AY 2019-20 ONWARDS

Course Structure and Curriculum

Master of Technology in Electrical Engineering

(Specialization: Power System Engineering)

DEPARTMENT OF ELECTRICAL ENGINEERING

VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY, ODISHA,

BURLA – 768018

VISION

To be recognized as a centre of excellence in education and research in the field of Electrical Engineering by producing innovative, creative and ethical Electrical Engineering professionals for socio-economic development of society in order to meet the global challenges.

MISSION

Electrical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

M1. Maintaining state of the art research facilities to provide enabling environment to create, analyze, apply and disseminate knowledge.

M2. Fortifying collaboration with world class R&D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil ‘Make in India’ policy of the Government.

M3. Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

PROGRAM EDUCATIONAL OBJECTIVES

The program educational objectives of M.Tech. in Electrical Engineering (Power System Engineering) program of VSSUT Burla are to prepare its graduates:

1. To acquire competency in analysis, design, modeling, programming and optimization skills to meet industrial challenges for solving real life problems and undertake research in broad area of power system engineering.
2. To excel in their professional career/entrepreneurial skill/research and higher studies and lead in the conception, design and implementation of new products, processes, services and systems according to the prevailing socio-economic context.
3. To augment the specialized workforce in the domain of power system engineering in private, government and public sector industries, educational institutions and state-of-the-art research laboratories.

PEO-MISSION MATRIX

	M1	M2	M3
PEO1	**3**	**1**	**1**
PEO2	**1**	**3**	**2**
PEO3	**2**	**3**	**3**

PROGRAM OUTCOMES for M.Tech. (PSE)

PO1	An ability to independently carry out research/investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	An ability to create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex problems in power system engineering with an understanding of the limitations.
PO5	An ability to understand of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research involving power system engineering in order to achieve common goals.
PO6	Demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis to further the learning of themselves as well as others.

Program Specific Outcomes for M.Tech. (PSE)

PSO1	Ability of design, modelling and analysis of power system components using the latest available tools.
PSO2	Develop suitable techniques and cutting-edge engineering hardware and software to solve problems in the domain of power system engineering.

COURSE STRUCTURE

Semester I

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-1	MEEPS101	Power System Analysis	3	0	0	3
2	Core-2	MEEPS102	Operation and Control of Restructured Power Systems	3	0	0	3
3	PE-1		PE-1	3	0	0	3
4	PE-2		PE-2	3	0	0	3
5	Common		Research Methodology & IPR	3	0	0	3
6	Lab-1	MEEPS103	Power System Lab-I	0	0	6	4
8	Audit -1		Audit -1				
Total Credits							19

Semester II

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-3	MEEPS201	Power System Dynamics	3	0	0	3
2	Core-4	MEEPS202	Reliability of Power Systems	3	0	0	3
3	PE-3		PE-3	3	0	0	3
4	PE-4		PE-4	3	0	0	3
5	Common		Minor project & Seminar	0	0	4	2
6	Lab-2	MEEPS203	Power System Lab-II	0	0	6	4
8	Audit -2		Audit -2				
Total Credits							18

Semester III

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	PE-5		PE-5	3	0	0	3
2	OE-1		OE-1	3	0	0	3
3	Minor Project		Dissertation (Phase-I)	0	0	20	10
Total Credits							16

Semester IV

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Major Project		Dissertation (Phase-II)	0	0	32	16
Total Credits							16

GRAND TOTAL CREDITS: 19+18+16+16= 69

Program Electives

First Semester			
Program Elective-I		**Program Elective-II**	
Course Code	**Course Name**	**Course Code**	**Course Name**
MPSPE101	Power System Management	MPSPE105	Distribution System Engineering
MPSPE102	Power Sector Policy and Regulations	MPSPE106	Distributed Generation Systems
MPSPE103	Power System Security	MPSPE107	Distribution System Automation and SCADA
MPSPE104	Energy Management and Audit	MPSPE108	Electric and Hybrid Vehicles
Second Semester			
Program Elective-III		**Program Elective-IV**	
MPSPE201	Digital Protection of Power Systems	MPSPE205	FACTS and Custom Power Devices
MPSPE202	Wide area monitoring and control	MPSPE206	Power Electronic Converters
MPSPE203	Advanced Digital Signal Processing	MPSPE207	Industrial Automation and Control
MPSPE204	Wireless Sensor Networks	MPSPE208	Industrial Load Modeling and Control

Third Semester			
Program Elective-V		**Open Electives**	
MPSPE301	Power System Optimization	MPSOE301	Forecasting Methods in Power Systems
MPSPE302	Smart Power Grids	MPSOE302	Operations Research
MPSPE303	Forecasting Methods in Power Systems	MPSOE303	Industrial Safety
MPSPE304	Nonlinear Dynamics	MPSOE304	Waste to Energy

Audit course 1 & 2

Sl.No.	Course Code	Subject Name
1.	BCAC1001	English for Research Paper Writing
2.	BCAC1002	Disaster Management
3.	BCAC1003	Sanskrit for Technical Knowledge
4.	BCAC1004	Value Education
5.	BCAC2001	Constitution of India
6.	BCAC2002	Pedagogy Studies
7.	BCAC2003	Stress Management by Yoga
8.	BCAC2004	Personality Development through Life Enlightenment Skills.

First Semester

Program Core Courses

Power System Analysis

SYLLABUS

Module-I (10 hours)

Power Systems Review: Review of basic concepts- per unit systems, ac circuits, phasors, power system structure and topology

System Modeling: From Detailed to Approximate Including Their Controls

Generation: generator, exciter, voltage and frequency regulators, prime-mover

Transmission systems: transformers and lines, including distributed parameter models

Loads: RL, motor drives and aggregated models

Module-II (8hours)

Power flow analysis, Optimal power flow, Solution of OPF by Gradient method, Newton's method, LP method, Security constrained OPF, Continuation power flow, Sparse matrix techniques for large scale system problems.

Module-III (8 hours)

Unit commitment of generators, Hydro-thermal coordination- hydrological coupling between hydropower stations, power balance and discharge equations, formulation of the operational planning problem, pumped storage units and their scheduling, Generation with limited energy supply, Probabilistic production simulation.

Module-IV (8 hours)

Power System Security, Contingency analysis: approximations in contingency analysis, adding and removing multiple lines, analysis of single contingencies, analysis of multiple contingencies, contingency analysis by DC model.

Module-V (7 hours)

State estimation of power systems: Method of least squares for state estimation; Estimation of power system state variables by the weighted least square estimation technique; statistical errors and bad data recognition; formation of Hessian matrix.

Recommended Books

[1]. P. Kundur, ”Power System Stability And Control”, McGraw-Hill, 1994
[2]. Olle I. Elgerd, *Electric Energy Systems Theory AN Introduction,* McGraw Hill E Pvt Ltd, New Delhi.
[3]. G.W. Stagg & A.H. EL-Abiad, “*Computer methods in power system analysis”,* McGraw Hill, 1968.
[4]. A. J. Wood & B. F. Wallenberg, *“Power generation, operation and control”,* Wiley-Interscience Publication, 2nd Edition, 1996.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Construct the power system model and simulate.
CO2	Perform optimal power flow using different techniques.
CO3	Analyze unit commitment and hydro-thermal coordination problems.
CO4	Carry out contingency analysis and ranking.
CO5	Demonstrate the state estimation in power systems.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Operation and Control of Restructured Power Systems

Module-I (8 hours)

Fundamentals of Electricity Markets and Energy Auctions, necessityfor restructuring the power industry. Review of Concepts- marginal cost of generation, least-cost operation, incremental cost of generation. Components of restructured systems, independent system operators,functions and responsibilities, Market models (pool, bilateral andmultilateral). Market power and imperfect competition, Supply and demand functions, equilibrium.

Module-II (8hours)

OPF: Role in vertically integrated systems and in restructured markets. Transmission Open Access, Power wheeling transactions and marginal costing, transmission costing, Transmission pricing paradigms- embedded cost based, incremental cost based methods. Optimal bidding. Power flow tracing. LMP based markets, auction models and price formation, price based unit commitment.Tagging electricity transactions.

Module-III (8 hours)

Transmission Congestion Management and Transmission Rights, Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs, Firm Transmission Rights, FTRs as benefits and liability, FTR auction models. Predicting electricity costs, electricity cost derivation, electricitypricing of inter provincial power market.

Module-IV (8 hours)

Electric energy trading: Trading framework. Derivative instrument for energy trading (forward contracts, futures contracts, swaps), Portfolio management, Energy trading hubs.

Hedging Tools: Definition of risk and hedge. Source of electricity market risks, Value-at-Risk, country party risk, hedging weather risks.

Module-V (7 hours)

Ancillary Services: Classifications and definitions. Types, Frequency control ancillary service, voltage control ancillary service, reserves & AGC services, System security in deregulation.

Different models of deregulation- Indian model, UK model, Californiamodel, Australian and New Zealand models, Japan model, Thailand model. AS management in various markets- country practices. IT applications in restructured markets. Recent trends in Restructuring.

