DELHI TECHNOLOGICAL UNIVERSITY

SCHEME OF TEACHING AND EVALUATION

MASTER OF TECHNOLOGY IN POWER ELECTRONICS AND SYSTEMS

The following alphanumeric coding scheme has been adopted

Core Courses XXXYMN

Elective Courses XXXYCMN

XXX abbreviates a particular M. Tech. program, Y – (5 for M. Tech. 1 st year, 6 for M. Tech. 2 nd year),

C – credit of the course (4/3/2),

MN – Subject code (Odd number for odd semester and even number for even semester courses)

Semester-I

	S. No.	Course Code	Course Name	Type/ Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE	Total Credits
Group A	1	PES501	Modelling of Electrical Systems	Core	4	3	0	2	15	25	20	40	-	17
	2	PES503	Power Electronics Converters	Core	4	3	0	2	15	25	20	40	-	
Group B	3	PES5401/5403/ …………	Elective 1	Elective	4	3	0	2	15	25	20	40	-	
	4	PES5301/5303/ ………	Elective 2	Elective	3	3	0	0	25	-	25	50	-	
	5	PES5201/5203/ ………… /UEC5201/5203/ …………	Elective 3/ University Elective I	Elective	2	2	0	0	25	-	25	50	-	

Semester-II															
	S. No.	**Course Code**	**Course Name**	**Type/ Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**	**Total Credits**
Group C	1	PES502	Advanced Power Semiconductor Devices and Magnetics	Core	4	3	0	2	15	25	20	40	-	**17**
	2	PES504	Controller Design for Power Electronic Converters	Core	4	3	0	2	15	25	20	40	-	
Group D	3	PES5402/5404/ …………	Elective 4	Elective	4	3	0	2	15	25	20	40	-	
	4	PES5302/5304/ 5312…………	Elective 5	Elective	3	3	0	0	25	-	25	50	-	
	5	PES5202/5204/ …………/ UEC5202/5204/ …………	Elective 6/ University Elective II	Elective	2	2	0	0	25	-	25	50	-	

Semester-III														
	S.No .	**Course Code**	**Course Name**	**Type/ Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**	**Total Credits**
	Track 1													**12**
Group E	1	PES651	Research Project	Core	12	0	0	12	0	-	0	100	0	
	Track 2													
	1	PES601	Major Project I	Core	3	3	0	0			40	60		**12**
	2	PES6401/6403/ 6409	Elective 7	Elective	4	3	0	2	15	25	20	40	-	
	3	PES6301/6303/ …………	Elective 8	Elective	3	3	0	0	25	-	25	50	-	
	4	PES6201/6203/ …………	Elective 9	Elective	2	2	0	0	25	-	25	50	-	

Semester-IV															
	S.No.	**Course Code**	**Course Name**	**Type/ Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**	**Total Credits**
Group F	**Track 1**													
	1	PES652	Research Project	Core	12	0	0	12	0	-	0	100	0	**12**
	Track 2													
	1	PES602	Major Project II	Core	12	0	0	12	0	-	0	100	0	**12**

LIST OF ELECTIVES

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 1	1	PES5401	Power Quality	Elective	4	3	0	2	15	25	20	40	-
	2	PES5403	Electrical Drives and Systems		4	3	0	2	15	25	20	40	-
	3	PES5405	Switch Mode Power Converters		4	3	0	2	15	25	20	40	-
	4	PES5407	Grid-Connected Power Converter and Systems		4	3	0	2	15	25	20	40	-
	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 2	1	PES5301	Multipulse and Multilevel Converters	Elective	3	3	0	0	25	-	25	50	-
	2	PES5303	Special Electromechanical System		3	3	0	0	25	-	25	50	-
	3	PES5305	Advanced Digital Signal Processing		3	3	0	0	25	-	25	50	-
	4	PES5307	Power Electronics for Photovoltaic and Wind Energy Systems		3	3	0	0	25	-	25	50	-
	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
	1	PES5201	Seminar		2	0	0	2	-	40	-	-	60
Elective 3	2	PES5203	Renewable Energy Systems	Elective	2	2	0	0	25	-	25	50	-
	3	PES5205	AC and DC Microgrids		2	2	0	0	25	-	25	50	-
	4	PES5207	Reliability Analysis of Power Electronic Converters		2	2	0	0	25	-	25	50	-
	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 4	1	PES5402	Flexible AC transmission and Distribution	Elective	4	3	0	2	15	25	20	40	-
	2	PES5404	Mechatronics and Vehicular Power Electronics		4	3	0	2	15	25	20	40	-
	3	PES5406	Advanced Topics on Power Electronics Converter		4	3	0	2	15	25	20	40	-
	4	PES5408	Distributed Generation Systems and System Design		4	3	0	2	15	25	20	40	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 5	1	PES5302	Minor Project	Elective	3	0	0	-	-	40	-	-	60
	2	PES5304	High/Medium Voltage DC Transmission		3	3	0	0	25	-	25	50	-
	3	PES5306	Electric Traction		3	3	0	0	25	-	25	50	-
	4	PES5308	Energy Storage Systems		3	3	0	0	25	-	25	50	-
	5	PES5310	Pulsed Power Electronics and Nuclear Energy		3	3	0	0	25	-	25	50	-
	6	PES5312	Pulse Width Modulation for Power Converters		3	2	0	2	15	25	20	40	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 6	1	PES5202	Standards for Microgrid Application and Control	Elective	2	2	0	0	25	-	25	50	-
	2	PES5204	Energy Management System		2	2	0	0	25	-	25	50	-
	3	PES5206	Machine learning*		2	2	0	0	25	-	25	50	-
	4	PES5208	PMU and Advanced Metering*		2	2	0	0	25	-	25	50	-
	5	PES5210	Electric Vehicle and E-mobility		2	2	0	0	25	-	25	50	

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 7	1	PES6401	Smart Grid and Distribution Automation	Elective	4	3	0	2	15	25	20	40	-
	2	PES6403	Non-Linear Control of Power Electronic Converter		4	3	0	2	15	25	20	40	-
	3	PES6405	Energy Efficiency Auditing and Loss Reduction		4	3	0	2	15	25	20	40	-
	4	PES6407	Heat Sink, Thermoelectrics and Thermal Design		4	3	0	2	15	25	20	40	-
	5	PES6409	Resonant Power Converters		4	3	0	2	15	25	20	40	-

	S.No.	Course Code	Course Name	Type/Area	Cr	L	T	P	CWS	PRS	MTE	ETE	PRE
Elective 8	1	PES6301	SCADA and Energy Management Systems	Elective	3	3	0	0	25	-	25	50	-
	2	PES6303	Energy & Environmental Economics and Energy Policy		3	3	0	0	25	-	25	50	-
	3	PES6305	Optimization Technique in Electrical System Design		3	3	0	0	25	-	25	50	-
	4	PES6307	Power Line Communication and Control Applications		3	3	0	0	25	-	25	50	-
	S.No.	**Course Code**	**Course Name**	**Type/Area**	**Cr**	**L**	**T**	**P**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Elective 9	1	PES6201	Condition Monitoring, System Modelling & Forecasting	Elective	2	2	0	0	25	-	25	50	-
	2	PES6203	Electricity Market and Regulations*		2	2	0	0	25	-	25	50	-
	3	PES6205	Digital Communication*		2	2	0	0	25	-	25	50	-
	4	PES6207	Industrial Safety		2	2	0	0	25	-	25	50	-
	5	PES6209	Artificial Intelligence*		2	2	0	0	25	-	25	50	-

*** Syllabus Same as M.Tech (PSY) Syllabus**

First Year M.Tech (PES) I Semester

PES-501 Modelling of Electrical Systems

Lectures: - 3 Hrs per week　　Pre-requisites: Nil
Practicals: - 2 Hrs per week

Reference frames, Electrical network terminology, Mesh networks, Rotating machines in quasi holonomic and nonholonomic reference frame, Generalised machine, Generated voltage, Impedance matrix, Inductance and torque matrix, Flux linkage and flux density matrices, Rotation matrix, Electromagnetic torque, Elimination of axes, Analysis using revolving field theory, Transformation from the stationary to rotating reference frame and vice-versa; Electrical machines in rotating reference frames, voltage equation, torque and inductance matrix in nonholonomic and holonomic reference frames, Impedance matrix of second generalised machine, voltage and torque equation transformation from second generalised machine to first.

Modelling of three phase Induction machine and synchronous machine in quasi-holonomic and holonomic frames, sequence impedances, Elimination of field and damper winding, torque in salient pole machine, determination of d-q axis reactances, under transients, with and without damper windings; State modelling of Electrical Machines, Voltage and torque equation under acceleration, Motional impedance matrix of generalized machine.

Transformer under sequence reference frame, Sequence reference frame, Impedance matrix, Δ-Y or Y-Δ transformers, measurement of positive, negative and zero sequence impedance, model under faults.

Analysis of Static Power converters, Modelling of AC-DC thyristorised converter, DC-DC PWM Converters, AC Voltage controller and single and three phase Pulsed and PWM inverters (3 ph -3 wire and 3 ph - 4 wire).

Text Books/Reference Books:

1. A.K. Mukhopadhyay, *Matrix Analysis of Electrical Machines*, New Age International Pvt. Ltd, 1996.
2. Paul Krause, Oleg Wasynczuk, Scott Sudhoff and Steven Pekark, *Analysis of Electric Machinery and Drive Systems*, IEEE Press, John Wiley & Sons, 2013.
3. William H. Kersting, *Distribution System Modeling and Analysis*, CRC Press, 2001.
4. Charles V. Jones, *Unified Theory of Electrical Machines*, Plenum Press, 1968.

PES-503 Power Electronics Converters

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

AC-DC Converters: Single phase diode rectifier with and without filter capacitor, Phase control, Single phase Semi converter & fully controlled converter, Three phase rectifier with and without capacitor filter, Three phase semi controlled & fully controlled converters with passive load impedance, twelve pulse converter, Power factor improvement methods, effect of source inductance, Pulse-Width Modulation (PWM) controlled rectifier circuits, design of converter circuits.

DC to AC Converters (Inverters): Principle of operation, performance parameters, single phase half and full bridge inverters and Three-Phase naturally commutated controlled bridge inverter, Three-Phase step - wave inverter circuits, Voltage control of single phase inverters: single/multiple pulse/SPWM/ modified SPWM methods, Voltage control of three phase inverter, SPWM/third harmonic included PWM/Space vector modulation, Harmonic reduction, Current source inverter, Comparison between VSI & CSI. Introduction to multilevel inverters, Diode clamped multi level inverters; Neutral point clamped multilevel inverters, Flying capacitor multilevel inverters, Applications.

AC to AC Converters : Single and three phase AC voltage controllers, Thyristor controlled reactors(TCR), Static VAr compensator (SVC), Thyristor controlled series capacitor (TCSC), Phase-Controlled Cycloconverters, Matrix Converters.

DC-DC Converters: Principle of operation, analysis of step-down and step-up converters, classification of PWM choppers, Analysis of two and four quadrant PWM choppers, Cúk and Sépic converters.

Text Books/Reference Books:

1. Ned Mohan, Tore. M. Undeland and William. P Robbins, *Power Electronics: Converters, Applications and Design*, John Wiley and Sons, 2003.
2. Daniel W. Hart, *Power Electronics*, Tata McGraw-Hill Education, 2011.
3. Marian P. Kazmierkowski, R. Krishnan and Frede Blaabjerg, *Control in Power Electronics*, Academic Press, 2002.
4. William Shepherd and Li Zhang Power, *Power Converter Circuits*, Marcel Dekker Inc., 2004.
5. Fang Lin Luo, Hong Ye and Muhammad H. Rashid, *Digital Power Electronics and Applications*, Elsevier (USA), 2005.
6. Robert W. Erickson, *Fundamentals of Power Electronics*, Kluwer Academic Publishers, 2001.
7. Barry W Williams, *Power Electronics: Devices, Drivers, Applications, and Passive Components*, McGraw Hill.
8. Marian K. Kazimierczuk, *Pulse-width Modulated DC–DC Power Converters*, John Wiley & Sons.
9. Muhammad H. Rashid and Hasan M. Rashid, "*SPICE for Power Electronics and Electric Power*", CRC Press.

PES-5401 Flexible AC Transmission and Distribution Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Concept of reactive power control, methods of voltage control, AC Transmission Line and Reactive Power Compensation- Uncompensated Transmission Line: Loadability characteristics of O/H lines, on open – circuit, uncompensated transmission line under load, effect of line length, load power, p.f. on voltage and reactive power, mare power & stability.

