
5. New Computational Methods in Power system Reliability by D. Elmakias (Springer)-2008

Special Electrical Machines

(EE5225)

Prerequisite: Basic courses on DC and AC machines, Generalized Machine Theory (EE 5108)

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Space vector theory of Electrical Machines**: Space vector concept as applied to electrical machines: Its application in modeling of electrical machines in both steady state and dynamics, control of machines using space vector concepts	10L
02	**Linear Motors**: Basic principle of operation and types, end effects & transverse edge effects, depth of penetration and its effects, field analysis & propulsion force, mathematical modeling, equivalent circuit. Linear Induction Motors (LIM), Linear Permanent Magnet Synchronous Machine (LPMSM), LSRM etc., TLIM, their applications, design challenges, modeling and analysis. Difficulties in constructing TLPM machines or TLSRM.	9L
03	**Switched Reluctance Motors (SRM)**: Construction, Basic principle of operation, importance of stator & rotor arc angles, design aspects and profile of the SRM, position sensor & indirect rotor position sensing, torque expression, steady state and dynamic performance.	6L
04	**Special Permanent Magnet (PM) Machines**: Outer rotor varieties, details of issues related to PM materials and design, use of Halbach array configuration in PM machines Non-overlapping winding PM machines and their applications: Concepts, design changes with regard to distributed winding machines, effects on performance, applications of both inner and outer rotor varieties.	7L
05	**Axial Flux Machines**: Axial flux varieties of SRM, BLDC and PMSM, applications, their design challenges, modeling and analysis.	7L
	TOTAL	**39L**

Suggested Readings:

1. K.Venkataratnam, "Special Electrical Machines", Universities Press (India) Private Limited, 2008.
2. T.J.E. Miller, "Brushless Permanent-Magnet and Reluctance Motor Drives", Clarendon Press, Oxford, 1989.

3. T. Kenjo and S. Nagamori, "Permanent Magnet and Brushless DC Motors", Clarendon Press, London, 1988.
4. R. Krishnan, "Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design and Applications", CRC press, 2001.
5. E. R. Laithwaite, "Induction Machines for Special Purposes", George Newnes, London, 1966.
6. S. A. Nasar& I. Boldea, "Linear Motion Electric Machines", Wiley 1976.

Power Electronic Converters for Bulk Power Conditioning

(EE5226)

Prerequisite: Courses on Power Electronics and Power Systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Phase Shifting Transformers:** Principle of operation, phasor diagram and calculation of turns ratio etc., some examples and applications	3L
02	**HVDC Converters:** Major problems of conventional 6-pulse rectifiers; 12, 18 and 24-pulse rectifiers – basic operating characteristics and waveforms – advantages over 6-pulse rectifiers; symmetrical and sequential modes of control; operating area; Harmonic cancellation techniques using SHE-PWM, multi-level and multi-pulse inverters; synthesis of receiving end HVDC inverters; general structures of HVDC systems	5L
03	**Static Converters for Shunt VAR Compensation:** Necessity and general methods of VAR compensation – SVG & SVC; TCR, TSC, FC-TCR & TSC-TCR – principle of operation and operating area, harmonic reduction, closed loop control schemes etc. for each; STATCOM – operating principle, direct and indirect methods of closed loop control; Hybrid VAR generators and control schemes etc.; basic design equations	13L
04	**Static Converters for Series Compensation:** Basic essence and advantages; GCSC, TSSC, TCSC and SSSC – Principles, control-modes, closed-loop control schemes and operating area, compensation of harmonics generated, ratings etc.; Hybrid compensation using SSSC and FC; basic design equations	18L
	TOTAL	**39L**

Suggested Readings:

1. G. K. Dubey, S. R. Doradla, A. Joshi and R. M. K. Sinha, "Thyristorised power controllers," Wiley Eastern Limited, 1986.
2. Bin Wu, "High Power Converters and AC Drives," IEEE Press Wiley-Interscience, 2006.
3. N. G. Hingorani and L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems," IEEE Press, 2000.