Recommended Books

[1]. K. Bhattacharya, M.H.J. Bollen and J.E. Daalder, *”Operation Of Restructured Power System”,* Kluwer Academic Publishers, 2001

[2]. Mohammad Shahidehpour, MuwaffaqAlomoush, “Restructured electrical power systems: operation, trading and volatility”, Marcel Dekker

[3]. S. Stott, ”Power System Economics: Designing Markets For Electricity”, Wiley-Interscience, 2002.

[4]. D. S. Kirschen and G. Strbac, *”Fundamentals Of Power System Economics”,* John Wiley & Sons, 2004

Course Outcomes:

Upon completion of the course, the students will:

CO1	Define the fundamentals of electricity markets.
CO2	Evaluate different transmission pricing paradigms.
CO3	Incorporate the operation of power systems under transmission congestion.
CO4	Analyze electrical energy trading and hedging concepts.
CO5	Demonstrate about ancillary services and different country practices.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Program Elective-I

Power System Management

Module-I (8hours)

Load characteristics and load forecast Basic definitions- load definitions, load factor definitions, diversity principle in distribution systems, Load Forecast- factors affecting load forecasting methods, small areas load forecasting, spatial load forecasting methods, simulation, trending and mixed load forecasting methods.

Module-II (8 hours)

Basics of Power System Economics & Short-term Operation Planning of Power System, Load curves and load duration curves, Economic load dispatch- concept of marginal cost and Kuhn-Tucker's condition of optimum in power dispatch, participation factors Classical method to calculate loss coefficients, Loss coefficient calculation using Y-Bus, Loss coefficients using sensitivity factors, Transmission loss coefficients, Transmission loss formula.

Module-III (7 hours)

Financial accounting of utility- balance sheet, income statement, accounting for depreciation, interest charges during construction, financial performance analysis
Investment proposal- interest and compounding, measure of price- public and private perspective, internal rate of return and pay-back period.

Module-IV (8 hours)

Time value of money, utility economic evaluation, Capacity planning issues and methods- Levelizing and levelized bus-bar analysis, Screening curve analysis, Horizon-year generation additions analysis, Capacity planning in competitive environment. Overview of role of Indian Power Finance Corporation Ltd. Green Energy financing

Module-V (8 hours)

Tariff for electricity: objectives, traditional approach, long-run marginal costs, generalprinciples of tariff design. Dynamic, spot and real time pricing strategy, bidding strategies
Concepts and methods of demand side management (DSM) - load control, energy efficiency, load management, DSM planning, design, marketing, customer incentives

Recommended Books

[1]. A. J. Wood and B. F. Wallenberg, *"Power Generation, Operation And Control",* Wiley-Interscience, 2nd Edition, 1996.

[2]. H. G. Stoll, "*Least-Cost Electric Utility Planning",* Wiley-Interscience, 1989.

[3]. Stoft, S., "Power System Economics: Designing Market for Electricity," IEEE Press, Wiley –Interscience.

[4]. D.P. Kothari, J.S. Dillon, "*Power System Optimization",* PHI Learning Private limited, 2ndEdition, 2011.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Develop different methods of load forecasting.
CO2	Compute effect of loss coefficients on economic load dispatch.
CO3	Demonstrate basic of power system financing.
CO4	Perform capacity planning in power systems.
CO5	Analyze tariff concepts and demand side management.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Power System Policy and Regulations

Module-I (6 hours)

Public Policy and Governance, Social Development and Accountability, Power Sector Reform Policy, Making and Governance in Monopoly Sectors, Independent Regulatory Agencies and other Governance Arrangements, Restructuring of power system operation and infrastructure. Economical Reforms, Rationale and Mechanisms of the Economic Reform Process, Liberalization, Privatization, and Globalization.

Module-II (8hours)

Hydro Policy, Wind Policy, Solar Energy Policy, Distributed Generation Policy, Renewable generation policy. Public policy options in the International Perspective.Environmental Policy, Energy conservation, audit and accounting.

Module-III (8 hours)

Overview of Indian Power Sector, Role of Ministry of Power, Ministry of New and Renewable Energy, Central Electricity Authority, State Electricity Authorities. Power sector financing, Role of Power Finance Corporation of India, Power Grid Corporation of India, POSOCO.Public policy for development, operation and management of Power Systems.

Module-IV (10 hours)

Regulation of power industries: Liberalization, competition, regulation, the role of regulators, regulator/market/user interaction in network industries; interconnection and costing of network services. Electricity regulation: Introduction, Rate-of-return regulation, price cap regulation, revenue cap regulation, Revenue Reconciliation, Performance based ratemaking, Rate structure. Power system regulation in India: Stakeholders in the power sector, Role of regulation and evolution of regulatory commissions in India, Types and methods of economic regulation, Regulatory process in India. Non price issues in electricity regulation: Quality of supply and service, Standards of performance by utility, Environmental and social considerations.

Module-V (7 hours)

Legal framework for power sector in India: Historical development and existing acts, regulations, laws pertaining to operation, management, and development of electrical power systems, Salient features of Electricity act 2003, 2015, various guidelines and developments under this act. Indian Electricity Grid Code.

Recommended Books

[1]. Literature on Power Policies.

[2]. Literature on Indian Power Sector.

[3]. Energy Conservation Act 2001, Govt of India. Avail: http://powermin.nic.in/sites/default/files/uploads/ecact2001.pdf.

[4]. The Electricity Act 2003, Govt of India. Avai: http://www.cercind.gov.in/Act-with-amendment.pdf.

[5]. Indian electricity grid code, CERC literature

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define various aspects of power sector policy and governance.
CO2	Plan policies governing different generation sources and environment policy.
CO3	Analyze the role of power sector.
CO4	Demonstrate the role of regulation and regulatory agencies.
CO5	Implement the legal frameworks governing power sector, electricity acts and codes.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Power System Security

SYLLABUS

Module-I (6 hours)

Various issues relatingto power system planning and security: overview of the generation,transmission and distribution aspects of planning Long term andshort term planning; Growth and development of the ElectricalPower Industry Global and Indian scenario, 5- year plans. Indianpower industry and current developments, Role of key institutionsin power system planning in Indian context.

Module-II (8hours)

Factors affecting power system security, contingency analysis, Detection of network problems, Linear sensitivity analysis, AC power flow methods contingency selection, concentric relaxation-Bounding area method, Power flow tracing.

Module-III (8 hours)

Load forecasting, importance and various methodologies, power system reliability, indices, Markov two state model for generating systems availability, up gradation of old power stations; technical and economic issues.

Line congestion in deregulated systems and their minimization Grid issues and regulations. Loss minimization in feeders by reactive power compensation: series and shunt compensation.

Module-IV (10 hours)

Methods of determination of Available Transfer Capability, ATC calculation considering the effect of contingency analysis, Transmission open access and pricing-cost components of transmission system, transmission pricing methods, Incremental cost based transmission pricing.

Module-V (7 hours)

Tariff for electricity: objectives, traditional approach, long-run marginal costs, general principles of tariff design. Dynamic, spot and real time pricing strategy, bidding strategies.

Concepts and methods of demand side management (DSM)- load control, energy efficiency, load management, DSM planning, design, marketing, customer incentives

Recommended Books

[6]. A. J. Wood and B. F. Wallenberg, *"Power Generation, Operation And Control",* Wiley-Interscience, 2nd Edition, 1996.

[7]. P. Venkatesh. B. V. Manikandan, S. Charles Raja- A. Srinivasan, "Electrical power systems: Analysis, security, Deregulation"– PHI 2012

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define various issues related to power system planning and security.
CO2	Demonstrate and utilize methodologies to determine power system security.
CO3	Implement power system planning in order to achieve security of power system.
CO4	Analyze available transfer capability of power systems.
CO5	Compile financial security of power systems.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Energy Management and Audit

MODULE-I (08 HOURS)

Introduction: Energy Scenario–global, sub continental and Indian, Energy economy relation, Future energy demand and supply scenario, Integrated energy planning with particular reference to Industrial Sector in India, Captive power units and others – demand v/s supply.

Types of Energy: Physical Aspects of Energy: Classification of energy – Hydel, Thermal, Nuclear, Wind, & from Waste Products, Efficiency and effectiveness of energy utilization in Industry, Renewable and non-renewable energy, Conventional and Non Conventional energy.

MOULE-II (06 Hours)

Demand Side Management: Energy Demand Management: Energy utilization, Instrumentation and data analysis, financial aspects of energy management, Energy management as a separate function and its place in plant management hierarchy. Energy Planning, Energy Staffing, Energy Organization, Energy Requirement. Energy Costing, Energy Budgeting, Energy Monitoring, Energy Consciousness, Energy Conversions, Energy Efficient Equipment, Energy Management Professionals, Environment Pollution due to Energy Use, Components of Pollution, Harmful Effects of Pollution, Measures taken to combat Pollution.

