NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

RULES AND REGULATIONS

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Program in

SMART ELECTRIC GRID

(Effective from AY 2021-22)

DEPARTMENT OF ELECTRICAL ENGINEERING

Vision and Mission of the Institute

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- **Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.**
- **Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.**
- **Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.**

Vision and Mission of the Department

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To excel in education, research and technological services in electrical engineering in tune with societal aspirations

MISSION

- **Impart quality education to produce globally competent electrical engineers capable of extending technological services**
- **Engage in research & development in cutting edge and sustainable technologies**
- **Nurture scientific temperament, professional ethics and industrial collaboration**

Department of Electrical Engineering:

Brief about the Department:

The Department of Electrical Engineering was established in the year 1959 in the Regional Engineering College Warangal, which was converted into a National Institute of Technology in the year 2003.

Since the inception of the Institute, the department has been developing state-of-the-art Infrastructure to cater to the needs of technical education and cutting-edge research. In its formative years, the department received considerable financial and logistical support from UNESCO. Later, the Department was funded principally by the MHRD, GOI, which is augmented by aid from various other agencies such as the Institutional Network Scheme (INS) and TEQIP. Well-qualified, well-trained and dedicated faculty propels the development of the department. The department enjoys a position of eminence in the field of technical education and research. The Department of Electrical Engineering started offering postgraduate programs since the year 1964. Currently, the Department offers three PG programs in Power Systems Engineering, Power Electronics and Drives, and Smart Electric Grid.

The establishment of postgraduate courses has significantly contributed towards the advancement of research and consultancy activities of the department. To fulfill the objectives stated in the mission and vision of the institute, the department organized several faculty development programs, conferences, and refresher courses, which cater to the needs of industries and utilities (DRDO, BHEL, TATA power companies, VSP to name a few). The department also organized several continuing education programs in emerging areas for faculty of educational institutions throughout the country. The Department is recognized as a QIP center for M. Tech programs in Electrical Engineering.

The Department of Electrical Engineering has always been a hub of active research. Several research projects, sponsored by MHRD, CSIR, DST, DRDO, SPARC, and other private and governmental organizations have successfully been executed by the faculty of the department. Currently, about 65 doctoral students are pursuing their Ph.D. degrees in various areas of research.

In its sixty-two years of journey, the department had quite a few academic and research accomplishments. A few of them are enumerated below:

- Several funded research projects, to the tune of Rs. 300 Lakhs, are currently under execution, promising high research outcomes.
- A Power System Study Cell was established by the erstwhile APSEB to train their engineers in software pertaining to power systems.
- A sponsored research project was successfully executed, which aims to study the impact of the electrical load of the Vizag Steel Plant on the grid. This project was awarded to the department despite stiff competition from several institutes of higher learning.
- The department has been awarded a center of excellence in power and energy systems, which is in the process of being established.
- All academic programs offered by the department had been accredited by NBA for a full-time period of 5 years in the years 2008 and 2013
- As many as 26 consultancy projects were completed for the vetting of electromechanical designs for lift irrigation projects by the Governments of Telangana and Andhra Pradesh.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Electrical and Electronics Engineering
BTech (Hons.)	Electrical and Electronics Engineering
	Minor in Electrical Engineering
M.Tech.	Power Electronics and Drives
	Power Systems Engineering
	Smart Electric Grid
PG diploma	Power Electronics and Drives
	Power Systems Engineering
	Smart Electric Grid
Ph.D.	Electrical Engineering

Note: Refer to the Rules and Regulations for M.Tech. program (https://oldweb.nitw.ac.in/media/uploads/2022/01/17/m-tech_rules-and-regulations-2021-22.pdf) given in the institute website.