Compensation of Lines: Objectives of compensation, types of compensation – surge impedance compensation, line length compensation, compensation by sectioning, passive & active compensators, uniformly distributed fixed compensation, its effect on voltage control, line charging reactive power, uniformly regulated shunt compensation, passive shunt compensation Dynamic Performance of Transmission Lines-Dynamics of ac Power Systems and the effect of reactive power control.

Static Compensation: Principle, properties, types – TCR, TSC etc. Sub synchronous Resonance: Introduction, methods of controlling SSR. Synchronous Condensers: Introduction, characteristics, and its operation, Unified Power Flow Controller, Interphase Power Controller, Reactive Power Management:

Custom Power Devices, Structure and Control of Power Converters, Solid State Limiting, Breaking and Transferring Devices, Networking type devices, Shunt and Series compensation, DSTATCOM, Voltage control and current control, 3Ph-3Wire system, 3 Ph - 4 Wire systems, Series devices, Selection of components, Design of the system, Insertion and desertion techniques, DVR, Capacitor supported and power supported, Neutral compensation.

Estimation and computation of parameters, The synchronous reference frame PLL under unbalanced and Distorted grid conditions. The Decoupled Double synchronous Reference Frame PLL (DDSRF-PLL), The double synchronous Reference Frame, The decoupling network, Analysis of DDSRF, Structure and responses of the DDSRF-PLL. The Double Second- order Generalized integration PLL (DSOGI-PLL), structure of the DSOGI, Relation between the DSOGI and the DDRF, The PLL for the DSOIG-PLL, Load Compensation using DSTATCOM, Realization and Control of DSTATCOM, Series Compensation of Power Distribution System, Unified Power Quality Conditioner- Left side and Right side.

Text Books/Reference Books:

1. N.G. Hingorani, Gyugi, *Understanding Facts, Concepts, Technology of Flexible AC Transmission Systems*, IEEE Press, 1999.
2. T.J.E. Miller, *Reactive Power Control in Electric Systems*, John Wiley & Sons, 1982.
3. Arindam Ghosh, Gerard Ledwich, *Power Quality Enhancement Using Custom Power Devices*, Springer US, 2002.

PES-5403 Electrical Drive Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Introduction, Energy Conversion in Electric Drives, Electric drives – an overview, Motor/mechanical load matching, Load dynamics and stability, Multiquadrant operation, Electric drives configurations, Electric motors for drives; Power Electronic Converters for Drives.

DC Motor Drives: Basic topologies, Performance equations- d-q model, Steady state motor characteristics, Transient operation for constant flux, P.M. brush motor transients, Transient operation for variable flux, Speed / excitation transfer function, Controlled Rectifier Fed D.C. Brush Motor Drives, Chopper-Controlled D.C. Brush Motor Drives, Closed Loop Motion Control in Electric Drives, The cascaded motion control, Torque loop, Speed loop, Digital position control, Positioning precision, State - space motion control, Torque perturbation observers, Path tracking, Force control, Sliding - mode motion control, Motion control by fuzzy logic, etc.

Induction Motor Drives: The stator and its travelling field, the inductance matrix, phase coordinate model, space phasor model, space phasor diagram for electrical transients, Electrical transients with flux linkages as variables, Complex Eigen values for electrical transients, Electrical transients for constant rotor flux, Motoring, generating, braking, Speed control methods, Vector control -general flux orientation, General current decoupling, Parameter detuning effects in rotor flux orientation current decoupling, Direct versus indirect vector current decoupling, A.C. versus D.C. current controllers, Voltage decoupling, Voltage and current limitations for the torque and speed control range, Impressing voltage and currents through PWM, Switching state voltage vectors, Indirect vector A.C. current control, Flux observers for direct vector control with motion sensors, Indirect vector synchronous current control with speed sensor - a case study, Flux and speed observers in sensor less drives: Performance criteria, A classification of speed observers, Speed estimators, Rotor slots ripple speed estimators, Direct torque and flux control (DTFC), Feedback linearized control.

Synchronous Motor Drives: Phase coordinate model, space phasor(d-q) model, PM-SM drives, Rectangular current control(Brushless D.C. motor drives), Rectangular current control system, Extending the torque - speed domain, Vector control, Optimum i_d - i_q relationships, The indirect vector current control, Indirect voltage and current vector control, Fast response PM-SM drives, surface PM rotor motors with predictive control, Direct torque and flux control (DTFC) of PM-SMs, The stator flux and torque observer, Sensorless control of PM-SMs, Initial rotor position detection, Reluctance synchronous motor (RSM) drives.

Switched Reluctance Motor (SRM) Drives: Construction and functional aspects, Average torque and energy conversion ratio, The peak kW/kVA ratio, commutation windings, SRM modelling, The flux-current-position curve fitting, SRM drives, Drive with position sensor, High grade (servo) drives, Sensor less SRM drives, The voltage -current model based position - speed observer.

Text Books/Reference Books:

1. Ion Boldea I., S. A. Nasar, *Electric Drives*, CRC Press, 2006.
2. G. K. Dubey, *Fundamentals of Electrical Drives*, CRC Press, 2002.
3. Ramu Krishnan, *Electric Motor Drives: Modeling, Analysis, and Control*, Prentice Hall, 2001

PES-5405 Switch Mode Power Converters

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Introduction: Classification of Power Supplies, Voltage Regulators: Types and characteristics, Topologies of PWM DC–DC Converters, Relationships among Current, Voltage, Energy, and Power, Electromagnetic Compatibility.

Design and Analysis of Non-Isolated DC-DC Converters: Buck in CCM, Boost in CCM, Buck-Boost in CCM; DCM Analysis of Buck, Boost and Buck-Boost Converter; Cuk Converter; Sepic Converter; Discontinuous mode of operation and Boundary conditions : Buck, Boost and Buck-Boost; Applications.

Design and Analysis of Isolated Power Supplies: Flyback converter in CCM and DCM mode; Advantage and Disadvantages of Flyback Converter; Forward PWM DC–DC Converter in CCM and DCM mode; Multiple-output Converters, Bidirectional Converter, Ringing in Flyback Converter, Forward Converter with Synchronous Rectifier, Converters with Active Clamping, Two-Switch Converters.

Design and Analysis of PWM Half-bridge, Full-bridge & Push-Pull PWM DC–DC Converter in CCM, DC Analysis of PWM Converters for DCM, Comparison of PWM DC–DC Converters.

Soft-switching DC–DC Converters: Zero-voltage-switching DC–DC Converters, Buck ZVS Quasi-resonant DC–DC Converter, Boost ZVS Quasi-resonant DC–DC Converter, Zero-current-switching DC–DC Converters, Boost ZCS Quasi-resonant DC–DC Converter, Multi resonant Converters.

Small-Signal Models of PWM Converters for CCM and DCM: Introduction to small signal modeling, Average model at ideal switching network in CCM and parameters, Linear models of power converters, average modeling in DCM, input and output impedance in open loop control, Feedback Controller design and impedance calculations.

Text Books/Reference Books:

1. Marian K. Kazimierczuk, *Pulse-width Modulated DC–DC Power Converters*, John Wiley & Sons, 2008.
2. Christophe Basso, *Switch-Mode Power Supplies Spice Simulations and Practical Designs*, Mc-Graw Hill, 2008.
3. Abraham Pressman, Keith Billings and Taylor Morey, *Switching Power Supply Design*, Mc Graw Hill, 2009.
4. Steven M. Sandler, “Switch-Mode Power Supply Simulation: Designing with SPICE”, McGraw-Hill, 2005.
5. Keng C. Wu, *Switch-Mode Power Converters: Design and Analysis*, Elsevier Science Publishing, 2005.
6. K. Kit Sum, *Switch Mode Power Conversion*, Marcel Dekker, 1984.
7. Fang Lin Luo and Hong Ye, *Synchronous and Resonant DC/DC Conversion Technology, Energy Factor, and Mathematical Modeling*, CRC Press, 2005.

PES-5407 Distributed Generation Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Distributed Generation: Purpose of Distributed Generation, Sizing and Siting, Demand-Side Management, Optimal Location of Distributed Energy Sources.

Alternative Sources of Energy: Renewable Sources of Energy, Planning and Development of Integrated Energy, Grid-Supplied Electricity, Load Distributed Generation, Calculation of Electricity Generation Costs, Sustainability, Modern Electronic Controls of Power Systems

Wind Power Plants: Appropriate Location; Evaluation of Wind Intensity; General Classification of Wind Turbines; System TARP–WARP; Generators and Speed Control Used in Wind Power Energy, **Photovoltaic Power:** Electricity Generation by Photovoltaic Effect, Solar Cell Output Characteristics and equivalent model, Applications of Photovoltaic Solar Energy - Residential and Public, Economical Analysis of Solar Energy. **Power Plants with Fuel Cell:** Fuel Cell Commercial Technologies and practical Issues for Generation of Electricity, Stacking Low- and High Temperature Fuel Cells, Constructional Features of various fuel cells: Proton Exchange Membrane Fuel Cells and Solid Oxide Fuel Cells, Advantages and Disadvantages, Equivalent Circuit of Fuel Cell, Aspects of Hydrogen as Fuel Future Perspectives. **Biomass-Powered Microplants:** Fuel from Biomass, Factors Affecting Biodigestion, Characteristics of Biodigesters, Construction of Biodigester, Generation of Electricity Using Biogas.

Microturbines: Princples of Operation of Microturbine, Fuel Control, Electrical-Side Structure, Control-Side Structure, Efficiency and Power of Microturbines, Site Assessment for Installation of Microturbines.

Induction Generators: Principles of Operation; Representation of Steady-Operation; Power and Losses Generated in Self-Excited Induction Generator; Frequency, Speed, and Voltage Controls; Load Control Versus Source Control for Induction Generators; The Danish Concept; Variable-Speed Grid Connection Control by the Load Versus Control by the Source, Economical Aspects.

Integration of Alternative Sources of Energy: Principles of Power Injection Converting Technologies; Power Converters for Power Injection into the Grid; Active and Reactive Power Control Approach; Integration of Multiple Renewable Energy Sources; Islanding and Interconnection Control; DG Control and Power Injection.

Text Books/Reference Books:

1. Gary L. Johnson, *Wind Energy Systems*, Prentice Hall, 1985.
2. Thomas Ackermann, *Wind Power in Power Systems*, John Wiley & Sons, Ltd, 2012.
3. Stefan C.W. Krauter, *Solar Electric Power Generation, Photovoltaic Energy Systems*, Springer, 2006.

PES-5301 Multipulse and Multilevel Converters

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Introduction to Harmonics, Multipulse Methods & Transformer: Voltage Distortion, Current distortion, Effects Of Negative Sequence Voltages, Effects of pre-existing harmonic Voltages, Different Circuit Topologies, Multipulse Methods, Multipulse Transformer Basics, Determining Phase Shift, Discussion of Vector representation; Doubly-Wound Multiphase transformers: Delta/Wye, Delta Zigzag/Fork, Delta /Polygon (Analysis, polygon Voltages and phase Shift, polygon Winding Currents), Delta/Delta/ Double Polygon, delta/Hexagon, Auto-Wound Transformer, Auto Connected Polygon (Design Analysis, Determination Of Line Input Current, Auto polygon Formulas, Auto-connected Fork, Differential Delta Connection, Differential fork connection, Delta/Wye With Center Tapped Delta, Transformer Primaries In Series

Current-Control Transformer: Interphase and Current control Transformer, Combining Two Or More Converters, Effects Of Interphase transformer Saturation, Paralleling by an Autotransformer**,** Current-Balancing Transformer (Zero Sequence Effects, ZSBT for 18 Pulses Operation), Harmonic Blocking Current Transformers, Multipulse Circuit Performance, Commutation Effects, AC line Reactance, 12 pulse with different type of Transformers, 18 Pulse with Fork Step – down Transformer, Eighteen- pulse converter, tests on other topologies, Field Test Results and their analysis.