MODULE-III (07 Hours)

Energy Audit and Energy Saving: Energy Audit and analysis, Energy load measurements, System evaluation and simulation, Energy saving techniques and guidelines: Administrative control, Proper Measurement and monitoring system, Process control, proper planning & scheduling, Increasing capacity utilization, Improving equipment control, waste heat recovery, Change of energy source, Up gradation of Technology, Change of product specifications, Use of High efficiency equipment, Design modification for better efficiency, Improved periodic maintenance;

MODULE-IV (09 Hours)

Energy Control Centers: Remote Telemetry, Remote Terminal Units, IEC TC 57 (870-5-1) Protocol Standard, Data Acquisition Procedure, Data Handling and Organization, Real Time Database, Alarm and Events, Disturbance Processing, Fault Locating Technology, Real Time Display, MIMIC Boards, Supervisory Remote Control, Load Dispatch Control Centers, Distribution Control Centers, Time Keeping Systems

MODULE-V (09Hours)

Integration of Distributed and Renewable Energy Systems to Power Grids: DC-to-AC Converters, AC-to-AC Converters, DC-to-DC Converters, Plug-In Hybrid Electric Vehicles, Energy Storage Technologies, Micro-grids.

Legal Provisions: The Prevention and Control of Pollution Act: 1974, The Energy Conservation Act: 2001,The Environmental Protection Act: 1986, The Electricity Act: 2003, National Electricity Policy, Rural Electrification.

Books:

TEXT BOOKS

[1]. Albert Thumann, William J. Younger, " Handbook of EnergyAudits", CRC Press, 2003.

[2]. Paul O'Callaghan, "Energy management", TMH Publisher

REFERENCE BOOKS

[3]. Craig B. Smith, "Energy management principles", PergamonPress.

[4].Barny L., Capehart, Wainey C. Turner, William J. Kennedy , " Guide to Energy Management", Fairmont Press Inc., GA 30047

[5]. K.V. Sharma, P. Venkataseshaiah, "Energy Management and Conservation". I K Int. Pvt. Ltd.

[6] NPC energy audit manual and reports

Course Outcomes:

Upon completion of the subject the students will demonstrate the ability to:

CO1	Demonstrate the concept of energy with economic review and different types of energy used in modern world.
CO2	Develop the energy demand management in this real world.
CO3	Compile the Energy audits and savings.
CO4	Evaluate the control centers for energy.
CO5	Analyze integration of power grids and legal provisions of energy act.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Program Elective-II

Distribution System Engineering

Syllabus

Module-I (8 hours)

Introduction to distribution systems, Load modeling and characteristics Distribution system planning Short term planning, Long term planning, Dynamic planning.

Module-II (8 hours)

Sub-transmission and substation design, Sub-transmission networks configurations, Substation bus schemes, Distribution substations ratings, Service areas calculations, Substation application curves.

Module-III (8 hours)

Primary and secondary system design considerations, Primary circuit configurations, primary feeder loading, secondary networks design, Economic design of secondaries, Unbalance loads and voltage considerations Distribution system performance and operation, Distribution automation and control.

Module-IV (8 hours)

Objectives of distribution system protection – Types of common faults and procedure for fault calculations – Protective devices: Principle of operation of fuses – Circuit reclosures – Line sectionalizes and circuit breakers.

Module-V (7 hours)

Voltage drop calculation for distribution networks, Power loss Calculation, Application of capacitors to distribution systems, Application of voltage regulators to distribution systems.

Books:

[1]. Anthony J. Pansini "Electrical Distribution Engineering", CRC Press.

[2]. H Lee Willis, "Distributed Power Generation Planning and Evaluation", CRC Press.

[3]. James A Momoh, “Electric Power Distribution Automation Protection And Control” CRC Press.
[4]. James J. Burke “Power distribution engineering: fundamentals and applications”, CRC Press.
[5]. T. Gonen, “Electric Power Distribution System Engineering”, McGraw-Hill, 1986, ISBN 0-07-023707-7.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define general concept of distribution generation system.
CO2	Perform planning for the distribution system and demonstrate the need of automation and control of distribution system.
CO3	Design sub-transmission and distribution substation and also design of primary and secondary system.
CO4	Evaluate voltage drop, voltage regulation and power loss calculation.
CO5	Analyze the effect of voltage control on distribution system.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Distributed Generation Systems

Module-I (8 hours)

Overview: Renewable sources in distributed generation – Current scenario in distributed generation – Planning of DGs – Sitting and sizing of DGs – Optimal placement of DG sources in distribution systems. **Wind/PV System Modelling:** Wind/PV variability and uncertainty. Forecasting methods and applications.

Module-II (8hours)

Grid integration of DGs: Different types of interfaces – Inverter based DGs and rotating machine based interfaces – Aggregation of multiple DG.

Technical impact of DGs: Transmission systems, Distribution systems, Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems. Limitations of DGs – Voltage control techniques, Reactive power control, Harmonics, Power quality issues – Reliability of DG based systems – Steady state and Dynamic analysis.

Module-III (8 hours)

Economics of DG: Value of power from DGs, Market value of power from DGs, Loss reduction, Investment reduction, Connection costs and charges, Distribution use of system charges, Allocation of losses in distribution networks with DG, Alternative framework for distribution tariff development. Market facts, issues and challenges. DGs in areas of limited transmission capacity. DGs in distribution networks. Active Management of Distribution systems. Ancillary Services with DGs, Markets for Ancillary Services. DER Management, Virtual Power Plants.

Module-IV: (7 hours)

Electric Vehicles: Technology, Components of EV and their modelling, Charging and Discharging Mechanisms, Driving & Plug-in pattern analysis, Scheduling issues, Challenges in EV integration, Bulk Electric Vehicles, Ancillary Services from EVs.

Energy Storage: Type and modelling of storage systems. Scheduling issues, Ancillary services from energy storage, Role in Energy Security, Reliability and Stability.

Module-V (7 hours)

Introduction to micro-grids: Concept, Design, Modelling, Operation and Analysis. Role in Energy Reliability, Cold Load Pick Up and Sustainability. Types of micro-grids – Autonomous and non-autonomous grids – Sizing of micro-grids – Modeling & analysis – Micro-grids with multiple DGs – Micro-grids with power electronic interfacing units – Transients in micro-grids – Protection of micro-grids – Case studies.

Recommended Books

1. Willis H. Lee and Scott W. G., "Distributed Power Generation Planning and Evaluation", Marcel Dekker, Inc, New York, 2000.
2. Math H. Bollen, Fainan Hassan, "Integration of Distributed Generation in the Power System", WileyIEEE Press, 2011.
3. Komarnicki, Przemyslaw, Lombardi, Pio, Styczynski, Zbigniew , "Electric Energy Storage Systems", Springer, 2017.
4. Garcia-Valle, Rodrigo, Peças Lopes, João A, "Electric Vehicle Integration into Modern Power Networks", Springer, 2012.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Express the need of distributed generation systems and their modeling.
CO2	Analyze the technical impact of distributed generation systems.
CO3	Analyze the economics of distributed generation systems.
CO4	Analyze the performance of electric vehicles and storage systems.
CO5	Demonstrate micro-grid concept.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Distributed System Automation and SCADA

SYLLABUS

Module 1: (8 Hours)

Distribution Automation System: Necessity, System Control Hierarchy- Basic Architecture and implementation Strategies for DA- Basic Distribution Management System Functions- Outage management- Integration of Distributed Generation and Custom Power components in distribution systems- Distribution system Performance and reliability calculations

Module 2: (8 Hours)

Electrical System Design: Distribution System Design- Electrical Design Aspects of Industrial, Commercials Buildings- Electrical Safety and Earthing Practices at various voltage levels- IS Codes

Module 3: (10 Hours)

Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface-Case Studies

Module 4: (8 Hours)

Power Quality and Custom Power: Concept- Custom Power Devices - Operation and Applications

Deregulated Systems: Reconfiguring Power systems- Unbundling of Electric Utilities- Competition and Direct access

Module 5: (8 Hours)

Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries.

References

1. James Northcote – Green, Robert Wilson, "Control and Automation of Electrical Power Distribution Systems", CRC Press, New York, 2007.
2. Turan Gonen: .Electric Power Distribution System Engineering. McGraw Hill Company, 1986.
3. M.V Deshpande: .Electrical Power System Design. Tata-McGraw Hill, 1966.
4. IEEE Press: IEEE Recommended practice for Electric Power Distribution for Industrial Plants, published by IEEE, Inc., 1993.
5. Pansini, Electrical Distribution Engineering, The Fairmont Press, Inc., 2007.
6. Michael Wiebe, A guide to utility automation: AMR, SCADA, and IT systems for electricpower, PennWell 1999.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define the fundamental principles of Distribution Automation Systems (DAS) and Distribution Management Systems (DMS).
CO2	Demonstrate the fundamental concept of different power quality issues and Custom Power components in a distribution system.
CO3	Evaluate the performance of electrical distribution system on the basis of reliability indices calculation.
CO4	Incorporate electrical distribution system design aspects of industrial and commercial buildings and associated protocols.
CO5	Develop the concept of SCADA system.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Electric and Hybrid Vehicles

SYLLABUS

Module-I (5 hours)

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance. Architectures of HEVs, series and parallel HEVs, complex HEVs.

Module-II (10 hours)

Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.

Module-III (10 hours)

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives. Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices.

Module-IV (7 hours)

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter, current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machies; Permanent magnet motor drives; Switched reluctance motors; Doubly salient permanent magnet machines. Case studies.