M.Tech. Program in Smart Electric Grid

Program Educational Objectives (PEOs)

PEO1	Design and develop independently innovative products and services in the field of Smart Grid Technologies.
PEO2	Adopt and utilize latest technologies and tools in design of Smart Grid systems.
PEO3	Communicate effectively to propagate ideas and promote teamwork
PEO4	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment

Program Articulation Matrix

PEO / Mission Statements	PEO1	PEO2	PEO3	PEO4
Impart quality education to produce globally competent electrical engineers capable of extending technological services	3	3	3	2
Engage in research & development in cutting edge and sustainable technologies.	3	3	2	3
Nurture scientific temperament, professional ethics and industrial collaboration	3	3	2	2

1-Slightly; 2-Moderately; 3-Substantially

Program Outcomes (POs)

At the end of the program, the student will be able to:

PO1	**Develop** scientific temperament and rational thinking abilities to pursue research and tackle complex problems related to smart electric grids.
PO2	**Communicate** with technical communities on engineering issues while creating awareness for all sections of society.
PO3	**Employ** the knowledge of smart electric grids to contribute towards the development of products / technologies which require a team with multidisciplinary expertise.
PO4	**Develop** eco-friendly and sustainable technologies using the knowledge of smart electric grids.
PO5	**Cultivate** an attitude of self-learning to cope with everchanging tools and technologies and be productive throughout his / her career.
PO6	**Foster** a temperament to manage projects, organizations and entrepreneurial ventures maintaining financial integrity and professional ethics.

SCHEME OF INSTRUCTION
M. Tech (Smart Electric Grid) Course Structure
I – Year: I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	EE5301	Elements of Smart Grid System	3	0	0	3	PCC
2.	EE5302	Microgrid Dynamics and Control	3	0	0	3	PCC
3.	EE5303	Modelling and Analysis of Renewable Energy Sources	3	0	0	3	PCC
4.	EE5304	Restructured Power Systems	3	0	0	3	PCC
5.		Elective -I	3	0	0	3	PEC
6.		Elective -II	3	0	0	3	PEC
7.	EE5305	Microgrid Dynamics and Control Lab	0	1	2	2	PCC
8.	EE5306	Renewable Energy Control Lab	0	1	2	2	PCC
9.	EE5348	Seminar -I	0	0	2	1	SEM
		TOTAL	18	2	6	23	

I – Year: II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	EE5351	Smart Grid Protection	3	0	0	3	PCC
2.	EE5352	Wide Area Monitoring and Control	3	0	0	3	PCC
3.	EE5353	Smart Grid Communications and Protocols	3	0	0	3	PCC
4.		Elective –III	3	0	0	3	PEC
5.		Elective – IV	3	0	0	3	PEC
6.		Elective – V	3	0	0	3	PEC
7.	EE5354	Smart grid Protection Lab	0	1	2	2	PCC
8.	EE5355	Smart Electric Grid Simulation Lab	0	1	2	2	PCC
9.	EE5398	Seminar – II	0	0	2	1	SEM
		Total	18	2	6	23	

II – Year: I – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1	EE6347	Comprehensive Viva-voce	2	CVV
2	EE6349	Dissertation-Part-A	12	DW
		Total	14	

II – Year: II – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
1.	EE6399	Dissertation-Part-B	20	DW
		Total	20	

Note: PCC – Professional Core Courses and PEC – Professional Elective Courses

Professional Elective Courses:

I Year I Semester

S. No	Course Code	Course Title
1	EE5311	Smart Grid Planning & Operation
2	EE5312	Advanced Control Systems
3	EE5313	Energy Storage Systems
4	EE5314	Numerical Optimization
5	EE5315	Signal Processing Techniques
6	EE5101	Analysis of Power Converters
7	EE5103	Applications of Digital Signal Processors
8	EE5202	Data Science Applications in Power Engineering
9	EE5215	Machine Learning and Applications