Multilevel Voltage Source Converters: PWM, Modulation Schemes, Space Vector Modulation, Dwell Time Calculation, Switching Sequence, Spectrum Analysis, Even-Order Harmonic Elimination, Discontinuous Space Vector Modulation, Cascaded H-Bridge Multilevel Inverters, Carrier Based PWM Schemes, Phase-Shifted Multicarrier Modulation, Level-Shifted Multicarrier Modulation, Comparison Between Phase- and Level-Shifted PWM Schemes, Staircase Modulation. **Diode-Clamped Multilevel Inverters:** Converter Configurations, Switching State, Commutation, Space Vector Modulation, Switching Sequence Design, Inverter Output Waveforms and Harmonic Content, Neutral-Point Voltage Control, Effect of Motoring and Regenerative Operation, Feedback Control of Neutral-Point Voltage, High-Level Diode - Clamped Inverters, Carrier-Based PWM, NPC/H-Bridge Inverter.

PWM Current Source Converters: PWM Current Source Inverter, Trapezoidal Modulation, Selective Harmonic Elimination, Space Vector Modulation, SVM Versus TPWM and SHE, Parallel Current Source Inverters (Inverter Topology, Space Vector Modulation for Parallel Inverters, Effect of Medium Vectors on dc Currents, dc Current Balance Control), PWM Current Source Rectifiers,

Text Books/Reference Books:

1. Derek A. Paice, *Power Electronic Converter Harmonics*, *Multipulse Method for Clear Power*, IEEE Press.
2. Bin Wu, *High Power Converters and AC Derives*, IEEE Press, 2006.
3. N. Mohan, T. M. Undeland, et al., *Power Electronics - Converters, Applications and Design*, 3rd edition, John Wiley & Sons, New York, 2003.
4. GE Toshiba Automation Systems, A New Family of MV Drives for a New Century—DURA BILT 5i MV, Product Brochure, 50 pages, March 2003.

PES-5303 Special Electromechanical Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Wound Rotor and Self-Excited Induction Generators: Equivalent Circuit, Phasor Diagrams, Operation at the Power Grid, Operation at Zero Slip, Autonomous Operation, Brushless Exciter Mode, Self-Excited Induction Generators**,** Steady-State Performance, Second-Order Slip Equation Methods, SEIGs with Series Capacitance Compensation, Performance Sensitivity Analysis, For Constant Speed and Unregulated Prime Movers, Pole Changing SEIGs, Unbalanced Operation of Three-Phase SEIGs, Transients, Parallel Connection, Stator Converter Controlled Induction Generators (SCIGs), Grid Connected SCIGs, Grid Connection and Four-Quadrant Operation of SCIGs, Stand-Alone Operation, Parallel Operation, Operation with DC Voltage Controlled Output, Dual Stator Winding for Grid.

Induction Starter/Alternators (ISAs), Permanent-Magnet-Assisted Reluctance Synchronous Starter/Alternators (PM-RSM) for HeVs : Essential Specifications, Topology Aspects, Space-Phasor Model and Characteristics, Vector Control, DTFC, Design Issues for Variable Speed, Measures for Wide Constant Power Range, PM-RSM, Topologies, Flux Distribution, d–q Model of PM-RSM, Steady-State Operation at No Load and Symmetric Short-Circuit Generator, Design Aspects for Wide Speed Range Constant Power Operation, Power Electronics for PM-RSM, Control of PM-RSM, State Observer for Motion Sensorless Control, Initial and Low Speed Rotor Position Tracking.

Switched Reluctance Generators and Permanent Magnet Synchronous Generator Systems: Practical Topologies and Principles of Operation, The kW/Peak kVA Ratio, SRG Modeling, The Flux/Current/Position Curves, Design Issues, Motor and Generator Specifications, Converters for SRGs, Control of SRG, Rotor Position and Speed Observers for Motion-Sensorless Control, Standstill Position Estimation, Permanent Magnet Synchronous Generator Systems, Practical Configurations and their Characterization, Distributed vs. Concentrated Windings, Airgap Field Distribution, The d–q Model of PMSG, Circuit Model of PMSG with Shunt Capacitors and AC Load, Utilization of Third Harmonic, Autonomous PMSGs with Controlled Constant Speed, Grid-Connected Variable-Speed PMSG System, The PM Genset with Multiple Outputs, Super-High-Speed PM Generators, Power Electronics Control Issues, Methods for Testing PMSGs, Medium-Power Vehicular Electric Generator Systems. Transverse Flux and Flux Reversal Permanent Magnet Generator Systems**,** Flux Reversal Generator (FRG) Control.

Linear Motion Alternators (LMAs): Introduction, LMA Principle of Operation, The Motion Equation, PM-LMA with Coil Mover, Multipole LMA with Coil Plus Iron Mover, PM-Mover LMAs, The Tubular Homopolar PM Mover Single-Coil LMA, The Flux Reversal LMA with Mover PM Flux Concentration, PM-LMAs with Iron Mover, The Flux Reversal PM-LMA Tubular Configuration, The Analytical Model, Control of PM-LMAs, Electrical Control, The Spark-Ignited Gasoline Linear Engine Model, Note on Stirling Engine LMA Stability, Progressive-Motion LMAs for Maglevs with Active Guideway, Magneto hydrodynamic (MHD) Linear Generators, Super Conducting Machines.

Text Books/Reference Books:

1. Ion Boldea, *Variable Speed Generators*, CRC Press, 2nd Edition, 2015.
2. Fitzerald, Kinglay, Umans, *Electrical Machniary*, Tata Mc Graw Hill, 2004
3. Rakosh Das Begamudre, *Electro Mechanical Energy Conversation with Dynamics of Machines*, New Age International, 2003.
4. Hughes, A., *Electric Motors and Drives*, Newnes, 1994.
5. Leonhard, W., *Control of Electrical Drives*, Springer-Verlag, Berlin Heidelberg New York, Tokyo, 2 Edition, 1990.

PES-5305 Advanced Digital Signal Processing

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Digital Signal Processing Fundamentals: Review of DSP Fundamentals; FIR filterdesign by windowing; Adaptive filtering techniques; Fourier analysis of signal using FFT; Introduction to Real time DSP and TMS320F2407/TMS320C6XXX/ADMC401, Architecture,; Instruction set; Addressing modes; Simple Assembly programs; Real time digital FIR filter; Real time LMS adoptive filers; Real time frequency domain processing.

Digital Control Systems: Review of difference equations and Z—transforms, Z-transfer function (Pulse transfer function), Z- Transforms analysis, sampled data systems, Stability analysis (Jury's Stability Test and Bilinear Transformation), Pulse transfer functions and different configurations for closed loop Discrete-time control systems.

Modern Control Theory: State model for continuous time and discrete time systems, Solutions of state equations (for both continuous and discrete systems), Concepts of controllability and observability (For both continuous and discrete systems), Pole Placement by state feedback (for both continuous and discrete systems), Full order and reduced order observes (for both continuous and discrete systems), Dead beat control by state feedback, Optimal control problems using state variable approach, State Regulator and output regulator, Concepts of Model reference control systems, Adaptive Control systems and design.

Text Books/Reference Books:

1. Oppenheim and Schafer, *Digital Signal Processing*, Prentice Hall.
2. Proakis J, *Digital Signal Processing*, Prentice Hall.
3. Rulph Chassaing and Donald Reay, *Digital Signal Processing and Applications with the TMS320C6713 and TMS320C6416 DSK*, John Wiley and Sons.
4. Samuel Stearns, *Digital Signal Processing with examples in MATLAB*, CRC Press
5. Ogata. K., *Modern Control Engineering*, PHI

PES-5307 Power Electronics for Photovoltaic and Wind Energy Systems

Lectures: - 3 Hrs per week   Pre-requisites: Nil
Practicals: - Nil

Photovoltaic (PV) Power: PV Cell Technologies: Single-Crystalline Silicon, Polycrystalline and Semi-crystalline, Thin Films, Amorphous Silicon, Spheral, Organic, Concentrated Cells; Module and Array; Building Integrated PV Systems (BIPV); PV Energy Maps.

Wind Power System: System Components, Yaw Control, Speed Control, Turbine Rating, Electrical Load Matching, Variable-Speed Operation, System Design Features, Constant Tip-Speed Ratio and Peak Power Tracking Scheme for Maximum Power Operation, Variable-Speed Wind-Power System Based on Doubly-Fed Asynchronous Machines, DC-Bus Voltage Regulation by Controlled DC-Voltage Power, Environmental Aspects

Solar Photovoltaic Power System- Equivalent electrical circuit of PV cell and Array, Open Circuit Voltage and Short Circuit Current, i-v and p-v Curves, Sun Angle, Shadow Effect, Temperature Effect, Effect of Climate, Electrical Load Matching, Sun Tracking; Peak Power Point Operation, PV System Components

Power Electronics: Voltage Source Converters(VSC), Voltage and Current control, PWM techniques, Parallel operation of VSCs, Grid Interface Controls - Voltage & Frequency Control, Battery Charge/Discharge Converters, Power Shunts, Voltage Current and Power Relations Component, Design for Maximum Efficiency, Static and Dynamic Bus Impedance, Voltage Regulation and Ripple, Harmonics, Power Quality and its problems, Renewable Capacity Limit, Systems Stiffness, Interfacing Standards.

Stand-Alone PV system, Wind Stand-Alone, Hybrid with Diesel and Fuel Cell, Mode Controller, Load Sharing, System Sizing, Grid-Connected System-Interface Requirements, Synchronizing with Grid, Inrush Current, Synchronous Operation, Load Transients, Safety, Operating Limit, Voltage Regulation, Stability Limit, Energy Storage and Load Scheduling, Utility Resource Planning, Grid Integration of Wind Energy Systems, Wind Energy Converters(WEC) Types, Energy Conversion, Power Limitation, Speed Control, Power Curves of WECs, Grid Integration , Types of Common Grid Coupling, Energy, Reactive Power Management in Wind Parks, Power Quality on WECs, Offshore Wind Energy, Wind Park Design, Transmission Types,

Energy Management, Storage and Communication, Grid Integration of Photovoltaics and Fuel Cells, PV Inverter Types, Plant, Grid Interfacing and Islanding Detection, Power Quality, Grid-connected Applications, Plant Economy, Energy Delivery Factor, Initial Capital Cost, Availability and Maintenance, Energy Cost Estimates, Sensitivity Analysis, Effect of Wind Speed Variations, Effect of Tower Height, Profitability Index, Wind Farm Screening Chart, PV Park Screening Chart, Stand-Alone PV Versus Grid Line, Hybrid Economics.

Text Books/Reference Books:

1. Bin Wu, Yongqiang Lang, Navid Zargari, Samir Kouro, *Power Conversion and Control of Wind Energy Systems*, IEEE Press.
2. Marian P. Kazmierkowski, R Krishnan and Frede Blaabjerg, *Control in Power Electronics*”, Academic Press.
3. William Shepherd and Li Zhang Power, *Power Converter Circuits*, Marcel Dekker.
4. Fang Lin Luo, Hong Ye and Muhammad Rashid, *Digital Power Electronics and Applications*, Academic Press.

PES-5203 Renewable Energy Systems

Lectures: - 2Hrs per week Pre-requisites: Nil
Practicals: - Nil

Introduction to energy systems and resources, Current Energy Requirements, Conventional Energy and environmental implications, Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy and their advantages and disadvantages.

Solar Energy: Solar radiation and its measurement, Solar thermal Collectors – Flat Plate and Concentrating Collectors, Solar Thermal Conversion System and applications, Basic of Photovoltaic cell, Equivalent Cell Equation, Array Design, Peak Power Point Operation, Power Electronics for PV System: Off-Grid and Grid-Connected Power Control and Management Systems.

Wind Energy: Wind mills and wind turbine systems, Classification of wind machines: Horizontal & Vertical axis configuration. **Analysis of Wind Regimes:** Wind Shear and Turbulence Effects, Statistical model for Wind data analysis. Aerodynamics of winds, Wind Speed Monitoring, Betz limit, Aerofoil sections and their characteristics, Estimation of power output and energy production, Wind Energy Conversion System: Components, characteristics and applications.

Biomass Energy: Production and Classification of Biomass, Characteristics of Biomass fuel, Biomass Conversion Routes, Biochemical conversion of biomass for energy production, Anaerobic digestion, Types of digesters, Liquid Biofuel, Chemical Conversion of biomass for energy production, Synthesis Biofuel, Thermo-chemical conversion of biomass: Biomass-gasification, Biomass based power plant, Basis of selecting the site for plant installation. **Ocean Energy:** Ocean energy resources, Principles of ocean thermal energy conversion systems, ocean thermal power plants, Principles of ocean wave energy conversion and tidal energy conversion.