Module-V (7 hours)

Communications, supporting subsystems: In vehicle networks- CAN, Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies

Recommended Books

[1]. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

[2]. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

[3]. Mi Chris, Masrur A., and Gao D.W., " Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives".

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate the requirements and architecture of EVs and HEVs.
CO2	Incorporate drive trains used in EVs and HEVs.
CO3	Design electric propulsion unit and storage systems for EVs and HEVs.
CO4	Design drives systems for EVs and HEVs.
CO5	Plan different communication systems used in EVs and HEVs.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Power System Lab-I

Syllabus:

[1]. Simulation experiments on Modeling of Transmission Lines
[2]. Formation of Bus Admittance Matrix
[3]. Formation of Bus Impendence Matrix
[4]. Load Flow Analysis using Newton-Raphson Method/ Decoupled Method
[5]. Optimal power flow solution
[6]. Fault Analysis-I
[7]. Transient and Small Signal Stability Analysis: Single-Machine Infinite Bus System
[8]. Load – Frequency Dynamics of Single –Area and Two Area Power Systems
[9]. Design of Distance Protection Scheme using PSCAD
[10]. Design of HVDC controller using PSCAD
[11]. Power flow analysis of standard test systems using ETAP & PowerFactory
[12]. Short-circuit analysis of standard test systems using ETAP & PowerFactory

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Build admittance and impedance matrices and simulate power systems
CO2	Perform load flow analysis and optimal power flow analysis.
CO3	Perform fault analysis in power systems.
CO4	Perform transient and small signal stability analysis.
CO5	Design of protection schemes and HVDC controllers using PSCAD.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**3**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**3**	**3**
CO3	**3**	**3**	**3**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**3**	**3**	**3**
CO5	**3**	**3**	**3**	**3**	**3**	**3**

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**3**	**3**	**3**	**3**	**3**

Second Semester

Program Core Courses

Power System Dynamics

SYLLABUS

Module-I (7 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.

Module-II (10 hours)

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

Module-III (10 hours)

Large Perturbation Stability: Transient stability: Time domain simulations and direct stability analysis techniques (extended equal area criterion) 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, Multi-machine PEBS.

Module-IV (6 hours)

Sub Synchronous Oscillations: Turbine generator torsional characteristics, Shaft system model, Torsional natural frequencies and mode shapes, Torsional interaction with power system controls: interaction with generator excitation controls, interaction with speed governors, interaction with nearby DC converters

Module-V (6 hours).

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.

Recommended Books

[1]. P. Kundur, *"Power system stability and control",* McGraw-Hill, 1994

[2]. P. Sauer and M. Pai, *"Power system dynamics and stability",* Prentice Hall, 1998

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate the concept of stability of large power system.
CO2	Analyze small signal stability problems.
CO3	Analyze large signal stability problems.
CO4	Analyze the torsional oscillation problems
CO5	Evaluate the sub-synchronous resonance phenomenon and demonstrate methods to counter this phenomenon.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Reliability of Power Systems

SYLLABUS

MODULE-I (10 HOURS)

Generating Capacity Basic Probability Methods: The generation system model, Loss of load indices, Equivalent forced outage rate, Capacity expansion analysis, Scheduled outages, Evaluation methods on period basis, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices.

MODULE-II (10 HOURS)

Generating Capacity Frequency & Duration Method: The generation model, System risk indices.

Interconnected Systems: Probability error method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected system, multi connected system, Frequency & duration approach.

MODULE-III (10 HOURS)

Operating Reserve: General concepts, PJM method, Extension to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems.

Composite Generation & Transmission Systems: Radial configurations, Conditional probability approach, Network configurations, State selection, System & load point indices, Application to practical systems, Data requirements for composite system reliability.

MODULE-IV (10 HOURS)

Distribution Systems Basic Techniques & Radial Networks: Evaluation techniques, additional interruption indices, Application to radial systems, effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, effect of transferring loads, Probability distributions of reliability indices.

MODULE-V (10 HOURS)

Distribution Systems-Parallel & Meshed Networks: Basic evaluation techniques, Inclusion of bus bar failures, Inclusion of scheduled maintenance, Temporary & transient failures, Inclusion of weather effects, Common modes failures, Common mode failures & weather effects, Inclusion of breaker failures.

Plant & Station Availability: Generating plant availability, Derated states & auxiliary systems, Allocation & effect of spares, Protection systems.

Recommended books

[1]. Billinton Roy& Allan Ronald *"Reliability of Power system",* Pitman Pub. 1984

[2]. Richard Elect. Brown, *"Electric Power Distribution Reliability",* CRC Press.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Evaluate reliability of generating capacity.
CO2	Evaluate the reliability of interconnected system.
CO3	Evaluate the reliability of operating reserves, composite generation & transmission system.
CO4	Evaluate reliability indices of simple radial distribution network.
CO5	Evaluate the reliability of parallel and meshed network and to study the effect of plant and station availability.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Program Elective-III

Digital Protection of Power Systems

Module-I (9 hours)

Evolution of digital relays from electromechanical relays, Performance and operational characteristics of digital protection, Expected benefits of digital relaying, Digital relay architecture, Analog to digital converter, Anti-aliasing filter, Substation computer hierarchy.

Module-II (5 hours)

Functions of a protection system, Protection of transmission lines, Transformer Protection, Reactor & generator protection, Digital Bus protection, Performance of current & voltage transformer.

Module-III (10 hours)

Mathematical Basis for Protective Relaying Algorithms: Introduction, Fourier series, Fourier transform, Use of Fourier transform, Discrete Fourier transform, Introduction to probability & random processes, Kalman filtering,

Transmission Line Relaying: Introduction, Sources of error, Symmetrical component distance relay, Protection of series compensated lines, Power transformer algorithm.

Module-IV (5 hours)

Hardware Organization In Integrated Systems: The nature of hardware issues, Computers for relaying, The substation environment, Industry environmental standards, Countermeasures against EMI, Supplementary equipment, Redundancy & backup, Servicing, Training & maintenance.

Module-V (10 hours)

Measurement of frequency & phase, Sampling clock synchronization, Application of phasor measurements to state estimation, Phasor measurement in dynamic state estimation, Developments in New Relaying Principles: Introduction, Traveling waves on single phase lines, Traveling waves on three phase lines, Traveling waves due to faults, Traveling wave distance relays, Directional wave relays, Differential relaying with phasors, Traveling wave differential relays.

Textbooks:

[1]. A.G. Phadke and J.S. Thorp, "*Computer Relaying for Power Systems*", John Wiley and Sons,1994.

[2] A.T. Johns and S. K. Salman, *"Digital Protection of Power Systems"*, IEEE Press,1999

Reference Books:

[1] Stanley H. Horowitz and Arun G. Phadke, "*Power System Relaying*", Research Studies Press Ltd., England. J.L. Blackburn, "*Protective, Relaying*", Marcel Dekker, Inc., 1987.

[2] Gerhard Zeigler, "Numerical Distance Protection", Siemens Publicis Corporate Publishing, 2006

[3] S.R. Bhide "Digital Power System Protection" PHI Learning Pvt. Ltd. 2014

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate concept of computer programming relaying and its architecture.
CO2	Analyze different protection schemes of power system.
CO3	Apply mathematical approach towards protection and will learn to develop various protection algorithm.
CO4	Demonstrate the basic requirements of digital protection.
CO5	Analyze different techniques to realize the protective measures over a computer network and fundamentals of phasor measurement unit.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Wide Area Monitoring and Control

Module-I (5 hours)

INTRODUCTION TO WIDE AREA MEASUREMENT SYSTEM (WAMS): Need of WAMS, Architecture, Components of WAMS, Applications: Voltage Stability Assessment, Frequency stability Assessment, Power Oscillation Assessment, Communication needs of WAMS, Wide Area Monitoring Protection & Control and Remedial Action Scheme.

Module-II (10 hours)

POWER SYSTEM AUTOMATION: Introduction, Evolution of Automation Systems, Supervisory Control and Data Acquisition (SCADA) Systems, Components of SCADA Systems, SCADA in Power Systems, SCADA Basic Functions,Advantages of SCADA in Power Systems, Deferred Capital Expenditure, Optimized Operation and Maintenance Costs, Equipment Condition Monitoring (ECM), Sequence of Events (SOE) Recording, Power Quality Improvement, Data Warehousing for Power Utilities, Types of Data and Signals in Power Systems, Flow of Data from the Field to the SCADA Control Center.

Module-III (10 hours)

SCADA FUNDAMENTALS: Introduction, Open System: Need and Advantages, Building Blocks of SCADA Systems, Remote Terminal Unit (RTU), Evolution of RTUs, Components of RTU, Communication Subsystem, Logic Subsystem, Termination Subsystem, Testing and Human Machine Interface (HMI) Subsystem, Power Supplies, Advanced RTU Functionalities, Intelligent Electronic Devices (IEDs), Evolution of IEDs, IED Functional Block Diagram, Hardware and Software Architecture of the IED, IED Communication Subsystem, IED Advanced Functionalities, Tools for Settings, Commissioning, and Testing, Programmable LCD Display, Typical IEDs, Data Concentrators and Merging Units, RTUs, IEDs, and Data Concentrator, Merging Units and IEDs.