I Year II Semester

S. No	Course Code	Course Title
1	EE5361	Grid Integration of Electric Vehicles
2	EE5362	Adaptive and Robust Control Systems
3	EE5363	Smart Appliances and Internet of Things
4	EE5364	Smart Grid Resiliency and Cyber Security
5	EE5365	Cloud Computing and Big Data Analytics in Smart Grids
6	EE5366	Transactive Energy Markets
7	EE5367	Challenges and Solutions in Renewable Integration
8	EE5368	Smart Electrical Distribution System
9	EE5153	Digital Control Systems
10	EE5264	Evolutionary Algorithms Application in Power Engineering

Open Elective Courses (offered to other departments):

Semester	Elective Number	Course Code	Course Title

Special Notes/Instructions:

In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of timetable

Credits in Each Semester					
	I Sem	II Sem	III Sem	IV Sem	Total
Core courses (PCC)	16	13	0	0	29
Elective courses (PEC)	6	9	0	0	15
Seminar	1	1	0	0	2
Comprehensive Viva-voce	0	0	2	0	2
Dissertation	0	0	12	20	32
Total credits (Sem. wise)	23	23	14	20	80

DETAILED SYLLABUS

M.Tech. – Smart Electric Grid

EE5301	ELEMENTS OF SMART GRID SYSTEM	3-0-0: 3

Pre-Requisites: Basics in power systems

Course Outcomes (COs):

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

CO1	Understand the features of Smart Grid
CO2	Assess the role of automation and digitization in Transmission and Distribution
CO3	Analyse Smart grids and Distributed energy resources (DER) with evolutionary algorithms
CO4	Investigate operation and the importance of data acquisition devices and their location for Voltage and Frequency control

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1		1	2	
CO2	1	1		2	1	
CO3	2	2	2		2	
CO4	3	2	1	2	3	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Smart Grid: Basics of power systems, definition of smart grid, need for smart grid, smart grid domain, enablers of smart grid, smart grid priority areas, regulatory challenges, smart-grid activities in India.

Smart Grid Architecture: Smart grid architecture, standards-policies, smart-grid control layer and elements, network architectures, IP-based systems, power line communications, supervisory control and data acquisition system, advanced metering infrastructure. The fundamental components of Smart Grid designs, Transmission Automation, Distribution Automation, Renewable Integration.

Tools and Techniques for Smart Grid: Computational Techniques – Static and Dynamic Optimization Techniques for power applications such as Economic load dispatch – Computational Intelligence Techniques – Evolutionary Algorithms in power system – Artificial Intelligence techniques and applications in power system.

Distribution Generation Technologies: Introduction to Distribution Energy Sources, Renewable Energy Technologies – Microgrids – Storage Technologies –Electric Vehicles and plug – in hybrids – Environmental impact and Climate Change – Economic Issues.

Communication Technologies in Smart Grid: Introduction to Communication Technology, Two Way Digital Communications Paradigm, Synchro- Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS)- Introduction to Internet of things (IoT)- Applications of IoT in Smart Grid.

Smart-cities: Smart city pilot projects, essential elements of smart cities, active distribution networks, microgrids, distribution system automation, Reliability and resiliency studies, decentralized operation of power network.

Learning Resources:

Text Books:

1. Smart Grids, Infrastructure, Technology and Solutions, S. Borlase, CRC Press, 2013, 1st Edition.
2. Renewable and Efficient Electric Power System, G. Masters, Wiley–IEEE Press, 2013, 2nd Edition.

Reference Books:

1. Synchronized Phasor Measurements and their Applications, A.G. Phadke and J.S. Thorp, Springer, 2017, 2nd Edition.
2. Wind Power in Power Systems, T. Ackermann, Hoboken, N J, USA, John Wiley, 2012, 2nd Edition.

EE5302	MICROGRID DYNAMICS AND CONTROL	3-0-0: 3

Pre-Requisites: Basic Control systems, Power electronics

Course Outcomes (COs):

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

CO1	Understanding of AC and DC microgrids
CO2	Dynamic modelling and analysis of microgrids
CO3	Analysis of different hierarchical control schemes for microgrid system and communication implementation of hierarchical control
CO4	Investigate the stability in microgrids and alternate options for stability improvement in microgrids

Course *Articulation* Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Concept of Microgrids: Introduction to the concept of microgrid, the overview of the structure and architecture of microgrid with brief control, operational aspects. Till date pilot microgrid projects and their outcomes.