Hydropower: Introduction to Hydropower, Classification of Hydropower Plants, Small Hydropower Systems: Overview of micro, mini and small hydro systems, Advantages and Disadvantages of Hydropower, Selection of site for hydroelectric plant, Hydrological cycle, Essential elements of a hydroelectric power plant, Components of Hydropower Plants, Hydraulic Turbines: Types and Operational Aspects, Types of generators, Dam and Spillway, Surge Chambers, Penstock, Tailrace. **Other Sources:** Geothermal energy: Origin, types of geothermal energy sites, site selection, geothermal power plants; Magneto-hydro-dynamic (MHD) energy conversion, Hydrogen Energy, Fuel Cell.

Text Books/Reference Books:

1. Godfrey Boyle, *Renewable Energy: Power for a Sustainable Future*, Oxford University Press, 2012.
2. Mukund R. Patel, *Wind and Solar Power System*, CRC Press, 2nd Edition, 2005.
3. R. Strzelecki; G. Benysek, *Power Electronics in Smart Electrical Energy Networks*, Springer, 2008.
4. Mital KM., *Biogas Systems, Principle and Applications*, New Age International Ltd., 1996.
5. J W Twidell & A D Weir, *Renewable Energy Resources*, ELBS, 2006.

PES-5205 AC and DC Microgrids

Lectures: - 2 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Microgrid Concept as a Means to Integrate Distributed Generation, Status Quo and Outlook of Microgrid Applications, Market Models for Microgrids, Case Study of Microgrid Projects in Europe and USA

Case Study: War of Currents, Types of Microgrids, Mathematical analysis of AC vs DC microgrid system, Advantages and Disadvantages of AC Microgrid, Advantages and Disadvantages of DC Microgrid, Applications of AC and DC Microgrids

Architecture of AC Microgrid, Converter Topologies and Modulation Strategies, AC Microgrid Protection

AC Microgrid Control Issues, Synchronisation techniques and power flow control in grid connected mode, Control of VSC in islanding mode, Supervisory Control for AC Microgrid, Virtual Inertia Control

Concept of DC Microgrid, Architecture of DC Microgrid, Interfacing Converter for DC Microgrid, Primary-Secondary-Tertiary Control for DC Microgrid

Text Books/Reference Books:

1. Nikos Hatziargyriou, *Microgrids: Architectures and Control*, IEEE Press, John Wiley & Sons, 2014.
2. Tomislav Dragicevic, Amjad Anvari - Moghaddam, Juan C. Vasquez, Josep M. Guerrero, *DC distribution systems and microgrids*, IET, 2018.
3. Suleiman M. Sharkh, Mohammad A. Abusara, Georgios I. Orfanoudakis, Babar Hussain, *Power Electronic Converters for Microgrids*, IEEE Press, John Wiley & Sons, 2014.
4. Rajeev Kumar Chauhan, Francisco Gonzalez-Longatt, Bharat Singh Rajpurohit, Sri Nivas Singh, *DC microgrid in residential buildings*, IET, 2018.

PES-5207 Reliability Analysis of Power Electronics Converters

Lectures: - 2 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Concept of Reliability in Power Electronic System, Requirement of reliability for power electronic application, Reliability engineering in power electronics, Challenges and opportunities for research on power electronics reliability

Reliability of power electronic packaging, Modelling for the lifetime prediction of power semiconductor modules, Lifetime modelling and prediction of power devices, Reliability of DC-link capacitors in power electronic converters, Minimization of DC-link capacitance in power electronic converter systems

Reliability of power conversion systems in photovoltaic applications, Reliability of High-Power Converters**,** Reliability of power supplies for computers

Faults in Microgrids, Protection Schemes in Microgrids

Text Books/Reference Books:

1. Frede Blaabjerg, Henry Shu-hung Chung, Michael Pecht, Huai Wang, *Reliability of Power Electronic Converter System*, IET, 2015.
2. Antonio Carlos Zambroni de Souza, Miguel Castilla, *Microgrids design and implementation*, Springer, 2019.

First Year M.Tech (PES) II Semester

PES-502 Advanced Power Semiconductor Devices and Magnetics

Lectures: - 3 Hrs per week   Pre-requisites: Nil
Practicals: - 2 Hrs per week

Power Diodes: Basic Structure, I-V and switching characteristics, Breakdown Voltages and Control, On-state Losses, Reverse Recovery Transients, Schottky Diodes, Snubber Design. **Thyristors:** Basic Structure, V-I and switching characteristics, Transient analysis, dv/dt and di/dt limitations, Snubber Design, Gate drive requirements. **Triacs:** Basic structure, V-I Characteristics, Snubber Design. **Gate Turn-off Thyristor (GTO):** Basic Structure, operation, switching characteristics, transient analysis. **Power BJTs:** Basic Structure, I-V and switching characteristics, Breakdown Voltages, secondary breakdown and its control, FBSOA and RBSOA Curves, Losses, Transient analysis, Snubber Design.

Power MOSFETs: Basic Structure, HexFet structure, V-I and switching characteristics, Resistive Switching Specifications, Clamped Inductive Switching Specifications, Transient Analysis, Switching Losses, Effect of Reverse Recovery Transients on Switching Stresses and Losses - di/dt and dv/dt limitations, Gating Requirements, FBSOA and RBSOA Curves, Snubber design.

Transistors (IGBTs): Basic Structure and Operation, Parasitic Diode and Latch up, IGBT Switching Characteristics, Resistive Switching Specifications, Clamped Inductive Switching Specifications, Transient analysis, Current Tail, FBSOA and RBSOA Curves, Switching Losses, Overcurrent and Short Circuit Protection, Snubber Design.

New power semiconductor devices: MOS Gated Thyristors, MOS Controlled Thyristors or MOS GTOs, Base Resistance controlled Thyristors, Emitter Switched Thyristor, etc.

Thermal design of power electronic equipment: Heat transfer by conduction, transient thermal impedance, heat transfer by radiation and convection, Heat Sink Selection.

Magnetics: Fundamentals of Magnetics, Types of Magnetic Materials, Magnetization Processes, Hysteresis Loop, Comparison and Applications of the Core Materials, Ferrite Core Losses with Non-Sinusoidal Voltage Waveforms, Steinmetz Equation, Insulation Requirements and Standards, Self-inductance and Mutual Inductance, Inductor Design.

Text Books/Reference Books:

1. Ned Mohan, Tore. M. Undeland and William. P Robbins, *Power Electronics converters, Applications and Design*, John Wiley and Sons, 2003.
2. G. Massobrio, P. Antognetti, *Semiconductor Device Modeling with Spice*, McGraw-Hill, 2nd Edition, 2010.
3. B. Jayant Baliga, *Power Semiconductor Devices*, PWS Publication, 2nd Edition, 2019.
4. V. Benda, J. Gowar, and D. A. Grant, "Discrete and Integrated Power Semiconductor Devices: Theory and Applications", John Wiley & Sons, 2nd Edition, 1999.
5. Barry W Williams, *Power Electronics: Devices, Drivers, Applications, and Passive Components*, McGraw Hill, 1987.
6. Alex Van den Bossche and Vencislav Cekov Valchev, *Inductors and Transformers for Power Electronics*, CRC Press, Taylor & Francis Group, 1st Edition, 2005.
7. L Umanand and S R Bhat, *Design of Magnetic Components for Switched Mode Power Converters*, New Age International, 1st Edition, 1992.

PES-504 Controller Design for Power Electronic Converter

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Architecture of DC-DC Converters, Small Signal Modelling of basic electrical circuits

AC equivalent Circuit Modelling, Perturbation and Linearization, State Space Averaging techniques

Circuit Averaging and Average Circuit Modelling, Development of Canonical Circuit Model, Modelling of Pulse Width Modulator.

Converter Transfer Functions, Bode Plot of converter transfer functions.

Compensator Design for Voltage Controller for Non-Isolated DC-DC Converters (Buck, Boost, Buck-Boost, Cuk, Sepic), Compensator Design for Voltage Controller for Isolated DC-DC Converters (Flyback, Forward, Full Bridge), Stability Analysis, PID Controller

Compensator Design for Current Controller for Non-Isolated DC-DC Converters (Buck, Boost, Buck-Boost, Cuk, Sepic), Compensator Design for Current Controller for Isolated DC-DC Converters (Flyback, Forward, Full Bridge), Stability Analysis, PID Control, Hysteresis Control.

Non-Linear Control of Non-Isolated Converter - Adaptive Control, Tracking Control, Sliding Mode Control.

Text Books/Reference Books:

1. Robert W. Erickson, Dragan Maksimovic, *Fundamentals of Power Electronics*, Kluwer Academic Publishers, 1997.
2. Ned Mohan, Tore. M. Undeland, William. P. Robbins, *Power Electronics – Converter, Application and Design*, John Wiley & Sons, 2003.
3. M. K. Kazimierczuk, *Pulse-Width Modulated DC-DC Power Converters*, John Wiley & Sons. 2015.
4. Slotine J.J.E, W. Li, *Applied Non-Linear Control*, Prentice Hall Inc., 1991.
5. V. Ramanarayanan, Asif Sabanovich, Slobodan Cuk, *Thesis- Sliding Mode Control of Power Converters*, 1989.

PES-5406 Power Quality

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Overview of Power Quality: Characterization of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves, Power quality problems, Poor load power factor, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage, power quality standards. Single phase static and rotating AC/DC converters, Three phase static AC-DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, Pulse modulated devices, Adjustable speed drives.

Measurement and Analysis Methods: Voltage, Current, Power and Energy measurements, power factor measurement and definitions, event recorders, Measurement Error – Analysis, Analysis in the periodic steady state, Time domain method, Frequency domain methods: Laplace, Fourier and Hartley transform, The Walsh transform, Wavelet Transform.

Analysis and Conventional Mitigation Methods: Analysis of Power outages, Analysis of unbalance: Symmetrical components of phasor quantities, instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion : On – line extraction of fundamental sequence components fro measured samples, Harmonic indices, Analysis of voltage sag: Detorit Edition sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)- Analysis of Voltage flicker, Reduced duration and customer impact of outgas, Classical load balancing problem: Open loop balancing, Closed loop balancing, current balancing, Harmonic reduction, Voltage sag reduction.

Power Quality Improvement: Utility- Customer interface-Harmonic filter: passive, Active and hybrid filter – Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC-Control strategies- Q theory, modified P-Q theory, Synchronous detection method–custom power park – status of a application of power devices.

Text Books/Reference Books:

1. Arindam Ghosh, *Power Quality Enhancement Using Custom Power Devices*, Kluwer Acadamic Publishers.
2. G. T. Heydt., *Electric Power Quality*, Stars in a Circle Publications, 2nd Edition.
3. J. Arrillaga, N.R. Watson, S. Chen, *Power System Quality Assessment*, John Wiley & sons, New York.
4. Math H. J. Bollen, *Understanding Power quality problems*, IEEE Press, New York
5. E. Acha, Manuel Madrigal, *Power system Harmonics*, John Wiley & sons, New York.
6. Moreno – Murioz (Ed), Power *Quality (Mitigation Technologies in Distribution Environment*) Springer, 2007.
7. George J. Wakileh, *Power System Harmonics*, Springer.]
8. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, *Power Quality: Problems and Mitigation Techniques*, John Wiley & Sons

PES-5404 Mechatronics and Vehicular Power Electronics

Lectures: - 3 Hrs per week | Pre-requisites: Nil
Practicals: - 2 Hrs per week

Introduction to Mechatronics, definition, key issues, evolution, elements, mechatronics approach to modern engineering design.

Sensors and Transducers, Types, displacement, position, proximity and velocity sensors, signal processing, data display. Actuation Systems, Mechanical types, applications, electrical types, applications, pneumatic and hydraulic systems, applications, selection of actuators

Control Systems, Types of controllers, programmable logic controllers, applications, ladder diagrams, microprocessor applications in mechatronics, programming interfacing, computer applications

Recent Advances, Manufacturing mechatronics, automobile mechatronics, medical mechatronics office automation, case studies.

Basic Power Electronic Converters: Stability and requirement in vehicular dynamics, Constant Power Loads and their characteristics, Concept of negative impedance stability in DC/DC Converter with Constant power loads. Vehicular AC Distribution System, Hybrid (DC and AC) Vehicular Systems with Constant Power Loads, Electric and Hybrid-Electric Propulsion Systems, Modeling of Hybrid Vehicles, Dynamic Modeling of Batteries and Supercapacitors, Electric Power Links, Torque Couplers.