Module-IV (5 hours)

SUBSTATION AUTOMATION: Substation Automation: Technical Issues, System Responsibilities, System Architecture, Substation Host Processor, Substation LAN, User Interface, Communications Interfaces, Protocol Considerations. The New Digital Substation, Process Level, Protection and Control Level, Station Bus and Station Level, Substation Automation Architectures, Legacy Substation Automation System, Digital

Substation Automation Design, New versus Existing Substations. Substation Automation (SA) Application Functions, Integrated Protection Functions: Traditional Approach and IED-Based Approach. Automation Functions.

Module-V (10 hours)

VOLTAGE STABILITY & SMALL SIGNAL STABILITY: Basic concepts, Voltage collapse – general characterization, classification, Voltage stability analysis – modeling, dynamic analysis, static analysis, shortest distance to instability, continuation power flow analysis, prevention of voltage collapse – design measures, operating measures, Real time wide area controller for mitigating small signal Instability, Advanced monitoring and control approaches for enhancing power system security.

Textbooks:

[1]. A. R. Messina, '*Wide Area Monitoring of Interconnected Power Systems'* IET, Power& Energy Series, 2005.
[2] Allen J. Wood and Bruce Woolenberg, '*Power System Generation, Operation and Control*', John Wiley and Sons, 1996.

Reference Books:

[1] P. Kundur, '*Power System Stability and Control*', McGraw Hill.
[2] A.R. Messina, '*Inter-area Oscillations in Power Systems*' Springer
[3] D. K. Mohanta & M. Jaya Bharata Reddy, '*Synchronized Phasor Measurements for Smart Grids*' IET, Power & Energy Series.
[4] Mini S. Thomas and John Douglas McDonald, '*Power System SCADA and Smart Grids*',CRC Press, 2015.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define the necessity of wide area measurement system and its basic concept.
CO2	Apply different automation systems.
CO3	Demonstrate the fundamentals of SCADA and its importance in real time power systems.
CO4	Implement substation automation, new digital substation and traditional approach and IED-based approach of integrated protective functions.
CO5	Evaluate voltage stability, prevention of voltage collapse, dynamic stability analysis and small signal stability analysis.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Advanced Digital Signal Processing

Module-I (8 hours)

Discrete time signals, systems and their representations: Discrete time signals (Linear Time Invariant systems, Stability and causality).

Discrete Fourier Transform: Properties of different transforms, Linear convolution using DFT- Computation of DFT.

Module-II (8 hours)

Digital filter design and realization structures: Design of IIR digital filters from analog filters, Impulse invariance method and Bilinear transformation method, FIR filter design using window functions, Comparison of IIR and FIR digital filter, Basic IIR and FIR filter realization structures, Signal flow graph representations.

Module-III (8 hours)

Finite Word-Length Effects on Digital Filter: Analysis of finite word-length effects Quantization process and errors, Coefficient quantization effects in IIR and FIR filters, A/D conversion noise- Arithmetic round-off errors, Dynamic range scaling, Overflow oscillations and zero input limit cycles in IIR filters.

MODULE-IV (7 hours)

Statistical digital signal processing: Linear Signal Models All pole, All zero and Pole-zero models, statistical properties of random signal.

MODULE-V (8 hours)

Power spectrum estimation: Spectral analysis of deterministic signal, Estimation of power spectrum of stationary random signals, Optimum linear Filters, Optimum signal estimation, Mean square error estimation, Optimum FIR and IIR filters.

TEXT BOOKS

[1]. John G. Proakis, and Dimitris G. Manolakis, "Digital Signal Processing" (third edition), Prentice-Hall of India Pvt. Ltd, New Delhi, 1997

[2]. Alan V. Oppenheim, Ronald W. Schafer, "Discrete-Time Signal Processing", Prentice-Hall of India Pvt. Ltd., New Delhi, 1997

REFERENCE BOOKS

[1] A. Nagoor Kani, "Digital Signal Processing", Second edition, Mc Graw Hill.

[2]. Sanjit K Mitra, "A computer-based approach", Tata Mc Grow-Hill edition .1998

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define the basic concept of Digital Signal Processing, Discrete Fourier Transform and its application.
CO2	Analyze digital filter design and its structural realization.
CO3	Demonstrate the errors of word length effect and their correction techniques.
CO4	Apply the knowledge of statistical digital signal processing.
CO5	Compile power spectrum estimation.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Wireless Sensor Networks

Syllabus:

MODULE-I(5 hours)

Limitations of Wired Network Protocols; Benefits of Wireless Network Protocols/ Wireless Sensor Networks (WSNs); Introduction to IEEE 802.xx Standards: specifications of bandwidth, SNR, range of measurement of physical parameters. Communication Networks for industry, home appliances, office automation and biomedical applications.

MODULE-II(10 hours)

Wireless LAN (WLAN): Direct Sequence Spread Spectrum (DSSS) technique, Frequency Hoping Spread Spectrum (FHSS) technique. Wi-Fi (IEEE 802.11); Bluetooth (IEEE 802.15.1), WRAN (IEEE 802.15.1), and Wireless HART (IEEE 802.15.1/ ISA 100.11a); Zigbee (IEEE 802.15.4); WiMAX (IEEE 802.16e); MBWA (IEEE 802.20).

MODULE-III(7 hours)

Advances in WSN: IEEE 1451.5 Standard: IEEE 1451.2 - transducer to microprocessor communication protocol and TEDS (transducer Electronic Data Sheet) formats; IEEE 1451.3 - digital communication and TEDS format for distributed multi-drop system; IEEE 1451.4 - mixed mode communication protocols and TEDS format; IEEE 1451.5 – wireless communication protocols and TEDS formats; IEEE 1451.6: high speed CAN open-band transducer network interface for intrinsically safe and non-intrinsically sate applications; IEEE 1451.7 – transducer to radio frequency identification (RFID) system communication protocols and TEDS formats.

MODULE-IV(9 hours)

Real-life Applications - Sensors interconnection with wireless sensor nodes: Xbee based modules can be used as it is mesh capable; Bluetooth 2.0 enabled hardware. Centralized gateways: Collect data from various sensor nodes; Pre-processing of data; Sending data to the cloud for further processing. Mesh compatible protocols: communicate over long distance; Consume low power, MQTT protocol, IPv6, Zigbee (IEEE 802.15.4), Bluetooth.

MODULE-V(9 hours)

Optimization of sensor networks using IoT enabled sensors: Sensor Placement Optimization; Coverage and connectivity; Energy Consumption optimization, and Fault Tolerance. IoT System architecture: Physical Layer - Sensor and actuators with embedded processing units; Communication Layer, and Application Layer; Enabling IEEE 1451.5 protocol with IoT.

Books:

1. Christian Poellabauer and Waltenegus Dargie, Fundamentals of Wireless Sensor Networks: Theory and Practice, Wiley, 2010.
2. Kazem Sohraby, Wireless Sensor Networks, Springer, edited by Taieb Znati, 2005.

Reference books:

1. Holger Karl, Andreas Willig, Protocols and Architectures for Wireless Sensor Networks, Wiley, 2005.

Course Outcomes:

CO1	Demonstrate the limitations of wired network protocols, benefits of wireless network protocols/ wireless sensor networks (WSNs), and their applications.
CO2	Define the existing WSN schemes and standards.
CO3	Incorporate WSN technology with TEDS.
CO4	Plan sensors interconnection with wireless sensor nodes and further developments in this direction.
CO5	Evaluate the advances in WSNs technologies and use of optimized sensor networks and IoT enabled sensors.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Program Elective-IV

FACTS and Custom Power Devices

Module-I (8 hours)

FACTS concepts and general system considerations: Power flow in AC system, transient stability and dynamic stability, basic description of FACTS controllers, brief review of voltage sourced converter and current sourced converter, modelling philosophy.

Module-II (8hours)

Static VAR compensator (SVC and STATCOM): objectives of shunt compensation, methods of controllable VAR Generation, regulation slope, transfer function, V-I and V-Q characteristics, transient stability enhancement, VAR reserve control, conventional power flow models, shunt variable susceptance model, firing angle model, transient stability model, voltage magnitude control using SVC & STACOM, Application example.

Module-III (8 hours)

Static Series compensators (TCSC and SSSC): objectives of series compensation, improvements of voltage and transient stability, power oscillation damping, sub-synchronous damping, transmittable power and transmittable angle characteristics, control range, conventional power flow models, variable series impedance model, firing angle model, transient stability model, active power flow control using TCSC & SSSC, Application example.

Module-IV: (8 hours)

Static voltage and phase angle regulator (TCVR and TCPAR): objectives of voltage and phase angle regulators, approaches to TCVR and TCPAR, switching converter based voltage and phase angle regulators, Unified power flow controller: Basic operating principles, transmission control, independent real and reactive power flow control, power flow models, transient stability model, control structure, basic control system for P and Q control, dynamic performance, Application example.

Module-V (7 hours)

Brief control studies such as Steady state analysis and control, EMTP studies, power oscillation stability analysis and control, transient stability control.