Decentralized local controllers: AC-microgrids: Control Mechanism of the DGs connected in microgrid. Virtual synchronous generator (VSG) and Droop control. Transient frequency response, active power Response, reactive power sharing and voltage regulation

DC-microgrids: DC microgrid control mechanism, droop control, issues in achieving active power sharing with impedance droop, remedies to achieve active power sharing.

Power system stability: Power system stability classification, Basic definitions of transient, dynamic, and small signal stability, basic synchronous machine dynamic modelling, k1-k6 model and analysis of SMIB systems.

Modelling and stability analysis of microgrids: Dynamic modelling of individual components in AC and DC microgrids, state space modal analysis and influence of system parameters on the microgrid dynamics, brief concept on the design of microgrid stabilizers to improve stability.

Hierarchical control scheme for microgrids: Control Objectives in AC Microgrids, bottleneck with only local control, need of secondary and tertiary control, implementation of hierarchical control with centralized and distributed control schemes for AC and DC microgrids. Advantages and disadvantages of centralized and distributed control schemes.

Multi-microgrid coordination and control: AC-AC, AC-DC and DC-DC microgrid clustering, coordinated control schemes in multi-microgrids, frequency, voltage regulations and volt-VAR support.

Control of Smart Power Grid System: Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids.

Learning Resources:

Text Books:

1. Microgrids Architecture and control, N. D. Hatziargyriou, IEEE Press Series, John Wiley & Sons Inc, 2013, 1st Edition.
2. Microgrid Dynamics and Control, H. Bevrani, B. François, and T. Ise, John Wiley & Sons, 2017, 1st Edition.

Reference Books:

1. Cooperative Synchronization in Distributed Microgrid Control, Bidram, V. Nasirian, A. Davoudi, F. L. Lewis, Springer, 2017, 1st Edition.
2. Power System Stability and Control, P. Kundur, McGraw-Hill, Inc., 1994, 2nd Edition.

EE5303	MODELLING AND ANALYSIS OF RENEWABLE ENERGY SOURCES	3-0-0: 3

Pre-Requisites: Basic Control system, Basic Power electronics

Course Outcomes (COs):

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

CO1	Understand different renewable energy sources
CO2	Evaluate dynamic models of Distributed Energy Systems
CO3	Analyse and simulate control strategies for grid connected and off-grid systems
CO4	Develop control strategies for off Grid and grid integration studies of Distributed Energy Sources.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Impacts of large-scale integration of renewable Energy sources. Types of conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro, solar and wind-based generation technologies.

Solar Photovoltaic Systems: Solar Resource, Generic Photovoltaic Cell, Equivalent Circuits, Cells to Modules to Arrays, I –V Curve, Impacts of Temperature and Insolation, Shading impacts on I–V curves, I–V Curves for different loads, MPPT, Grid-Connected Systems, Stand-Alone PV Systems, Dynamics of PV generation sources. Advances in PV controls.

Wind Energy System: Wind Energy-generating Systems, Power extraction in the Wind, Impact of Tower Height, Maximum Rotor Efficiency, Types of Wind Turbines, Fixed-speed Induction Generator (FSIG) based Wind Turbines, Doubly Fed Induction Generator (DFIG) based Wind Turbines, Fully Rated Converter-based (FRC) Wind Turbines, Dynamic modelling and analysis of wind energy system, Wind energy control system, Forecasting and techno-economic analysis of RES.

