***Specialization:** Power Engineering and Energy System/ Power And Energy Engineering*

Second Semester							
Theory					Practical		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Foundation For Energy Systems Technology	4-0	4	100	50	-	-	-
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.EHVAC Transmission 3.Operation & Control Of Electrical Energy Systems 4.Power System Reliability	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Protection & Digital Relaying	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.System Identification & Adaptive Control	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

FOUNDATION FOR ENERGY SYSTEMS TECHNOLOGY

MODULE-I:

Renewable Energy Alternatives:
Solar Photovoltaic conversion, Wave Energy and Ocean Thermal Energy Conversion, Wind Energy Conversion, Biomass Energy Conversion, Energy from Waste, Mini/Micro-hydel

MODULE-II:

Basic Concepts of Thermodynamics:
First law and its application, second law and its application, Irreversibility and power generation cycles.
Basic Concepts of Heat transfer: Heat exchangers, overall heat transfer co-efficient, Design of single and multiple pass heat Exchangers, Heat Pipes, Heat Pumps and their applications in Solar Energy systems.

MODULE-III:

Basic Concepts of Fluid Mechanics:
Basic Concepts**,** Flow through pipes, Fluid flow in solar water heaters
Combustion Process Overview: Basic physical laws governing combustion, air as a source of oxygen for combustion, combustion principles of solid-liquid-gaseous fuels.

MODULE-IV:

Effiency Calculation:
Proximate and ultimate analysis of solid and gaseous fuels, Estimation of calorific values, combustion process, flame velocity, excess air requirements and estimation, flue gas analysis, combustion efficiency.

Text Books /References:

1. RE Sonntag, C Borgnakke, GJ Van Wylen, *Fundamentals of Thermodynamics*, 6th Edition, (Wiley-India)
2. PK Nag, *Engineering Thermodynamics*, Third Edition (*Tata McGraw-Hill)*
3. YA Cengel and MA Boles, *Thermodynamics: An Engineering Approach*, 6th Edition (Tata McGraw-Hill)
4. SR Turns, *An Introduction to Combustion: Concepts and Applications*, 2nd Edition (McGraw Hill)
5. JB Jones and RE Dugan, *Engineering Thermodynamics*, PHI, New Delhi,
6. SP Sukhatme, *Solar Energy - Principles of thermal collection and storage*, 2nd edition, Tata McGraw-Hill, New Delhi
7. JA Duffie and WA Beckman, *Solar Engineering of Thermal Processes*, 2nd edition, John Wiley, NY
8. DY Goswami, F Kreith and JF Kreider, *Principles of Solar Engineering*, Taylor and Francis, Philadelphia
9. M. W. Zemansky, *Heat and Thermodynamics*, 4th Edn. McGraw Hill, 1968.
10. A. L. Prasuhn, *Fundamentals of Fluid Mechanics*, Prentice Hall, 1980
11. S. P. Sukhatme, *A Text book on Heat Transfer*, Orient Longman, 1979.
12. John Twidell and Tony Weir, "Renewable Energy Resources" Second Edition, Taylor and Francis (2006)
13. G. N. Tewari and M. K. Ghosal, Renewable Energy Sources: Basic Principles and Applications, Narosa Publishing House (2005)

POWER SYSTEM DYNAMICS

Module-I (12 Hours)

Power System Stability Problems: Basic concepts and definitions, Rotor angle stability, Synchronous machine characteristics, Power versus angle relationship, Stability phenomena, Voltage stability and voltage collapse, Mid-term and long-term stability, Classification of stability.

Small Signal Stability: State space concepts, Basic linearization technique, Participation factors, Eigen properties of state matrix, small signal stability of a single machine infinite bus system,

Module-II (10 Hours)

Studies of parametric effect: effect of loading, effect of K_A, effect of type of load, Hopf bifurcation, Electromechanical oscillating modes, Stability improvement by power system stabilizers. Design of power system stabilizers.

Large Perturbation Stability: Transient stability: Time domain simulations and direct stability analysis techniques (extended equal area criterion)

Module-II (10 Hours)

Energy function methods: Physical and mathematical aspects of the problem, Lyapunov's method, Modeling issues, Energy function formulation, Potential Energy Boundary Surface (PEBS): Energy function of a single machine infinite bus system, equal area criterion and the energy function, Multimachine PEBS.

Sub Synchronous Oscillations: Turbine generator torsional characteristics, Shaft system model, Torsional natural frequencies and mode shapes,

Module-III (12 Hours)

Torsional interaction with power system controls: interaction with generator excitation controls, interaction with speed governors, interaction with nearby DC converters,

Sub Synchronous Resonance (SSR): characteristics of series capacitor – compensated transmission systems, self – excitation due to induction generator effect, torsional interaction resulting in SSR, Analytical methods, Counter measures to SSR problems. Voltage stability, System oscillations

References:

1. Prabha. Kundur, *Power system stability and control*, Tata McGraw-Hill, 1994
2. P. Sauer and M. Pai, *Power system dynamics and stability*, Prentice Hall, 1998. 12

HVDC TRANSMISSION & FACTS

Module-I(10hours)

Introduction: Comparison of AC-DC Transmission, Description and application of HVDC transmission, DC System components and their functions

Analysis of HVDC Converters: Pulse number, Converter configuration, Analysis of Graetz circuit, Bridge characteristics, 12 pulse converter.