Recommended Books

1. Y. H. Songs, A. T. Johns, "Flexible AC Transmission Systems", IEE Press, 1999
2. N. G. Hingorani, L. Gyugyi, "Understanding FACTS", IEEE Press, Indian Edition, 2001.
3. E. Acha, "FACTS: Modelling And Simulation In Power Networks", John Wiley & Sons, 2004.
4. K. R. Padiyar ,"FACTS Controllers in Power Transmission & Distribution", New Age International Publishers.
5. Vijay K. Sood , "HVDC and FACTS Controller: Applications of Static Converters in Power Systems" , Kluwer Power Electronics & Power System Series , 2006.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define basic philosophy of FACTS devices and modeling and control aspect of FACTS devices.
CO2	Analyze fundamental function of SVC and STATCOM.
CO3	Analyze power system operation with TCSC and SSSC.
CO4	Demonstrate power flow control using TCVR, TCPAR and UPFC.
CO5	Evaluate the comprehensive control of power system using FACTS devices.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Power Electronic Converters

Module-I (8 hours)

Power Electronic Devices: Diodes, Transistors, Thyristors, MOSFET and IGBT - operating principle, Static, dynamic and thermal characteristics, Data sheet ratings, gate drive circuits.

Module-II(8hours)

Single phase half controlled and fully controlled AC/DC bridge converter with R, R-L, R-L-E (motor) loads: operation (both rectifier and inverter modes) , waveforms ,harmonics (output voltage/current and input current) assuming continuous conduction, input current (ac) displacement, distortion and power factor, effect of input line inductance assuming constant current dc load, closed form expression of output dc current with general R-L-E load, discontinuous conduction mode of operation.

Module-III (8 hours)

Three phase half controlled and fully controlled AC/DC bridge converter assuming constant dc current load : operation in rectifier and inverter modes, waveforms, output voltage and input current harmonics, input power factor and effect of input line inductance, series and parallel operation of converters, power factor improvement, 12 pulse/18 pulse operation, transformer connection, dual converters.

Module-IV: (8 hours)

DC-DC choppers: basic voltage commutated thyristor chopper analysis , Separately excited DC motor drive using DC-DC choppers made of gate controlled devices, four quadrant operation, dynamic and regenerative braking of series DC motor using choppers; Basic DC-DC converters: buck, boost buck-boost and Cuk converter, operation, waveforms.

Module-V(7 hours)

DC-AC inverters using gate controlled devices: single phase and three phase square wave inverters, operation waveforms and harmonics in pole voltage, load phase voltage and line voltage, output voltage control in single phase square wave inverter using chopper control and phase shift, harmonic analysis, operating principles of single phase and three phase

PWM inverters, modulation techniques, SPWM, Selective Harmonic Elimination PWM and delta modulation, harmonic spectrum and comparison among different PWM techniques. Variable frequency operation of three phase induction motors: Steady state analysis, Torque-speed, current, speed and slip frequency -speed characteristics and operating limits with constant volts/Hz and constant air gap flux operation, implementation using PWM VSI.

Text Books

1. N. Mohan, T.M. Undeland& W.P. Robbins, *Power Electronics: Converter, Applications & Design*, John Wiley & Sons , New York, 2003.
2. G. K. Dubey, *Fundamentals of Electrical Drives*, Narosa Publishing House , 2002

Reference Books:

1. M.H. Rashid, *Power Electronics, Circuits, Devices, and Applications,* Pearson , 2003
2. B. K. Bose, *Modern Power Electronics and A.C. Drives*, PHI , 2002

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate principle, characteristics rating of various power electronic devices such as transistor, MOSFET, IGBT etc.
CO2	Analyze single phase AC/DC bridge converter operation, output and input (voltage and current) waveforms.
CO3	Analyze three phase AC/DC bridge converter operation, output and input (voltage and current) waveforms.
CO4	Analyze basic DC-DC converter: buck, boost, buck-boost and Cuk converter, operations and waveforms.
CO5	Analyze DC-AC inverters, its operation and waveforms.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Industrial Automation and Control

Syllabus:

MODULE-I

Introduction to process dynamics, its type and classifications. Control actions and controller tuning: Basic control actions-on/off, P, P+I, P+I+D, floating control, pneumatic and electronic controllers, pneumatic vs hydraulic control, controller tuning.

MODULE-II

Introduction to PLC, PAC, DCS and SCADA. IEDs, RTUs, HMI, Smart Sensors and Actuators. IEEE 802.11 / 15 Standards, IEEE 1451.5 Std. Communication Networks for PLC. The Instrument Lists of PLC and HMI. Sequential and Programmable controllers, System Architecture, Programming languages of PLC, Relay logic and Ladder logic, Ladder Diagram Elements.

MODULE-III

Computer controlled processes: PLC based control of different types of processes such as liquid level system and flow control, open-and-closed chamber pressure control, temperature control, different types of heat exchangers, control of pressurized gases.

MODULE-IV

Physical Ladder Diagram and Programmable Ladder Diagram. Different Modules of the System Architecture of PLC. Case Studies: frost free refrigerator / freezer system; composite discrete / continuous control; conveyor system; oven system; elevator system; uniformly heated liquid control system, and hydro-phonic system.

MODULE-V

Advances in Automation: Programmable Automation Controllers. NI my-DAQ, my-RIO, c-RIO, and ELVIS. Role of Internet of Things and Cyber Physical System in Industry Automation, MQTT protocol.

Books:

1. Peter D. Harriot, “Process Control”, Tata McGraw-Hill, New Delhi, 2009.
2. Liptak, “Process Control: Instruments Engineer’s Handbook”, Butterwirth Heinemann, 1995.
3. Curtis D. Johnson, “Process Control and Industrial Technology”, Pearson India, 8th ed., 2012.

Reference books:

1. Norman A Anderson, Instrumentation for Process Measurement and Control, CRC Press, 2008.
2. B. Wayne Bequette, "Process Control – Modeling, Design, and Simulation", Pearson India, 2015.
3. John W. Webbs, "Programmable Logic Controllers – Principals and Applications", fifth Edition, Pearson India /PHI (Old edition), 2012.

Course Outcomes:

CO1	Describe the basic principles and importance of process control applications using automation;
CO2	Express the required instrumentation, knowledge of the P&ID, the Instrumentation Lists, and final elements to ensure that well-tuned control is achieved;
CO3	Create computer control mechanism of various processes
CO4	Design, install, operate, control and maintain different process and automated applications using PLCs/PACs. Further, PLC / PAC algorithm using Ladder Logic Diagram or equivalent languages while handling a plant process;
CO5	Apply knowledge on advances in use of automation platform such as PACs and IoT while handling a plant process.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Industrial Load Modelling and Control

UNIT I MODELING OF PHASE CONTROL OF DC DRIVES (10)

Motor-drives, load torque-speed characteristics, power devices and switches, modeling of DC motor-load- block diagram and transfer function for armature and field control, phase controlled dc motor drives-single phase and three phase controlled converters, control circuit, current source with three phase controlled converter, four quadrant operation, steady state analysis of three phase converter, speed control of two quadrant dc motor drives.

UNIT II CHOPPER CONTROL OF DC MOTOR DRIVES (8)

Principle of operation of the chopper, Steady-state analysis of Chopper-controlled dc motor drive, Continuous Current Conduction, Discontinuous Current Conduction, Closed-loop operation, Pulse-Width-Modulated Current Controller, Hysteresis-Current Controller, dynamic analysis of the speed-controlled dc motor drive.

UNIT III CONTROL OF INDUCTION MOTOR DRIVES (10)

Steady state performance equations of the induction motor, dynamic modeling of induction machines,phase-controlled induction-motor drives- stator voltage control, Closed-Loop Operation, Closed loop control of slip-energy recovery scheme, Pulsating torque, Static Scherbius Drive, frequency-controlled induction motor drives, VSI and CSI fed V/f and PWM control scheme of induction motor drive system.

UNIT IV CONTROL OF SYNCRONOUS AND BLDC MOTOR DRIVES (8)

True mode and Self-control of synchronous motor–Torque control, Power factor control–Brushless excitation systems, Sinusoidal and trapezoidal type of Brushless dc motors – Block diagram of current controlled Brushless dc motor drive.

UNIT V: VECTOR CONTROL OF INDUCTION MOTOR DRIVE (10)

Principle of vector control of IM - Direct vector control – Indirect vector control with feedback - Indirect vector control with feed-forward - Indirect vector control in various frames of reference, Decoupling of vector control with feed forward compensation – Direct Torque Control of IM.