Fuel Cell: Principles of Operation of Fuel Cells, Dynamic modelling and Simulation of PEM Fuel Cells, Dynamic modelling and Simulation of Solid Oxide Fuel Cells, Principles of Operation and modelling of Electrolysers, Power Electronic Interfacing Circuits for Fuel Cell Applications, Analysis and Control of Grid Connected Fuel Cell Power Generation Systems, Control of Stand Alone Fuel Cell Power Generation Systems, Hybrid Fuel Cell Based Energy System Case Studies.

Microturbine: Operating Principle of Microgrids, Microturbine Fuel and emissions, design and component of Microturbines, control of Microturbines, Efficiency and Power of Microturbines, Application and performance of microturbines, Site Assessment for Installation of Microturbines. Case studies.

Learning Resources:

Text Books:

1. Renewable and Efficient Electric Power Systems, G. Masters, IEEE- John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.
2. Integration of Renewable Sources of Energy, F. A. Farret, M. G. Simoes, Wiley, 2017, 2nd Edition.

Reference Books:

1. Solar Photovoltaic: Fundamentals, technologies & Applications, C. S. Solanki, PHI Publishers, 2019, 3rd Edition.
2. Wind Energy Generation Modelling and Control, O. Anaya-Lara, N. Jenkins, J. Ekanayake, P. Cartwright, M. Hughes, John Wiley & Sons Publishers, Ltd, 2009, 1st Edition.
3. Modelling and Control of Fuel Cells: Distributed Generation Applications, M. H. Nehrir, C. Wang, Wiley-IEEE Press, 2009, 1st Edition.
4. Microturbines: Applications for Distributed Energy Systems, P.E Claire Soares, Elsevier Inc., 2007, 1st Edition.

EE5304	RESTRUCTURED POWER SYSTEMS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand the need for restructured power system and economics.
CO2	Analyse transmission congestion and Estimate loss allocation in Power System
CO3	Analyse demand response in smart grid systems
CO4	Evaluate economics and ancillary services within the Smart Grid

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	2
CO3	3		3	3	2	3
CO4	3	2	3		2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Restructuring of power industry and Fundamentals of Economics: Introduction, Reasons for restructuring / deregulation of power industry, Fundamentals of Deregulation, Motivation of restructuring the power industries, restructuring process – unbundling & privatization, restructuring models, Components of restructured systems.

Transmission Pricing

Cost components, Postage Stamp Method, Megawatt Mile Method, Contract Path Method

Smart Grid in Power Market:

Independent System Operator (ISO): Functions and responsibilities, Smart Grid trading arrangements (Pool, bilateral & multilateral), Open Access Transmission Systems, and Open Access Same time Information system (OASIS)

Definitions transfer capability issues: ATC, TTC, TRM, CBM calculations, methodologies to calculate ATC, Electricity Pricing

Smart Grid Bidding Strategies: Forward and Future market; Operation and control: Old vs New, Integrated bidding strategy in smart multi energy system, Smart grid Optimization with risk constraints-General risk measures, Portfolio selection problem, penalty formulation.

Transmission Congestion Management: Classification of congestion management methods, Calculation of ATC-TTC-CBM, Non-market methods, Market based methods, Nodal pricing, Inter-zonal Intra-zonal congestion management, Price area congestion management.

Demand Response in Smart Grid: Demand response, Potential benefits of demand response in smart grid, enabling smart technologies for demand response, control devices for

demand response, Monitoring and communication system. Demand response for Electric Vehicles, Examples

Ancillary Services within Smart Grid framework: Reactive power as an ancillary services, Energy Storage System, Power Quality, Reliability analysis.

Smart Grid Economic and market operations: Energy and Reserve Markets, Market Power, Generation Firms, Locational Marginal Prices, Financial Transmission Rights. Concepts of block chain technologies in energy trading and power purchase agreements (PPA).

Learning Resources:

Text Books:

1. Power System Restructuring and Deregulation, L. L. Lai, John Wiley & Sons Ltd., 2012, 1st Edition.
2. Operation of restructured power systems, K. Bhattacharya, J. E. Daadler, and Math H.J Bollen, Kluwer Academic Pub., 2012, 1st Edition (Reprint).
3. Fundamentals of Power System economics, D. Kirschen and G. Strbac, John Wiley & Sons Ltd, 2019, 2nd Edition.