Hybrid Electric Vehicle, Plug-In Hybrid, Series Hybrid, Parallel Hybrid, Series and Parallel Hybrid, Regenerative Braking, Brake Cooling, Aerodynamic Drag, and Regenerative Braking and Coasting, Time and Stopping Distance, Regenerative Braking Integrated with Conventional Hydraulic System, Directional Stability.

Text Books/Reference Books:

1. Rajesh Rajamani, *Vehicle Dynamics and Control*, Springer, 2006
2. Uwe Kiencke and Lars Nielsen, Automotive *Control Systems For Engine, Driveline, and Vehicle*, Springer, 2005.
3. Ali Emadi, Mehrdad Ehsani, John M. Miller, *Vehicular Electric Power Systems: Land, Sea, Air and Space Vehicles*, Marcel Dekker, 2004.
4. SystemsLino Guzzella, Antonio Sciarretta, *Vehicle Propulsion*, Springer, 2007.

PES-5402 Advanced Topic on Power Electronics Converters

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Multiple-Quadrant Choppers, Fundamental Pump Circuits, Developed Pump Circuits, Transformer-Type Pumps, Double/Enhanced Circuit (DEC), Development of DC/DC Conversion Technique, Fundamental Converters, Transformer Type Converters Developed Converters, Zero-Current-Switching Quasi-resonant Converters, Zero-Voltage-Switching Quasi-Resonant Converters, Zero-Transition Converters, The Fifth Generation Converters, The Sixth Generation Converters, Categorize Prototypes and DC/DC Converter Family Tree.

Voltage-Lift Converters - Self-Lift Cúk Converter, Self-Lift SEPIC, Enhanced Self-Lift Converter, Variations of Currents and Voltages, Discontinuous Mode, Stability Analysis, Multiple-Lift Circuits, Double Output Converters, Super-Lift Luo-Converters. **Cascade Boost Converters -** Boost Circuit, Two-Stage Boost Circuit, Three-Stage Boost Circuit, Higher Stage Boost Circuit, Additional Series Circuits, Single and Double Stage Double Boost Circuit, Three-Stage Double Boost Circuit, Higher Stage Double Boost Circuit, Triple Boost Circuit, Two-Stage Triple Boost Circuit, Higher Stage Triple Boost Circuit, Multiple Boost Circuits.

Multiple Quadrant Operating Converters - Quadrant I, II, III and IV**,** Circuit Description, Variations of Currents and Voltages, Discontinuous Region, Switched Component Converters, Switched Capacitors DC/DC Converters, Switched Inductor Four-Quadrant DC/DC Converter, Continuous Mode, Discontinuous Mode. **Multiple-Lift Push-Pull Switched-Capacitor Converters -** Re-Lift Circuits, Higher Order Lift Circuit, Multiple-Lift Push-Pull Switched-Capacitor Converters, Integrated Switch Mode Power Converters.

Multiple-Quadrant Soft-Switch Converters & Synchronous Rectifier-Multiple-Quadrant DC/DC ZCS Quasi-Resonant Converters, Multiple-Quadrant DC/DC ZVS Quasi Resonant Converter, Multiple-Quadrant Zero-Transition DC/DC Converters, Design Considerations, Flat Transformer Synchronous Rectifier, Active Clamped Synchronous Rectifier Converter, Double Current Synchronous Rectifier Converter, Zero-Current-Switching Synchronous Rectifier Converter, Zero-Voltage-Switching Synchronous Rectifier Converter, Multiple Energy-Storage Element Resonant Power Converters, Two-Element RPC, Three-Element RPC, Four-Element RPC, Bipolar Current and Voltage Source, Bipolar Voltage Source, Input Impedance, Current Transfer Gain, Operation Analysis.

Text Books/Reference Books:

1. Fang Lin Luo & Hong Ye, *Advanced DC/DC Converters*, CRC Press, 2004.
2. Ali Emadi, Alireza Khaligh, Zhong Nie& Young Joo Lee, *Integrated Power Electronic Converters and Digital Control*, CRC Press, 2009.

PES-5408 Grid Connected Power Converter and Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Grid Connected Converters: The grid connected converter-key element in the grid integration of Wind Turbine (WT) and Photovoltaic (PV) system, Grid Connected Inverter Structures, Inverter structure derived from H-bridge topology, full bridge inverter, H5 inverter (SMA), HERIC inverter, REFU inverter, Inverter NPC Topology, neutral point clamped (NPC) half-bridge inverter, H-bridge based boost PV inverter with high frequency transformer, PV String Inverters, Three phase PV inverters.

Grid Connectivity Requirement and Synchronization : International regulations, IEEE 1547, IEC 61727, VDC 0126-1-1, IEC 61000, EN 50160, voltage quality, Response to abnormal Grid condition and resynchronization, Power quality, current harmonics, average power factor; Anti-islanding requirements and standards: IEEE 1547/UL 1741, IEC 6211 and VED 0126-1-1; Grid synchronization techniques for single phase systems, Grid synchronization using Fourier Analysis, phase-locked loop, Phase Detection based on in-quadrature signals, signal generation, Adaptive filters, etc. for Islanding Detection, Non detection Zone, Passive islanding detection methods, OUF-OUV Detection, Phase jump detection(PJD), Harmonic detection (HD), Passive method evolution, Active islanding detection methods, Frequency Drift Methods, Voltage Drift Methods, Grid Impedance Estimation, PLL-Based Islanding Detention, Comparison of active Islanding Detection Methods, Synchronous reference frame PLL under unbalanced grid conditions, Decoupled Double synchronous Reference Frame PLL(DDSRF-PLL), Double Second-order Generalized integration PLL(DSOGI-PLL) and structure of the DSOGI.

Grid Converter Structures and Control: Power configurations, Grid Power Converter Topologies, single- cell (VSC–CSC), Multicell, Grid control, Active power Control Under Normal Operation, Power curtailment, Frequency control, Reactive power control, Discussion of Harmonization of Grid Code, local voltage control, inertia emulation(IE), Power oscillation damping(POD), L- filter and LCL-filter inverter, AC and DC Voltage Control, DC Link Voltage Management, PQ Open-Loop control, synchronous frame and stationary frame VOC, Virtual flux based control, Direct Power Control, Linear current control, Modulation Techniques, single phase, Operating limits of controllers.

Control of Grid Converters under Grid Fault: Overview of Control Techniques for grid connected converter under Unbalance Grid voltage Conditions, Control structures for Unbalanced Current Injection, Power control under unbalanced grid conditions, instantaneous active reactive control (IARC), Positive and negative sequence control (PNSC), Average active-reactive control (AARC), balanced positive control (BPSC), Flexible positive and negative sequence control (FPNSC), Flexible Power control with current limitation, locus of the current vector under unbalanced grid conditions.

Text Books/Reference Books:

1. Remus Teodorescu, Marco Liserre, Pedro Rodríguez, Frede Blaabjerg, *Grid Converters for Photovoltaic and Wind Power Systems*, John Wiley & Sons, 2011.
2. Ali Keyhani, Mohammad N. Marwali, Min Dai, *Integration of Green and Renewable Energy in Electric Power Systems*, John Wiley & Sons, 2010.
3. Ryszard Strzelecki and Grzegorz Benysek, *Power Electronics in Smart Electrical Energy Networks*, Springer, 2008.
4. Amirnaser Yazdani and Reza Iravani, *Voltage Source Converters in Power systems: Modeling, Control, and Applications*, John Wiley and Sons, 2010.

PES-5304 High/Medium Voltage DC transmission Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Introduction: A more Flexible Power Grid, Power Electronics Control, Thyristor-Based CSC Transmission, VSC Transmission, Multi-terminal HVDC, Comparison of AC and DC Transmission Lines, The Impact of Distributed Generation, The Effect of Electricity Deregulation; HVDC Transmission Systems.

HVDC Conversion - Basic CSC Operating Principles, Effect of Delaying the Firing Instant, The Commutation Process: Analysis of the Commutation Circuit, Power Factor and Reactive Power, Characteristic Harmonics, Multi-Pulse Conversion, DC Ripple Re-injection, Uncharacteristic Harmonics and Interharmonics, Control System Imperfections, Firing Asymmetry, Magnification of Low- Order Harmonics, Harmonic Reduction by Filters; Voltage Source Conversion, VSC Operating Principles, Converter Components, Comparison of LCC and VSC, Analysis of the CSC Waveforms, The Re-injection Concept with Self-Commutation, Application to VSC, Application to CSC.

Line-Commutated CSC Transmission and their developments in Line Commutated HVDC schemes: Line-Commutated CSC Transmission, The Line-Commutated HVDC Converter, Structure of the HVDC Link, DC System Configurations, Control and Operation, AC–DC System Interactions, Voltage Interaction, Dynamic Voltage Regulation, Dynamic Stabilisation of AC Systems, Controlled Damping of DC -Interconnected Systems, Damping of Sub-Synchronous Resonances, Active and Reactive Power Coordination, Transient Stabilisation of AC Systems, AC–DC–AC Frequency Interactions, DC Link Response to External Disturbances: Response to AC System Faults, Response to DC Line Faults, Reliability of LCC Transmission; Capacitor Commutated Conversion, Tuned AC Filters, Active DC Side Filters, STATCOM-Aided DC Transmission.

VSC Transmission, Multi-Level VSC and CSC Transmission: VSC Transmission, Power Transfer Characteristics: Current Relationships, Structure of the VSC Link: VSC-HVDC Cable Technology, VSC DC System Control, Assistance During Grid Restoration, HVDC Light Technology, Potential for Multi-Terminal Sub-Transmission Systems, **Multi-Level VSC Transmission:** Power Flow Considerations, DC Link Control Characteristics, Independent Reactive Power Control, **Multi-Level CSC Transmission.**

Text Books/Reference Books:

1. Arrillaga J., Liu Y.H., Watson N.R., *Flexible Power Transmission The HVDC Options*, John Wiley & Sons, 2007.
2. Sood Vijay K., *HVDC and FACTS Controllers Applications of Static Converters in Power Systems*, Kluwer Academic Publishers, 2004.
3. Kimbark, E.W., *Direct Current Transmission*, Wiley Interscience, New York, 1971.
4. Padiyar, K. R., *HVDC Power Transmission Systems – Technology and System Interactions*, New Delhi-Eastern, 1990.
5. Adamson, C. and Hingorani, N.G., *High Voltage Direct Current Power Transmission*, Garraway, London, 1960.

PES-5306 Electric Traction

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Types of electric traction, system of track electrification, Traction mechanics-types of services, speed time curve and its simplification, average and schedule speeds, Tractive effort specific energy consumption, mechanics of train movement, coefficient of adhesion and its influence, ideal speed torque characteristics of Traction motors.

Salient features of traction drives, Series-parallel control of dc traction drives (bridge traction) and energy saving, Power Electronic control of dc & ac traction drives, Diesel electric traction.

Constructional and Design aspects of DC single phase and 3-phase I.Ms for Electric traction, constraints and comparison w.r.t. commercial machines, problem associated with voltage rises, Temporary Interruption of supply, commutation of current rush, Ability of motors to withstand current rushes.

Solid-state device controllers for DC Traction motors used for starting, speed control and electric braking in Electric traction for main line and suburban services, Controllers for 1-phase Traction motors, trends in main line railways using polyphase I.M.s and their controllers, Electric braking requirements and thyristorised controllers.

Battery operated vehicles for city service, Light weight batteries, Diesel-Electric Traction systems for main line service and controllers, Soft starting of Traction motors, Conservation of Electrical energy.

Text Books/Reference Books:

1. A. T. Dover, *Electric Traction*, Sir ISAAC Pitman Publisher, 4th Edtion, 1965.
2. G. K. Dubey, Dorodla, Joshi and Sinha, *Thyristorised Power Controllers*, Wiley Eastern Ltd., 1st edition, 1986.
3. M. S. Berde, *Thyristor Engineering (Power Electronics)*, Khanna Publishers, 9th Edition, 2005.
4. Prakash, *Modern Electric Traction*.

PES-5308 Energy Storage System

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Battery: Energy Storage Parameters; Lead–Acid Batteries-Constructional Features, Charge–Discharge Cycles, Operating Limits, Maintenance and Sizing, Types, Applications; Performance measurement, storage density, energy density, and safety issues in Lead-Acid, Nickel-Cadmium, Zinc Manganese dioxide batteries, Modern batteries as Zinc-Air, Nickel Hydride, Lithium Battery, Flow Batteries.