Reference Books

1. R.Krishnan,, Electric Motor Drives - Modeling, Analysis and Control Prentice- Hall of India Pvt. Ltd., New Delhi, 2003.
2. Dubey, G.K, Power semiconductor controlled devices, Prentice Hall International New jersey, 1989.
3. Ned Mohan, "Power Electronics and drives", Wiley 2006Bimal K. Bose, Modern Power Electronics and AC Drives, Pearson Education (Singapore) Pte. Ltd., New Delhi.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate closed loop control of DC motor-load drives using phase control.
CO2	Demonstrate closed loop control of DC motor-load drives using DC-DC chopper control.
CO3	Demonstrate closed loop control of Induction motor drives using phase control.
CO4	Analyze operation of Synchronous motor and BLDC machines, torque control using current and flux controllers.
CO5	Analyze direct and indirect vector control on induction motors.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Power System Lab-II

Syllabus:

[1]. Economic Load Dispatch by traditional optimization methods using MATLAB

[2]. Study of Unit Commitment Problem using MATLAB

[3]. Study of Load Forecasting by conventional and soft computing methods using MATLAB

[4]. Fault Analysis-II using MATLAB

[5]. Simulation of Power System under Different Conditions

[6]. Transient Stability Analysis of Multi machine Power Systems using SIMULINK

[7]. Load – Frequency Dynamics of Multi- Area Power Systems using SIMULINK

[8]. Simulation of Fuzzy Interfacing Power System using SIMULINK

[9]. Distribution Transformer Steep Front Analysis using PSCAD

[10]. Study of Static Var Compensator Connected to an Infinite Bus using PSCAD

[11]. Development of Microgrid Model in DigSilent Power Factory

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Perform economic load dispatch.
CO2	Perform load forecasting using different techniques.
CO3	Perform detailed fault analysis using MATLAB.
CO4	Demonstrate power system simulation using SIMULINK.
CO5	Express emerging power system problems and develop solutions using PSCAD and DigSilent Power Factory.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**3**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**3**	**3**
CO3	**3**	**3**	**3**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**3**	**3**	**3**
CO5	**3**	**3**	**3**	**3**	**3**	**3**

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**3**	**3**	**3**	**3**	**3**

Minor Project and Seminar

Course description:

As a part of the curriculum, this is a sessional course, in which the students are trained in basic tools and presentation skills.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Identify and analyze engineering problems and research problem.
CO2	Utilize technical resources for problem solving.
CO3	Develop skills to use modern engineering tools, software and equipment.
CO4	Write technical reports and demonstrate the findings in terms of oral presentations.
CO5	Develop confidence and plan for future work.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**3**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**3**	**3**
CO3	**3**	**3**	**3**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**3**	**3**	**3**
CO5	**3**	**3**	**3**	**3**	**3**	**3**

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	**3**	**3**	**3**	**3**	**3**	**3**

Third Semester

Program Elective-V

Power System Optimization

SYLLABUS

Module-I (8 hours)

Classical optimization techniques: General formulation of unconstrained and constrained optimization problems. Classical Method of solution. Karush-Kuhn-Tucker (KKT) conditions. Overview of Linear programming, non-linear programming, Quadratic programming and mixed-integer linear programming, and dynamic programming problems.

Module-II (8 hours)

Modern optimization techniques: Concept of heuristic and meta-heuristic methods, Derivative free optimization, Genetic algorithms, neural networks, swarm optimization techniques. Stochastic optimization, application of joint distribution and copula.

Multiobjective optimization: pareto-optimality, selection using fuzzy membership, weighting method, utility function method, global criterion method, goal programming method. Application of evolutionary and swarm optimization approaches.

Module-III (8 hours)

Real power optimization: Lagrange's method of solution of economic dispatch and hydrothermal scheduling problems. Iterative technique. Gradient method. Loss sensitivity calculation. Calculation of constrained shift sensitivity factors. Perturbation method for sensitivity analysis. Voltage sensitivity analysis.Application of evolutionary and swarm optimization techniques. Application of Analytical Hierarchy process for unit commitment.

Module-IV (8 hours)

Reactive Power Optimization: Classical method, linear programming method, Interior point method. VAR optimization by evolutionary algorithm and PSO. Optimal Load Shedding: conventional and intelligent load shedding. Formulation with and without network constraints.

Module-V (7 hours)

Optimization of power system control: formulation of objective function and solution of frequency and voltage control problems. parameter tuning of different controllers using classical and modern techniques.

Recommended Books

1. Jizhong Zhu, Optimization of Power System Operation, Wiley. 2009.
2. James A Momoh, "Electric Power System Application of Optimization", CRC Press.
2. Engineering optimization by S. S. Rao.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Develop an optimization problem and use classical solution techniques.
CO2	Demonstrate modern optimization techniques.
CO3	Solve real power optimization problems.
CO4	Solve reactive power optimization problems.
CO5	Solve real and reactive power control optimization problems.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Smart Power Grids

Module-I (6 hours)

Introduction to Smart Grid, Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Concept of Robust & Self-Healing Grid, Present development & International policies in Smart Grid.

Module-II (8hours)

Introduction to Smart Meters, Real Time Pricing, Smart Appliances, Automatic Meter Reading (AMR), Outage Management System (OMS), Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Smart Substations, Substation Automation, Feeder Automation.

Module-III (7 hours)

Geographic Information System (GIS), Intelligent Electronic Devices (IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System (WAMS), Phase Measurement Unit (PMU).

Module-IV (10 hours)

Concept of micro-grid, need & applications of micro-grid, Formation of micro-grid, Issues of interconnection, Integration of renewable energy sources, Protection & control of micro-grid. Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Module-V (7 hours)

Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighbourhood Area Network (NAN), Wide Area Network (WAN), Bluetooth, ZigBee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Basics of CLOUD Computing & Cyber Security for Smart Grid, Broadband over Power line (BPL), IP based protocols.

References:

1. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, "*Smart Grid: Technology and Applications*", Wiley 2012.
2. Clark W. Gellings, "*The Smart Grid: Enabling Energy Efficiency and Demand Response*", CRC Press, 2009.
3. Ali Keyhani, "*Design of smart power grid renewable energy systems*", Wiley-IEEE, 2011.
4. Stuart Borlas'e, "*Smart Grid: Infrastructure, Technology and solutions*", CRC Press.
5. A.G.Phadke, "*Synchronized Phasor Measurement and their Applications*", Springer.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate the difference between smart grid & conventional grid.
CO2	Apply smart metering concepts to industrial and commercial installations.
CO3	Formulate solutions in the areas of smart substations, distributed generation and wide area measurements& PMUs.
CO4	Analyze problems associated with integration of distributed generations& come up with their solutions through smart grid.
CO5	Express smart grid solutions using AMI and modern communication technologies.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Forecasting Methods in Power Systems

Module-I (8 hours)

Introduction to data analytics and Python fundamentals. Basics of R programming.

Introduction to probability, Sampling and sampling distributions, Hypothesis testing, Two sample testing and introduction to ANOVA.

Module-II (8 hours)

Nature of time series data, time series statistical models, measures of dependence, stationary time series, estimation of correlation. Classical regression, exploratory data analysis, smoothing, Linear regression and multiple regression, Concepts of MLE and Logistic regression, ROC and Regression Analysis Model Building.

Module-III (8 hours)

Spectral Analysis and Filtering: Cyclical behavior and periodicity. Spectral Density. Periodogram and Discrete Fourier Transform, Nonparametric and parametric spectral estimation, Multiple series and cross-spectra. Linear filters. Lagged regression models. Signal extraction and Optimal filtering. Rprograms.

Module-IV (8 hours)

ARIMA Models: Autoregressive Moving Average Models, difference equations, autocorrelation and partial autocorrelation. Forecasting, estimation.

Long memory ARMA and fractional differencing, Unit Root testing, GARCH models. Threshold models. Lagged regression and transfer function modelling.

Module-V (8 hours)

State Space Models: Linear Gaussian model. Filtering, smoothing and forecasting. Maximum Likelihood estimation, Signal extraction and Forecasting,

Frequency Domain Models: Spectral Matrices and Likelihood functions, Regression for jointly stationary series and with deterministic inputs, Discriminant and Cluster Analysis.

Books

1. Robert H. Shumway, David S. Stoffer. “Time Series Analysis and its Applications”, Fourth Edition.,Springer.

2. Jonathan D. Cryer, Kung-Sik Chan. “Time Series Analysis”, Second Edition, Springer.

3. Larry Wasserman, “All of Statistics”, Springer.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Perform basic R and Python programming for data analytics.
CO2	Perform exploratory data analysis.
CO3	Perform spectral analysis and filtering of power system data.
CO4	Build ARIMA, GARCH and ARMAX models.
CO5	Analyze state space and frequency domain models.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	**3**	**1**	**3**	**3**	**2**	**1**

Nonlinear Dynamics

Module-I (8 hours)

One dimensional flows: Flows on the line, fixed points and stability, Linear stability analysis, existence and uniqueness, Potentials. Bifurcations: Saddle-node, Transcritical, Pitchfork bifurcations, Imperfect bifurcations and catastrophe. Flows on the circle.

Module-II (8 hours)

Two dimensional flows: Linear systems, classification. Phase plane: phase portraits. existence, uniqueness and topological consequence, Fixed points and linearlization. Conservative and reversible systems. Index theory.

Module-III (8 hours)

Limit cycles: Introduction, examples, Ruling out closed orbits. Poincare-Bendixson theorem, Lienard systems, Relaxation oscillators, Weakly non-linear oscillators.

Bifurcations: Saddle-node, Transcritical and Pitchfork bifurcations in two dimensions. Hopf bifurcations. Global bifurcations of cycles. Quasiperiodicity.

Module-IV (8 hours)

Lorentz equations: Introduction, a chaotic waterwheel, simple properties, chaos on a strange attractor, Lorentz map, exploring parameter space.