Energy Informatics

(EE5261)

Prerequisite: Basic knowledge about Computing, power and Energy Systems

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hr.
01	**Introduction to Energy Informatics** Energy, sustainability and climate change, Energy options and their national and environmental impact, Green IT : policy and standards, Green IS	5L
02	**Energy efficiency design principles**: manufacturing, logistics, farming, transportation, buildings	8L
03	**Energy efficient grid (smart grid)**: Penetration of renewable energy, distributed energy resources, smart appliances, low voltage DC distribution in homes / buildings, home energy management system, Smart Metering, Building to Grid B2G, Vehicle to Grid V2G, Solar to Grid, role of communication and ICT	8L
04	**Processing energy data streams** : Big Data-driven smart Energy Management Systems, Pattern based energy consumption analysis	6L
	Energy Performance study: Data Envelopment Analysis	6L
05	**Data Analytics:** Application of ” Block chain Technology” in energy-cost efficient system operation	6L
	TOTAL	**39L**

Suggested Reading:

1. Paris Agreement, UNFCCC, December, 2015
2. Information Systems and Environmentally Sustainable Development : Energy Informatics and New Directions for the IS community, by R. T. Watson et al., MIS Quarterly, 2010
3. Advances and New Trends in Environmental and Energy Informatics, by J. M. Gomez et. al., Springer2014
4. Energy Informatics: Fundamentals and Standardizations, by B. Huang et al., ICT Express(Elsevier), 2017
5. Analysis for Smart Energy Management, by S. C. Ohet. al, Springer, 2017
6. Energy Economics, by S. C. Bhattacharjee, Springer, 2011
7. Blockchain Technology in Energy Sector: A Systematic Review of Challenges and Opportunities, M. Andoni et.al, Renewable and Sustainable Energy Reviews(Elsevier), 2019
8. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press, 2009

Power Supplies for Electrical Equipment

(EE 5262)

Prerequisites:A preliminary course on (i) basic electrical engineering and (ii) basic electronics at undergraduate level

Weekly contact: 3 – 0 – 0 (L- T- S) **Full Marks-100**

Module No.	Module Name and Topics	No. of Lecture-Hrs.
01	**Introduction:**Electrical utility distribution systems, DC and AC electrical power supplies – basic requirements and desired general specifications, issue of regulation, electrical isolation, output ripple, efficiency etc.	3L
02	**Power Electronic devices used as switches:**Power diodes, power MOSFETs, IGBT's and thyristors, quadrant operation of power electronic devices, power losses in power devices, dissipation and idea of heat sinks, driver stages of power devices.	7L
03	**DC power supplies:**Linear power supplies – advantages and disadvantages, relevance of switched mode power conversion, DC-DC converters – non-isolated and isolated DC-DC converters, role of high frequency transformers.	5L
04	**DC switched mode power supplies (SMPS):**Basic block diagram of a switched mode power supply, power supplies with bidirectional power flow capabilities.	3L
05	**AC power supplies:**Voltage source inverters – Single phase and three phase inverters, pulse width modulation (PWM), harmonics, AC power supplies based on inverters, AC power supplies with bidirectional power flow capabilities.	7L
06	**Front end of AC/DC power supplies fed from electrical utilities:** Rectifiers - Single phase diode rectifiers with R-paralleled-C loads, thyristorized rectifiers, effects on utility, power quality aspects, PWM rectifier as a solution.	5L
07	**Batteries and Battery chargers:** Different types of batteries used at present, their types, basic characteristics, basic terminologies of a battery. Types of battery chargingbatteryCharger block diagrams employing discussed power converters, control.	4L
08	**Uninterruptible Power Supplies (UPS):** Classification, block-diagram based explanations	3L
09	**Passive components in power electronic applications**: Inductorsand capacitors	2L
	TOTAL	**39L**

Suggested Readings:

1. M. H. Rashid, “Power Electronics - Circuits, Devices and Applications”, Prentice Hall, Pearson Education, 2014.
2. N. Mohan, T. M. Undeland and W.P. Robbins, “Power Electronics: Converters, Applications and Design”, John Wiley & Sons, 2007.
3. C. W. Lander, “Power Electronics”, McGraw Hill Book Co, 1987.
4. G. K. Dubey, S. R. Doradla, A. W. Joshi, R. M. K. Sinha, “Thyristorised Power Controllers”, Wiley, 1986.
5. R. M. Dell and D. A. J. Rand, “Understanding Batteries”, The Royal Society of Chemistry, Cambridge, UK, 2001.

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