Ultracapacitors/Supercapacitors: Double-Layer Ultracapacitors, High-Energy Ultracapacitors, Rating, Size & Applications; Supercapacitors - Basic components, Types of electrodes and electrolytes, Advantages and Disadvantages, Comparison with battery systems, applications in public transport vehicles, private vehicles, and consumer electronics; Aspects of energy density, power density, price, and market.

Fuel Cell: Fuel cells for direct energy conversion, physical interpretation of the Carnot efficiency factor, electrochemical energy converters, power outputs, maximum intrinsic efficiency of an electrochemical converter. Types of fuel cells: Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, Alkaline fuel cell and Phosphoric fuel cell; Advantages and Disadvantages

Other Storages: Pumped Hydroelectric Energy Storage, Storage Capabilities of Pumped Systems, Compressed Air Energy Storage, Storage Heat, Energy Storage as an Economic Resource.

Flywheels: Advanced Performance of Flywheels, Applications of Flywheels, Design Strategies, Superconducting Magnetic Storage System, SMES System Capabilities, Developments in SMES Systems.

Power Electronics For Charging Control -Basic operation and modeling of power electronic devices applied in power transmission and distribution systems for electrical vehicles, various types of power electronics circuits used in energy processing; analysis and design of power converter circuits such as AC-DC, AC-AC, DC-DC and DC-AC converters; applications of power electronics circuit in electrical vehicles charging; methods of protection of power semiconductor devices and calculation of power device losses.

Text Books/Reference Books:

1. M. Broussely and G. Pistoia, Eds, *Industrial Applications of Batteries: From Cars to Aerospace and Energy Storage*, Elsevier, Amsterdam, 2007.
2. M. Broussely, G.A. Nazri and G. Pistoia,Eds., *Lithium Batteries – Science and Technology*, Kluwer Academic Publishers, Boston, USA, 2004.

PES-5310 Pulsed Power Electronics & Nuclear Energy Systems

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Introduction to Nuclear Physics, Basics atomic structure, mass energy equivalence, Interaction of radiation with matter, fission and fusion, Energy released in reactions, Particle Accelerators, Electrical & Magnetic Forces, High Voltage Machines, Linear Accelerators, Cyclotron, Betatron, Synchrotron, Collider, Spallation, Separators, Mass Spactrography, Separation of Deuterium, Detectors.

Heat generation and heat removal from the reactor, steam-cycles, types of Thermal Reactors, Nuclear power plant layout, Type of Reactors, Isotope Production and Consumption, Breeding & Uranium resources, Fusion reactors, Comparison of Fusion reactors, Magnetic and Inertial confinement machines, Other Fusion concepts.

Nuclear power station operation, Types of Pumps, Condensate booster, Feed water pump, Sodium Pump, Instrumentation and control, Irradiation effects, effects of temperature, Fuel cycles, instability, reactor control, start up and shunt down, reactor safety, reactor power level measurement, safety circuits, Radiation Shielding.

Pulse Discharge Capacitors, Types of Generators, Transformers, Transformers using long lines, Basic Pulsed-Power Energy Transfer Stage, Inductive Energy Storage, Power and Voltage Multiplication, Rotors and Homopolar Generators, Gas Switches, Magnetic switches, Summery, Mechanical Interrupters, Superconducting Opening Switches, Plasma Opening Switches, Voltage adding, cumulative Pulse Lines, KALIF, PBFA 2 and the Z- Machine, RHEPP.

Semiconductor closing switches, Types of thyristors, Semiconductor Opening Switches(SOS), Operation of SOS diodes, SOS-diode-based nanosecond pulse devices, Pulse power generators in circuits with magnetic elements, Properties of magnetic elements in pulsed fields, Generation of nanosecond high-power pulses, Magnetic generators using SOS diodes, Long lines with nonlinear parameters, Formation of electromagnetic shock waves due to induction drag, Generation of nanosecond high-power pulses with the use of electromagnetic shock waves.

LCSB, Cathodes, Explosive electron emission from a triple junction, Metal-dielectric cathode designs , Physical processes in LCSB diodes, Designs of LCSB accelerators, AEB, Principle of operation of diodes, Device of electron guns for MICD's The cathode plasma in a magnetic field, Formation of electron beams, Dense Electron Beam & their focusing, diode operation, Focusing of electron beams, High-power x-ray pulses, high-power pulsed gas lasers, generation of high-power pulsed microwaves, generation of ultrawideband radiation pulses.

Text Books/Reference Books:

1. Raymond Murray, *Nuclear Energy: an introduction to the concepts, systems, & applications*, Butterworth Heinmann, 2009.
2. Gennady A. Mesyats, *Pulsed Power*, Springer, 2005.
3. Samuel Glasstone & Alexander Sesonske, *Nuclear Reactor Engineering: Reactor Systems Engineering*, Chapman& Hall, 1994.
4. Ronald Allen Knief, *Nuclear engineering: theory and technology of commercial nuclear power*, Taylor & Francis, 1992.
5. J. Kenneth Shultis & Richard E. Faw, *Fundamentals of Nuclear Science and Engineering*, CRC Press, 2008.
6. Hansjoachim Bluhm, *Pulsed Power Systems: Principles and Applications*, Springer, 2006.

PES-5312 Pulse Width Modulation for Power Converters

Lectures: - 2 Hrs per week   Pre-requisites: Power Electronics Converters (PES-503)

Practical: - 2 Hrs per week

Introduction to Power Electronic Converters: Basic Converter Topologies; Switch Constraints; Bidirectional Converters; Switching Function representation of Converters; Output Voltage Control and Phase Shift Modulation; Concept of a Space Vector Modulation; Multilevel Inverter Topologies; Hybrid Voltage Source Inverter. **5 Hours**

Modulation of One Inverter Phase Leg: Fundamental Concepts of PWM; Evaluation of PWM Schemes; Double Fourier Integral Analysis of Two-Level Pulse Width Modulated Waveform; Sine-Triangle Modulation; PWM Analysis by Duty Cycle Variation; Sine-Sawtooth Modulation; Direct Modulation; Integer vs Non-Integer Frequency Ratios; Comparison of PWM Variations. **5 Hours**

Modulation of Single-Phase Voltage Source Inverters: Three-Level Modulation of a Single-Phase Inverter; Sideband Modulation; Switched Pulse Position; Continuous Modulation; Discontinuous PWM-Single-Phase Leg Switched; Two-Level Single-Phase PWM. **5 Hours**

Modulation of Three-Phase Voltage Source Inverters: Three-Phase Modulation with Sinusoidal References; Third-Harmonic Reference Injection; Optimum Injection Level; Analytical Solution for Third-Harmonic Injection; Harmonic Losses; Discontinuous Modulation Strategies; Triplen Carrier Ratios and Subharmonics. **5 Hours**

Zero Space Vector Placement Modulation Strategies: SVM Compared to Regular Sampled PWM; Phase Leg References for SVM; Naturally Sampled SVM; Harmonic Losses; Placement of the Zero Space Vector; Discontinuous Modulation: 120°, 60° & 30° Discontinuous Modulation; Phase Leg References for Discontinuous PWM; Comparison of Harmonic Performance; Harmonic Losses for Discontinuous PWM; Single-Edge SVM; Switched Pulse Sequence; Naturally Sampled CSI Space Vector Modulator. **6 Hours**

Overmodulation of an Inverter: Overmodulation Region; Naturally Sampled Overmodulation of One Phase Leg of Inverter; Naturally Sampled Overmodulation of Single and Three-Phase Inverters; PWM Controller Gain during Overmodulation; SVM and discontinuous reference. **4 Hours**

Text Books/Reference Books:

1. D. Grahame Holmes and Thomas A. Lipo, *Pulse Width Modulation for Power Converters*, John Wiley & Sons. 2003.

2. Euzeli dos Santos and Edison R. da Silva, *Advanced Power Electronics Converters: PWM Converters Processing AC Voltages*, Wiley-IEEE Press 2014.

3. Eric Monmasson, *Power Electronic Converters: PWM Strategies and Current Control Techniques*, John Wiley & Sons, 2011.

4. Ned Mohan Tore. M. Undeland and William. P Robbins, *Power Electronics converters, Applications and Design*, John Wiley and Sons., 2012.

5. Marian K. Kazimierczuk, *Pulse-width Modulated DC–DC Power Converters*, John Wiley & Sons, second edition 2016.

PES-5202 Standards for Microgrid Application and Control

Lectures: - 2Hrs per week Pre-requisites: Nil
Practicals: - Nil

Overview of smart grids, smart grid related organizations, smart grid in developed nations like United States, Europe, Japan and China, Influence of Renewable Energy generation on smart grid, important standards for power grid (communication, energy management system and tele protection)

Standards for electric storage, distributed energy sources (DER's) and e – mobility / electric vehicles (batteries, grid to vehicle (G2V) and vehicle to grid (V2G)), standards for energy consumption – metering infrastructure and automation standards

Communication standards for microgrid, communication requirement in smart grid, standards and protocols for communication, IP in smart grid, wired and wireless communication in microgrids.

Security and safety for microgrids, threats and vulnerabilities for smart grid , standards for safety (IEC 62351, IEC 61508), levels of safety, network interoperability, cyber security, future of smart grids

Text Books/Reference Books:

1. Takuro Sato, Daniel M. Kammen, Zhenyu Zhou, Martin Macuha, Jun Wu, Muhammad Tariq, Solomon Abebe Asfaw, *Smart Grid Standards – Specifications, Requirements and Technologies*, Wiley & Sons, 2015.
2. Mathias Uslar, Michael Specht, Christian Danekas, JornTrefke, Sebastian Rohjans, Jose M Gonzalez, Christine Rosinger, Robert Bleiker, *Standardization in Smart Grids*, Springer Publications, 2013.

PES-5204 Energy Management System

Lectures: - 2 Hrs per week
Practicals: - Nil

Pre-requisites: Nil

Intermittencies in renewable energy systems, microgrid and electric vehicle fundamentals and requirement of energy systems, energy systems and management technologies, Integration of Energy Storage systems in microgrids.

Modeling of energy storage systems (Battery, Fuel cell, Ultra capacitor, flywheel), equivalent circuit models and parameter identifications, Super capacitors and Ultra capacitors as energy storage device, transient/dynamic matching of energy storage system.

Battery state of charge (SoC) and State of Energy (SoE) estimation, Battery state of health (SoH) estimation using experimental method, model based method, joint estimation method, and dual estimation method, Battery state of power (SoP) estimation using instantaneous SoP and continuous SoP estimation method.

Battery balancing techniques, Battery sorting, battery passive balancing, battery active balancing, battery active balancing systems. Battery management systems in electric vehicles, typical structures of BMS, future generation of BMS

Text Books/Reference Books:

1. Rui Xiong and Weixiang Shen, *Advanced Battery Management Technologies for Electric Vehicles*, Wiley & Sons, 1st Edition, 2019.
2. Jingshan Li, Shiyu Zhou, Yehui Han, *Advances in Battery manufacturing, service and management systems*, Wiley & Sons, 2017.

PES-5210 Electric Vehicles and E-Mobility

Lectures: - 2 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Evolution and introduction to e-vehicle, socio- ecological impact of e-vehicle over fuel driven vehicle, components of EV, basic EV architectures.

Forces and their affects over vehicle dynamics [Aerodynamic forces, Rolling resistance, Gradient resistance], formulation of dynamic equation, tire dynamics for vehicle movement, torque-speed, power-speed characteristics, performance analysis- Acceleration, Braking , power and energy analysis, braking distance calculation.

Selection of motor drive and its sizing, selection of HEV's architectures, fundamentals of regenerative braking, control of HEV's for maximum energy recovery.

Power electronics converters - (Non-isolated and Isolated) and storage systems for EV application.

Levels of charging (AC/DC charging), standards- CCS and Chademo, charging architectures, onboard, off board, wireless power transfer..

Text Books/Reference Books:

1. Mehrdad Ehsani, Yimin Gao, Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles-Fundamentals, Theory and Design Second Design*, 2005.
2. Iqbal Husain, *Electric and Hybrid Vehicles- Design Fundamentals*, 2nd Edition, 2011.
3. G. R. C. Mouli, J. Kaptein, P. Bauer and M. Zeman, *Implementation of dynamic charging and V2G using Chademo and CCS/Combo DC charging standard*, 2016 IEEE Transportation Electrification Conference and Expo (ITEC), Dearborn, MI, 2016.
4. M. Yilmaz and P. T. Krein, *Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles*, in IEEE Transactions on Power Electronics, vol. 28, no. 5, pp. 2151-2169, May 2013.