One dimensional maps: Introduction, fixed points and cobwebs, Logistic map, Periodic windows, Liapunov exponent, Universalit and experiments.

Module-V (7 hours)

Fractals: countable and uncountable sets, Cantor set, Dimension of self-similar fractals, Box dimension, Pointwise and correlation dimensions.

Strange Attractors: Introduction, Henon Map, Rossler systems, Attractor reconstruction

Recommended Books

[1]. Steven H. Strogatz, Nonlinear Dyanmics and Chaos, Levant publications.

[2]. M Vidyasagar, "Nonlinear Systems Analysis", Prentice Hall.

[3]. R Seydel, "Practical Bifurcation and Stability Analysis", Springer Verlag.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define one dimensional flow on the line and circle.
CO2	Analyze two dimensional flows of linear systems and phase plane.
CO3	Analyze limit cycles and bifurcations in two dimensions.
CO4	Analyze Lorentz equations and one-dimensional maps.
CO5	Demonstrate fractals and strange attractors.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**
CO2	**3**	**1**	**3**	**3**	**2**	**1**
CO3	**3**	**1**	**3**	**3**	**2**	**1**
CO4	**3**	**1**	**3**	**3**	**2**	**1**
CO5	**3**	**1**	**3**	**3**	**2**	**1**

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	**3**	**1**	**3**	**3**	**2**	**1**

Open Elective

Forecasting Methods in Power Systems

Module-I (8 hours)

Introduction to data analytics and Python fundamentals. Basics of R programming.

Introduction to probability, Sampling and sampling distributions, Hypothesis testing, Two sample testing and introduction to ANOVA.

Module-II (8 hours)

Nature of time series data, time series statistical models, measures of dependence, stationary time series, estimation of correlation. Classical regression, exploratory data analysis, smoothing, Linear regression and multiple regression, Concepts of MLE and Logistic regression, ROC and Regression Analysis Model Building.

Module-III (8 hours)

Spectral Analysis and Filtering: Cyclical behavior and periodicity. Spectral Density. Periodogram and Discrete Fourier Transform, Nonparametric and parametric spectral estimation, Multiple series and cross-spectra. Linear filters. Lagged regression models. Signal extraction and Optimal filtering. Rprograms.

Module-IV (8 hours)

ARIMA Models: Autoregressive Moving Average Models, difference equations, autocorrelation and partial autocorrelation. Forecasting, estimation.

Long memory ARMA and fractional differencing, Unit Root testing, GARCH models. Threshold models. Lagged regression and transfer function modelling.

Module-V (8 hours)

State Space Models: Linear Gaussian model. Filtering, smoothing and forecasting. Maximum Likelihood estimation, Signal extraction and Forecasting, Frequency Domain Models: Spectral Matrices and Likelihood functions, Regression for jointly stationary series and with deterministic inputs, Discriminant and Cluster Analysis.

Books

1. Robert H. Shumway, David S. Stoffer. "Time Series Analysis and its Applications", Fourth Edition., Springer.

2. Jonathan D. Cryer, Kung-Sik Chan. "Time Series Analysis", Second Edition, Springer.

3. Larry Wasserman, "All of Statistics", Springer.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Perform basic R and Python programming for data analytics.
CO2	Perform exploratory data analysis.
CO3	Perform spectral analysis and filtering of power system data.
CO4	Build ARIMA, GARCH and ARMAX models.
CO5	Analyze state space and frequency domain models.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Operations Research

Module-I (8 hours)

Statement of an optimization problem, classical optimization techniques: single variable optimization, unconstrained and constrained multivariable optimization problems, Karush-Kuhn-Tucker (KKT) conditions, convex programming problem.

Linear programming problem, simplex algorithm, duality, transportation model and its variants. Linear programming solvers in MATLAB, SCILAB and OCTAVE.

Module-II (8 hours)

Nonlinear programming algorithms: direct search method, gradient method, separable programming, quadratic programming, chance constrained programming. Non-linear programming solvers in MATLAB, SCILAB and OCTAVE.

Module-III (8 hours)

Overview of the geometric programming problem. Dynamic programming: multi-stage decision process, computational procedure. Integer programming: solution using cutting-plane method, branch-and-bound method. Mixed-integer programming problems.

Module-IV (8 hours)

Stochastic processes: review of basic probability, empirical distributions, Monte carlo simulation. generation of discrete and continuous random variables, joint distribution and copula. Decision making under certainty, risk and uncertainty, game theory. Markov chains.

Module-V (7 hours)

Multiobjective optimization: pareto optimality, selection using fuzzy membership, weighting method, utility function method, global criterion method, goal programming method. Concept of heuristic and meta-heuristic methods, Derivative free optimization, Genetic algorithms, neural networks, swarm optimization techniques.

Books

1. S.S.Rao, “Engineering Optimization”, 3rd Ed.,New Age International (P) Ltd,New Delhi, 2007
2. H.A. Taha, Operations Research, An Introduction, PHI, 2008

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Apply classical optimization and linear programming techniques
CO2	Solve nonlinear programming problems.
CO3	Solve dynamic programming and integer programming problems.
CO4	Utilize stochastic processes and tools for solving decision making problems
CO5	Apply multiobjective optimization and evolutionary programming techniques

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Industrial Safety

Module-I (8 hours)

Introduction to Industrial Safety Engineering, Key concepts and terminologies, Safety domain ontology, Risk Assessment & Control, Safety Engineering & Accident causing mechanisms, Preliminary Hazard List, Preliminary Hazard Analysis, Hazard and operability study (HAZOP), ailure Modes and Effects Analysis (FMEA)- Identification of Failure Modes.

Module-II (8 hours)

Fault tree and event tree analysis (qualitative & quantitative). Bow-tie and quantitative risk assessment (QRA). Safety function deployment

Module-III (8 hours)

Safety vs reliability – quantification of basic events (repair to failure, repair-failure-repair, and combined processes), Safety vs reliability – quantification of basic events (contd.).

Module-IV (8 hours)

Systems safety quantification (e.g., truth tables, structure functions, minimal cut sets). Human error analysis and safety

Module-V (7 hours)

Accident investigation and analysis, Application of virtual reality, OSHAS 18001 and OSHMS.

Recommended Books

[1]. "Industrial safety management", L M Deshmukh, TATA McGraw Hill, 2010.

[2]. "Occupational safety Manual" BHEL.

[3]. R. Seydel, "Practical Bifurcation and Stability Analysis", Springer Verlag.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Define key concepts and terminologies of industrial safety.
CO2	Perform fault tree and event tree analysis.
CO3	Visualize safety vs reliability.
CO4	Perform systems safety quantification.
CO5	Perform accident investigation and analysis.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Waste to Energy

Module-I (8 hours)

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Global warming, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction, Managing Waste. Status of technologies for generation of Energy from Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration .

Module-II (8 hours)

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leach ate and gases, Environmental monitoring system for land fill gases.

Module-III (8 hours)

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, anaerobic digestion of sewage and municipal wastes, direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion.

Module-IV (8 hours)

Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers, Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo-chemical conversion.

Module-V (7 hours)

E-waste: e-waste in the global context – Growth of Electrical and Electronics Industry in India – Environmental concerns and health hazards – Recycling e-waste: a thriving economy of the unorganized sector – Global trade in hazardous waste – impact of hazardous e-waste in India. Management of e-waste: e-waste legislation, Government regulations on e-waste management – International experience – need for stringent health safeguards and environmental protection laws of India.

Books

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies. An Imprint of Elsevier, New Delhi (2003).
2. Capareda S, Introduction to biomass energy conversion, CRC Press (2013).
3. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons (2011).

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Demonstrate technologies for generation of energy from solid waste
CO2	Incorporate methods of solid waste disposal
CO3	Identify sources of energy from bio-chemical conversion
CO4	Demonstrate bio-gas production and gasification of wastes
CO5	Analyze methods for management of e-waste

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	2	1

Dissertation (Phase-I)

Course description:

As a part of the M.Tech PSE curriculum, this is a sessional course, in which the students of are trained to perform literature review and formulation of a research problem.

Upon completion of the course, the students will demonstrate the ability to:

CO1	Evaluate published literature and express the research gaps.
CO2	Construct a research problem.
CO3	Compile modern engineering tools, software and equipment and develop research methodology.
CO4	Write technical documents and give oral presentations related to the work completed.
CO5	Develop confidence for self education and ability for life-long learning.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**3**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**3**	**3**
CO3	**3**	**3**	**3**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**3**	**3**	**3**
CO5	**3**	**3**	**3**	**3**	**3**	**3**

Program Articulation Matrix row for this Course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	**3**	**3**	**3**	**3**	**3**	**3**

Dissertation (Phase-II)

Course description:

As a part of the M.Tech PSE curriculum, this is a sessional course, in which the students are trained to analyze a research problem and develop the solution.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Apply selected solution methodology to produce solutions to the chosen problem.
CO2	Analyze the output and demonstrate its validity.
CO3	Organize the results and compile the conclusions.
CO4	Write technical report and express the findings in oral presentations.
CO5	Develop confidence for identifying future scope and ability for life-long learning.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	3	3	3	3