Reference Books:

1. Making competition work in electricity, S. Hunt, John Wiley & Sons, Inc., 2002, 1st Edition.
2. Power System Deregulation: Loss Sharing in Bilateral Contracts and Generator Profit Maximization, Ashikur Bhuiya: Publisher VDM Verlag, 2008
3. Restructured Electrical Power Systems, Mohammad Shahidehpour and Muwaffaqalomoush, Marcel Dekker, Inc., 2001, 1st Edition

Online Resources:

1. NPTEL – Restructured Power Systems – Prof. S.A. Khaparde, Dr. A.R. Abhyankar, IIT Delhi
2. www.isgf.com
3. www.iexindia.com
4. www.posoco.in
5. http://www.ferc.fed.us
6. http://www.nordpool.no
7. http://www.statnett.no
8. http://www.ofaem.gov.uk
9. http://www.caiso.com
10. http://www.nationalgrid.com
11. http://www.bmreports.com/bwx_home.htm
12. http://www.elexon.co.uk/
13. http://www.fingrid.fi
14. http://www.svk.se
15. http://www.ucei.berkeley.edu/ucei/datamine/datamine.htm

EE5305	MICROGRID DYNAMICS AND CONTROL LAB	0-1-2: 2

Pre-Requisites: Power Electronics, Control Systems

Course Outcomes (COs):

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

CO1	Understand the operation of AC microgrid system power sharing and control
CO2	Understand the concept of DC microgrids and impacts of constant power loads on system
CO3	Analyse the hierarchical control for AC and DC microgrids.
CO4	Analyse the dynamic behaviour of Micro grid system & its grid integrations issues

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Simulation of Voltage and frequency control of a load connected inverter.
2. Simulation of decentralized inverter-based AC microgrid with P-f and Q-V droop control.
3. Impact of droop gains on stability of the inverter based microgrids.
4. Centralized Secondary control design for inverter-based AC microgrids.
5. Distributed secondary control for the inverter-based AC microgrids.
6. Simulation of decentralized DC microgrid systems.
7. Dynamic assessment of DC microgrids with constant power loads.
8. Distributed control for converter-based DC microgrid system.
9. Interconnection of AC and DC microgrid system.
10. Design of stabilizer for inverter based microgrid.

EE5306	RENEWABLE ENERGY CONTROL LAB	0-1-2: 2

Pre-Requisites: Power System Operation and Control, Renewable Energy Systems

Course Outcomes (COs):

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

CO1	Understand the Grid integration of renewable resources such as PV, Wind etc.
CO2	Understand the impacts of virtual inertia in autonomous mode with diesel generators
CO3	Analyse and evaluate the effect of additional sources (like micro turbine, ultra-capacitors) in improving the system dynamics performance
CO4	Chose and design a efficient controller for off-grid/grid fed Renewable Energy applications

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		1	
CO2	3	1	2		1	
CO3	3		2	3	1	2
CO4	3	1	2	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Modelling of PV system
2. Modelling of DFIG based wind power system
3. Simulation of Grid connected PV MPPT (P&O) single stage
4. Simulation of Grid connected PV MPPT (P&O) double stage.
5. Virtual inertia emulation using PV Battery systems and its studies under varying loads
6. Grid connected DFIG wind generation analysis under varying wind, and grid conditions.
7. PV+BESS+Diesel generator simulation with virtual inertia in autonomous mode.
8. Use of ultra-capacitors to improve dynamic performance of PV+BESS+Diesel generator autonomous system.
9. Fuel Cell grid integration studies and analysis.
11. Improving dynamic response with Fuel cell and Microturbine combination.
12. Forecasting of wind and solar energy for techno-economic analysis.
13. Modelling and simulation of electric vehicle charging system.