Second Year M.Tech (PES) III Semester

PES-6401 Smart Grid and Distribution Automation

Lectures: - 3 Hrs per week   Pre-requisites: Nil
Practicals: - 2 Hrs per week

Introduction: Structure and Fundamental Problems of Electrical Power Systems, Principles of Electrical Power Control, Classical Power Theory & Instantaneous Power Theory Power, Distributed Generation and Energy Storage Benefits to Grids, Damping of the System Oscillations, Fully Integrated Power System; **Distributed Generation and Microgrid:** Active distribution network, Configuration and Interconnection of Microgrids, Technical and economical advantages and challenges, Dynamic interactions of Microgrid, Ride through, Grid Synchronization.

Distributed Energy Resources : Variable and Adjustable Speed Generation Systems (SEIG & DFIG), Wind energy conversion systems (WECS), Grid Integration of Wind Energy Systems, Reactive Power Requirements, Power Fluctuations and Harmonics, Grid Integration of Photovoltaics and Fuel Cells, Dynamics of Small-scale hydroelectric power generation; **Microgrid and Active Distribution Network Management System :** Network management needs, Micro generation control, Energy storage, Regulation and load shifting, Source controller and EMS with protection, Demand-side Management.

Protection issues for Microgrids: Different islanding scenarios, Protection issues of stand-alone Microgrid, Parallel operation issues and protection requirements, Distribution transformer protection, Under/overvoltage protection, Under/Over frequency protection, Unbalanced loading, Loss of mains protection, Rate of change of frequency.

Power Electronic Interfaces: Overview of Power converter and Controls, PWM Rectifiers, Two level and Multi-level Converters, Neutral Point Clamped Voltage Source Converter (VSC), Space Vector PWM, Z-source Converters, Grid-Imposed Frequency VSC System - Control in αβ & dq-frames, D-STATCOM, Integration and Interconnection Concerns, Voltage and Current Control of a 3-Phase 4 Wire distributed Interface Converters in Islanded Mode.

Power Quality and Reliability issues of Distributed Generation (DG): Power quality disturbances, Existing power quality improvement technologies, Load compensation, Voltage regulation, Harmonic Filtration and Balancing of the Voltage in Three-wire Systems, Dynamic Voltage Restorer, Primary & Secondary DG system with power quality support, Soft grid-connected DG, DG with intermittent solar PV/wind generator, Controllers with Energy-storage Systems.

SCADA and Active Distribution Networks: Existing Distributed Network operator (DNO) SCADA systems and its Control, Requirement of Communication in Microgrids, Distributed control system (DCS), Sub-station communication standardisation, smart transformers, Online Condition monitoring, SCADA communication and architecture, Automated Meter Reading, Operational issues of Serial Communication, Broadband Powerline Communiation, Optical & Wireless Communication.

Text Books/Reference Books:

1. S. Chowdhary, P. Crossley, *Microgrids and Active Distribution Network*, IET 2009
2. Nick Jenkins, Nicolas Jenkins, *Embedded Generation*, 2000.
3. R. Strzelecki, G. Benesek, *Power Electronics in Smart Electrical Energy Networks*, Springer.
4. Amirnaser Yazdani& Reza Iravani, *Voltage Sourced Converters in Power Systems: Modeling, Control, and Applications*, John Wiley & Sons, Inc., 2010.

PES-6403 Non Linear Control of Power Electronic Converters

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Introduction to nonlinear systems and their behavior, Analysis of nonlinear systems using perturbation theory, phase plane trajectories, Describing functions, Lyapunov&Pupov's methods.

Nonlinear control design techniques – tracking control, deadbead control, passivity based control, Feedback linearization, input-state and input-output linearization, design issues for MIMO nonlinear systems.

Modeling and state space averaging of power electronic converters (buck, boost, buck – boost, cûk and sepic converter), small signal analysis of power electronic converters (buck, boost, buck – boost, cûk and sepic converter)

Non linear control of basic power converters (buck, boost, buck – boost, cûk and sepic converter) like adaptive -(MRAC, self tuning, gain scheduling control), adaline, tracking control .

Text Books/Reference Books:

1. Hassan. K. Khalil, *Non linear systems*, Prentice Hall Inc., 2002
2. Slotine J.J.E and W. Li, *Applied nonlinear control*, Prentice Hall Inc., 1991.
3. Mohler R.R., *Nonlinear systems: Dynamics and Control*, Prentice Hall Inc., 1991.
4. Adrian Ioinovici, *Power Electronics and Energy Conversion Systems: Fundamentals and Hard-switching Converters*, John Wiley & Sons Ltd., 2013 .
5. Marian P. Kazmierkowski, R Krishnan and Frede Blaabjerg, *Control in Power Electronics*, Academic Press, 2002.
6. V. Ramanarayanan, Asif Sabanovich and Slobodan CûK, *Thesis - Sliding Mode Control of Power Converters*, 1989.
7. Shankar Sastry, Marc Bodson, *Adaptive Control- Stability, Convergence and Robustness*, Prentice Hall Inc., 2011.

PES-6405 Energy Efficiency, Auditing and Loss Reduction

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Electrical system & Electric Motors: Electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses. Electric motors: Types, losses in induction motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors

Compressed Air System: Types of air compressors, compressor efficiency, efficient compressor operation, Compressed air system components, capacity assessment and leakage test, factors affecting the performance and savings opportunities

Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Pumps and Pumping System- Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities. Cooling Tower and Energy Efficient Technologies- Types and performance evaluation, efficient system operation, flow control strategies and energy saving opportunities assessment of cooling towers Different types of Energy Efficient Technologies.

Energy AUDIT-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments

Loss Reduction- losses, Techniques, Advantages of loss reduction.

Text Books/Reference Books:

1. Wayne C. Turner, *Energy management handbook*, John Wiley and Sons, 6th Edition, 2007.
2. Cape Hart, Turner and Kennedy, *Guide to Energy Management*, 8th Edition, 2016
3. Cleaner Production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Productivity Council.

PES-6407 Thermal Design for Heat Sinks, Thermoelectrics and EMI/EMC

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - 2 Hrs per week

Introduction: Thermodynamics - Energy, Heat and work, the first law of Thermodynamics, Heat Engines, Refrigerators, and Heat pumps, The second Law of Thermodynamics, Carnot Cycle. Theory of Heat Transfer (Conduction, Convection and Radiation).

Heat Sinks: Longitudinal Fin of Rectangular Profile, Heat Transfer from Fin, Fin Effectiveness, Fin Efficiency, Corrected Profile Length, Optimizations- Constant profile Area, Constant Heat Transfer from a Fin, Constant Fin Volume or Mass, Multiple Fin Array I- Free (Natural) Convection Cooling- Small Spacing Channel, Large Spacing Channel, Optimum Fin Spacing, Force Convection Cooling- Small Spacing Channel, Large Spacing Channel, Multiple Fin Array for Natural (Free) Convection Cooling, Thermal Resistance and Overall Surface efficiency, Fin Design With Thermal Radiation.

Thermoelectrics: Thermoelectric Effect, Thomson Relationships, Thermoelement Couple, The Figure of merit, Similar and Dissimilar Materials, **Thermoelectric Generator (TEG)-** Similar and dissimilar Materials, Theory of Conversion Efficiency and Current, , Maximum Power Efficiency, Maximum Performance Parameters, Multicouple Modules, **Thermoelectric Coolers (TEC)-**Coefficient of Performance, optimum Current For the Maximum Cooling Rate and maximum COP, Maximum Performance Parameters, Generalized Charts, Optimum Geometry for the Maximum Cooling in Similar Materials, Thermoelectric Modules/Design, Commercial TEC, Multistage Modules, Applications and Design - Thermoelectric Generators, Thermoelectric Coolers, Design Example- Design of Internal and External Heat Sinks, Performance Curves for Thermoelectric Air Cooler, Thermoelectric Module Design-Thermal and Electrical Contact Resistances for TEG and TEC.

Compact Heat Exchanger: Fundamentals of Heat Exchangers-Over Heat Transfer Coefficient, Log Mean Temperature Difference (LMTD), Flow Properties, Nusselt Numbers, Effectiveness-NTU (e-NTU) Method- Parallel Flow, Counterflow, Crossflow, Heat Exchange Pressure Drop, Fouling Resistances (Fouling Factor), Overall Surface (Fin) Efficiency, Reasonable Velocities of Various Fluid in Pipe Flow, Double Pipe Heat Exchangers, Shell and tube Heat Exchangers, Plate Heat Exchangers (PHE), Pressure Drop in Compact Heat Exchangers, Contraction and Expansion Loss Coefficient, Types of tube cores, Finned-Tube Heat Exchangers, Correlation for Circular Finned-Tube Geometry, Pressure Drop, Correlation For Louvered Plate-Fin Flat-tube Geometry, Plate Fin Heat Exchangers, Louver-Fin-Type Flat-Tube Plate-Fin Heat Exchangers.

Text Books/Reference Books:

1. Halid Hrasnica, Abdel fatteh Haidine and Ralf Lehnert, *Broadband Powerline Communications Networks: Network Design*, John Wiley & Sons Ltd, 2004.
2. Ho Sung Lee, *Thermal Design: Heat Sinks, Thermoelectrics, Heat Pipes, Compact Heat Exchangers, and Solar Cells*, John Wiley & Sons Inc, 2010.
3. Allan D. Kraus,*Design and Analysis of Heat Sinks*, John Wiley & Sons Inc, 1995.
4. Younes Shabany, *Heat Transfer: Thermal Management of Electronics*, CRC Press, 2009.
5. Gordon Ellison, *Thermal Computations for Electronics: Conductive, Radiative, and Convective Air Cooling*, CRC Press 2010.

PES-6409 Resonant Power Converters

Lectures: - 3 Hrs per week Pre-requisites: Power Electronics Converters (PES-503)

Practical: - 2 Hrs per week

Objective: To familiarize the students with the various soft switched, resonant power electronic converters, calculation of switching frequency losses, design of high frequency converters, and the effect of high frequency converters on power transfer, size and weight of the converters.

Introduction: Need of Resonant Power Converter; Resonant Converter Applications; Overview of Resonant Converter Topologies. **(2 Hours)**

Rectifiers: Basics and types of Rectifiers; Current Rectifiers; Voltage Rectifiers; Half-wave Rectifiers; Center-Tapped Rectifiers; Bridge Rectifiers; Role of Equivalent Series Resistance (ESR) and Equivalent Series Inductance (ESL) in Capacitor; Low dv/dt Rectifier with Capacitor; Resonant Low dv/dt Rectifier; Low di/dt Rectifier with Series Inductor; Low di/dt Rectifier with Parallel Inductor. **(10 Hours)**

Series / Parallel Resonant Inverters: Introduction; Series Resonant Inverters: half-bridge series resonant inverters; full-bridge series resonant inverters; Conduction loss and Switching loss; Parallel Resonant Inverters: half-bridge parallel resonant inverters; full-bridge parallel resonant inverters; Series-parallel Resonant Inverters. **(8 Hours)**

Multi-frequency Resonant Inverters: CLL Resonant Inverters; Current Source Resonant Inverters; Phase Controlled Resonant Inverters; Zero Voltage switching Resonant Inverters; Zero Current Switching Resonant Inverters. **(8 Hours)**

Resonant DC-DC Converters: Introduction; Series Resonant Converters: half-bridge series resonant converters; full-bridge series resonant converters; Parallel Resonant Converters: half-bridge parallel resonant converters; full-bridge parallel resonant converters; Series-Parallel Resonant converters; LLC Converters; Bidirectional CLLC Converters. **(16 Hours)**

Text Books/Reference Books:

1. Marian K. Kazimierczuk, Dariusz Czarkowski, *Resonant Power Converters*, 2nd Edition, John Wiley & Sons, 2011.
2. Ivo Barbi, Fabiana Pottker, *Soft Commutation Isolated DC-DC Converters*, Springer 2019.
3. Ned Mohan Tore. M. Undeland and William. P Robbins, *Power Electronics converters, Applications and Design*, John Wiley and Sons., 2012.

PES-6301 SCADA & Energy Management System

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

General Theory: Purpose and necessity, general structure, data acquisition, transmission & monitoring. General power system and hierarchical Structure; Overview of the methods of data acquisition systems, commonly acquired data, transducers, RTUs, data concentrators, various communication channels- cables, telephone lines, power line carrier, microwaves, fiber optical channels and satellites.