Module-II :(11hours)

HVDC Control: Principles of DC Link control-Converter control characteristics- System control, Firing angle control- Current and extinction angle control, DC link power control, Reactive power control and VAR sources, MTDC system- types- control and protection- DC circuit breakers

Module-III:(15hours)

FACTS Concept and General System:

Transmission interconnections, Flow of power in AC system, Power flow and dynamic stability considerations of a transmission interconnection, Relative importance of controllable parameters, Basic types of FACTS controllers, Benefits from FACTS Technology, In-perspective: HVDC or FACTS

Module-IV:(15hours)

Compensators: Objective of series and shunt compensation, SVC and STATCOM, GCSC, TSSC, TCSC, and SSSC, UPFC, IPFC, Generalized and Multifunctional FACTS Controllers

Text/References:

1. Padiyar K.R., "HVDC Power Transmission System", Wiely Eastern PVT Limited
2. Kimbark, "Direct Current transmission", Vol.1, John Wielly, New York, 1971
3. Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani and L. Gyugi, Standard Publisher Distributors, IEEE Press, Delhi
4. Flexible AC Transmission Systems. By J. Arillage 13

POWER QUALITY IMPROVEMENT TECHNIQUES

Module-I : (15 Hours)

Concept of Power Quality: Frequency variations, voltage variations- sag and swell,waveform distortion –dc offset,harmonics, inter-harmonics, notching and noise. Fundamentals of Harmonics: Representation of harmonics,waveform, harmonic power, measures of harmonic distortion;Current and voltage limits of harmonic distortions: IEEE, IEC, EN,NORSOK.
Causes of Harmonics: 2-pulse, 6-pulse and 12-pulse converter configurations, input current waveforms and their harmonic spectrum; Input supply harmonics of AC regulator, integral cycle control, cycloconverter, transformer, rotating machines, ARC furnace, TV and battery charger.

Module-II : (14 Hours)
Effect of Harmonics: Parallel and series resonance, effect of harmonics on static power plant – transmission lines, transformers,capacitor banks, rotating machines, harmonic interference withripple control systems, power system protection, consumer equipments and communication systems, power measurement.
Elimination/ Suppression of Harmonics: High power factorconverter, multi-pulse converters using transformer connections(delta, polygon).

Module-III : (15 Hours)
Passive Filters: Types of passive filters, single tuned and high passfilters, filter design criteria, double tuned filters, damped filters andtheir design.Active Power Filters: Compensation principle, classification ofactive filters by objective, system configuration, power circuit and control strategy.
PWM Inverter: Voltage sourced active filter, current sourced active filter, constant frequency control, constant tolerance bandcontrol, variable tolerance band control.

Module-IV : (15 Hours)
Shunt Active Filter: Single-phase active filter, principle of operation, expression for compensating current, concept of constant capacitor voltage control; Three-phase active filter: Operation, analysis and modelling; Instantaneous reactive power theory..Three-phase Series Active Filter: Principle of operation, analysis and modelling. Other Techniques: Unified power quality conditioner, voltagesource and current source configurations, principle of operation for sag, swell and flicker control.

Text/Reference Books:

1. Derek A. P., "Power Electronic Converter Harmonics", IEEE Press. 1989
2. Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., "PowerSystem Harmonic Analysis", 2nd2008Ed., Wiley India.
3. Arthur R. B., "Power System Analysis", 2nd Ed., Pearson Education. 2008
4. Arrillaga J., Braedlley D. A. and Bodger P. S., "Power System Harmonics", John Wiley and Sons.1985
5. Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System Quality", McGraw-Hill International Book Company.1996
6. Sankaran C., "Power Quality", CRC Press. 2001

GREEN ENERGY RESOURCES & TECHNOLOGY

Module-I :

Solar photovoltaics: Introduction, Solar cell characteristics, Losses in solar cells, Modeling of solar cell, Solar PV modules, Bypass diode in PV module, Design of PV module, PV module power output, I-V curve of PV module, BOS of PV module, Batteries for solar PV, Battery charge controllers, DC-DC converters, DC-AC converters, MPPT, Different algorithm for MPPT, Types of PV system, Performance analysis of solar cell, Working of solar cell power plant.

Module-II :

Wind energy: Wind energy conversion, power ~ speed and torque ~ speed characteristics of wind turbines, wind turbine control systems; conversion to electrical power: induction and synchronous generators, grid connected and self excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single and double output systems, reactive power compensation;

Ocean Energy: Ocean energy resources-ocean energy routes - Principles of ocean thermal energy conversion systems- ocean thermal power plants- Principles of ocean wave energy conversion and tidal energy conversion.

Module-III :

Biomass Energy: Introduction, Biomass conversion technology, Biogas, Composition of Biogas, Properties of Biogas, Biogas production reaction, Factor affecting biogas production, Biogas plant site selection, Biogas plants, Types of Biogas plants, Biogas purification, Biogas storage, Biogas dispensing, Advantages and disadvantages of Biogas, Emission from Biogas engines, Digester Filling and Biogas plant operation, Biogas digester sizing.

Module-IV :

Hybrid Power Syatems: Introduction, Need for hybrid systems, Range of hybrid systems, Types of Hybrid systems, Diesel-PV system, Wind-PV system, Micro hydel-PV system, Biomass-PV system, Electric vehicles, Hybrid electric vehicles.

Energy Conservation, Management and Economics: Impact of renewable energy on environment, Principle and strategies of energy conservation, energy management, energy audit, energy planning, Total energy system concept, Power tariff, Cost of electricity production from renewable.

Text/Reference Books:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.
2. S. S. Thipse, Non Conventional and Renewable Energy Sources, Narosa Publishing House, 2014.