Supervisory and Control Functions: Data acquisitions, status indications, majored values, energy values, monitoring alarm and event application processing. Control Function: ON/ OFF control of lines, transformers, capacitors and applications in process in industry - valve, opening, closing etc. Regulatory functions: Set points and feedback loops, time tagged data, disturbance data collection and analysis. Calculation and report preparation.

MAN- Machine Communication: Operator consoles and VDUs, displays, operator dialogues, alarm and event loggers, mimic diagrams, report and printing facilities.

Data Basis - SCADA, EMS and network data basis. SCADA system structure - local system, communication system and central system. Configuration- NON-redundant- single processor, redundant dual processor, multicontrol centers, system configuration. Performance considerations: real time operation system requirements, modularization of software programming languages.

Energy Management Center: Functions performed at a centralized management center, production control and load management economic dispatch, distributed centers and power pool management.

Text Books/Reference Books:

1. Torsten Cergrell, *Power System Control Technology*, Prentice Hall International, 1986.
2. George L Kusic, *Computer Aided Power System Analysis*, Prentice Hall of India, 2nd Edition, 2009.
3. A. J. Wood and B. Woolenberg, *Power Generation Operation and Control*, John Wiley & Sons, 2nd Edition, 1996.
4. Sunil S Rao, *Switchgear Protection & Power System*, Khanna Publishers, 11th Edition, 2008.

PES-6303 Energy, Environmental Economics and Energy Policy

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Overview of Energy Markets: Introduction to energy fundamentals, Pricing of exhaustible resources, Discussion of energy prices and markets, Economic regulation of energy markets, Electricity regulation and restructuring.

Environmental Implications of Energy: Externalities of conventional fuels, Discussion of externalities, Economics of pollution control, Discussion of pollution control policies, Economics of climate change, Introduction to climate change policies.

Investment in Renewable Energy Sources: Overview of renewable technology, Discussion of investing in energy projects, Introduction to Policies for Renewables, Discussion of Policies for Renewables.

Issues in Energy Economics: Energy efficiency and conservation, Introduction to transportation economics, "Mobile-Source Air Pollution" CAFE and transportation policies, other transportation policies.

Text Book/Reference Book:

1. Thomas Tietenberg., *Environmental and Natural Resource Economics*, 7th edition, (Boston, MA: Addison Wesley, 2006).

PES-6307 Optimization Techniques

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Introduction to optimization

Unconstrained One Dimensional Optimization Techniques: Necessary and sufficient conditions, unrestricted search methods, Fibonacci and golden section methods, quadratic and cubic interpolation methods.

Unconstrained multi-dimensional Optimization Techniques: Direct search methods, Random search methods, univariate methods, pattern Search methods, steepest descent methods

Constrained optimization Techniques: Kuhn Tucker conditions, penalty function methods, gradient projection methods, cutting plane methods.

Artificial Intelligent Optimization Techniques: Particle swarm optimization, Genetic algorithms, Ant-colony optimization, neural and fuzzy optimization techniques.

Text Books/Reference Books:

1. Singiresu S. Rao *Engineering Optimization: Theory and Practice* Wiley India Pvt Ltd; Fourth edition (29 January 2013)
2. Deb K *Optimization for Engineering Design: Algorithms and Examples* Prentice Hall India Learning Private Limited; Second edition (2012)
3. D.P. Kothari, J.S.Dhillon *Power System Optimization* Prentice Hall India Learning Private Limited; 2 edition (2010)

PES-6305 Power Line Communication and Control Applications

Lectures: - 3 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Introduction- Power line Communications Systems, Historical Overview, Power Supply Networks, Standards, Narrowband PLC, Broadband PLC. PLC Access Networks, Structure of PLC Access Networks, PLC Network Elements Connection to the Core Network, Medium-voltage PLC. Specific PLC Performance Problems, Features of PLC Transmission Channel, Electromagnetic Compatibility, Impact of Disturbances and Data Rate Limitation, Realization of Broadband PLC Transmission Systems, Performance Improvement by Efficient MAC Layer. Summary

Network Characteristics- Network Topology, Topology of the Low-voltage Supply Networks, Organization of PLC Access Networks, Structure of In-home PLC Networks, Complex PLC Access Networks, Features of PLC Transmission Channel, Channel Characterization, Characteristics of PLC Transmission Cable, Modeling of the PLC Channel, Electromagnetic Compatibility of PLC Systems, Different Aspects of the EMC, PLC EM Disturbances Modeling, EMC Standards for PLC Systems. Disturbance Characterization, Noise Description, Generalized Background Noise, Impulsive Noise, Disturbance Modeling.

Realization of PLC Access Systems- Architecture of the PLC Systems, Modulation Techniques for PLC Systems, Choice of Modulation Scheme for PLC Systems. Error Handling, Overview, Forward Error Correction, Interleaving, ARQ Mechanisms. PLC Services, PLC Bearer Service, Telecommunications Services in PLC Access Networks, Service Classification.

PLC MAC Layer - Structure of the MAC Layer, MAC Layer Components, Characteristics of PLC MAC Layer, Requirements on the PLC MAC Layer. Multiple Access Scheme, TDMA ,FDMA, CDMA, Logical Channel Model. Resource-sharing Strategies, Classification of MAC Protocols, Contention Protocols, Arbitration Protocols, IEEE 802.11 MAC Protocol. Traffic Control, Duplex Mode, Traffic Scheduling, CAC Mechanism.

Performance Evaluation of Reservation MAC Protocols- Reservation MAC Protocols for PLC, Reservation Domain, Signaling Procedure, Access Control, Signaling MAC Protocols. Modeling PLC MAC Layer, Analysis Method, Simulation Model for PLC MAC Layer, Traffic Modeling, Simulation Technique. Investigation of Signaling MAC Protocols, Basic Protocols Protocol Extensions, Advanced Polling-based Reservation Protocols. Error Handling in Reservation MAC Protocols, Protection of the Signaling Procedure, Integration of ARQ in Reservation MAC Protocols, ARQ for Per-packet Reservation Protocols. Protocol Comparison, Specification of Required Slot Structure Specification of Traffic Mix, Simulation Results, Provision of QoS in Two-step Reservation Protocol.

Text Books/Reference Books:

1. Halid Hrasnica, Abdel fatteh Haidine and Ralf Lehnert, *Broadband Powerline Communications Networks: Network Design*, John Wiley & Sons Ltd, 2004.
2. Gilbert Held, *Understanding Broadband over Power Line*, Auerbach Publications, 2006.
3. Michael M. A. Mirabito and Barbara L. Morgenstern, *The New Communications Technologies,* Elsevier Inc., 2004.

PES-6201 Condition Monitoring, System Modeling & Forecasting

Lectures: - 2 Hrs per week   Pre-requisites: Nil
Practicals: - Nil

General concept of condition monitoring, general issues of condition monitoring, Main components in a condition monitoring system, condition monitoring techniques, Power Transformer Condition Monitoring-Transformer faults and monitoring techniques, monitoring for on-load top changer, insulation monitoring, sweep frequency response test for condition monitoring, recent trend/research on power transformer condition monitoring.

Power-generation faults and monitoring methods, stator winding faults, rotor body faults, rotor winding faults, stator-core faults, condition monitoring for generator stator windings, Induction motor faults and monitoring methods, faults such as stator faults, rotor faults, bearing faults, air gap eccentricities. Popular Monitoring Techniques such as Vibration monitoring, current monitoring.

Modelling philosophies, Rationales for mathematical modeling, Dynamic versus steady state models, General modelling principles, Degrees of freedom in modeling, Transfer function models, Procedure for developing transfer function models, Performance modeling; Modelling of automated manufacturing systems; Role of performance modeling, Performance measure, Petrinet models, Introduction to Petrinet, Basic definitions and analytical techniques, S-Net models; Preliminary definitions and analytical techniques.

Modelling with active graph theory, General concepts, Events and conditions, Synchronisation, Mutual exclusion problems, Standard Problems - Dining philosophers' problems, Readers/ writers problems, Analysis problems of active graph, Petrinets, S-Nets. Their popular extensions, Different case studies of Petrinet and S-Net models related to super computer pipe line, Flexible manufacturing systems. Computer communication system, Computer controlled data acquisition system- computer communication network, Process control systems.

Need of forecasting, philosophy of forecasting, requirement of good forecasting, types of forecasting: day to day forecasting, short term forecasting, long term forecasting, factor affecting forecasting.

Text Books/Reference Books:

1. P. J. Tavner and J. Penman, *Condition Monitroing of Electrical Machine*, Letchworth, RS Press, Ltd., 2nd Edition, 2008.
2. Mazen A. S., Ed., *High Voltage Engineering – Theory and Practices*, Marcel Dekker, Inc., 2000.
3. Kuffel E, Zaengl WS and Kuffel L, *High Voltage Engineering Fundamentals*, Butterworth Heimann, 2000.
4. B. K. N. Rao, *Handbook of Condition Monitoring*, Elsevier Science Publisher, 1996.
5. RA Colacott, *Mechanical Faults Diagnostics and Condition Monitoring*, John Wiley & Sons, 1997.
6. Ernest O Doeblin., *Measurement Systems: Application and Design*, McGraw Hill (Int. edition) 1990
7. C.L. Liu, *Elements of Discrete Mathematics*, McGraw Hill Int. Editions, 1985.
8. J.L. Peterson., *Petrinet Theory and Modelling of Systems*, Prentice Hall Inc., Englewood Cliffs, N.J, 1981.
9. John O. Moody, Panos J Antsaklis, *Supervisory Control of Discrete Event System Using Petrinets*, Kluwer academic Publishers Boston/Dordrecht/ London, 1998.
10. N. Viswanathan, Y. Narahari, *Performance Modelling of Automated Manufacturing Systems*, Prentice Hall of India Pvt. Ltd., New Delhi, 1994.

PES-6207 Industrial Safety

Lectures: - 2 Hrs per week Pre-requisites: Nil
Practicals: - Nil

Concepts and Statutory Requirements: Introduction – electrostatics, electro magnetism, stored energy, energy radiation and electromagnetic interference – Working principles of electrical equipment-Indian electricity act and rules-statutory requirements from electrical inspectorate-international standards on electrical safety – first aid-cardio pulmonary resuscitation(CPR).

Electric Hazards: Primary and secondary hazards-shocks, burns, scalds, falls-human safety in the use of electricity. Energy leakage, clearances and insulation, classes of insulation, voltage classifications excess energy, current surges, Safety in handling of war equipments, over current and short circuit current, heating effects of current, electromagnetic forces, corona effect, static electricity – definition, sources, hazardous conditions, control, electrical causes of fire and explosion ionization, spark and arc-ignition energy-national electrical safety code ANSI. Lightning, hazards, lightning arrestor, installation – earthing, specifications, earth resistance, earth pit maintenance.

Protection Systems: Fuse, circuit breakers and overload relays, protection against over voltage and under voltage, safe limits of amperage, voltage, safe distance from lines, capacity and protection of conductor, joints, and connections, overload and short circuit protection, no load protection, earth fault protection; FRLS insulation, insulation and continuity test, system grounding, equipment grounding earth leakage circuit breaker (ELCB), cable wires, maintenance of ground, ground fault circuit interrupter, use of low voltage, electrical guards, Personal protective equipment, safety in handling hand held electrical appliances tools and medical equipments.

Selection, Installation, Operation and Maintenance: Role of environment in selection, safety aspects in application, protection and interlock self diagnostic features and fail safe concepts, lock out and work permit system, discharge rod and earthing devices, safety in the use of portable tools, cabling and cable joints preventive maintenance.

Hazardous Zones: Classification of hazardous zones, intrinsically safe and explosion proof electrical apparatus (IS, API and OSHA standard), increase safe equipment, their selection for different zones temperature classification, grouping of gases, use of barriers and isolators, equipment certifying agencies.

Text Books/Reference Books:

1. Fordham Cooper, W., *Electrical Safety Engineering*, Butterworth and Company, London, 1986.
2. *Accident prevention manual for industrial operations,* N.S.C., Chicago, 1982.
3. *Indian Electricity Act and Rules,* Government of India.
4. *Power Engineers – Handbook of TNEB,* Chennai, 1989.
5. *Martin Glov Electrostatic Hazards in powder handling*, Research Studies Pvt. LTd., England, 1988.