EE5348	SEMINAR – I	0-0-2: 1

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Identify and chose appropriate topic of relevant to the Smart Electric Grid.
CO2	Assimilate literature on technical articles of specified topic
CO3	Write technical report.
CO4	Present a technical talk on the chosen topic

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	1		1	
CO2	3	3	2		1	
CO3	3	2	3	2	1	
CO4	3	3	3		1	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

There is no specific syllabus for this course. Student can choose any topic, of his / her choice, pertaining to Advance technologies in Smart Electric Grid. Topic should be a relevant and currently researched one. Students are advised to refer articles published in current journals in the area of Smart Electric Grid for choosing their seminar topics. Student should review minimum of 10 to 15 research papers relevant to the topic chosen, in addition to standard textbooks, codebooks, etc. Students are required to prepare a seminar report, in the standard format and give presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. It is mandatory for all the students to attend the presentations of their classmates.

Learning Resources:

1. IEEE Electrical Engineering Journals.
2. Research Articles / Industrial Reports available on Internet.
3. Smart Electric Grid Textbooks, Handbooks and Codebooks.

EE5311	SMART GRID PLANNING & OPERATION	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand the analysis and planning of Smart Grids
CO2	Evaluate the tools for modelling and analysis of smart grid dynamics
CO3	Analyse and synthesize different control schemes of smart grid operation
CO4	Assess the influence of smart grid on power system

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	2	2	2	1	
CO3	3		3	3	3	3
CO4	3	2	3	2	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Analysis of Smart Grid System

Smart grid concepts, smart grid components and control elements, Distributed generation resources and Energy Storage, Plug-in-Hybrid Electric Vehicles (PHEV), Microgrids, Load Flow study for AC/DC power system, smart grid Monitoring, smart grid standards and policies.

Smart Grid Planning

Planning Aspects of smart grid, Optimal power flow, Demand side management of smart grid, Demand response analysis of smart grid, Planning and Design of smart grid systems.

Voltage and frequency control of Smart Grid

(Angle/Voltage instability Phenomena, stability constraints), frequency & voltage regulations, Automatic generation Control, Tie-line power sharing, Voltage Stability assessment, Voltage and reactive power control, Shunt compensation, SVC, Voltage stability Indexing, and volt-VAR support

Operation and Control of Smart Grids

Operational aspects of smart grid system, Economic Dispatch, Load Dispatch Centre Functions: Contingency Analysis, preventive, Emergency and Restorative, control objectives of smart distribution system, architecture and different schemes of smart grid control, bottleneck in smart grid control, Ancillary Services.

Learning Resources:

Text Books:

1. Smart Grid: Fundamentals of Design and Analysis, J. Momoh, Wiley-IEEE Press, 2012, 1st Edition.

2. Introduction to the Smart Grid: Concepts, Technologies and Evolution, S. K. Salman, IET Energy Engineering Series, 2017, 1st Edition.
3. Power System Stability and Control, Prabha Kundur, McGraw Hill Education, 2006, 1st Edition.

Reference Books:

1. Power System SCADA and Smart Grid, Mini S Thomas and J. D MacDonald, CRC Press, 2015, 1st Edition.
2. Microgrids Architecture and control, N. Hatziargyriou, Wiley-IEEE Press Series, 2013, 1st Edition.
3. Smart Grid Applications and Developments, D. Mah, P. Hills, Victor O.K. Li, R. Balme, Springer-Verlag London, 2014, 1st Edition.
4. Smart Grid: Technology and Applications, J. Ekanayake, N. Jenkins, K. Liyanage, J. Wu, A. Yokoyama, John Wiley & Sons, 2015, 1st Edition.
5. Reliability Standards for the Operation and Planning of Future Electricity Networks, G. Strbac, D. K. Rodrigo Moreno, IEEE, 2016, 1st Edition.
6. Design of smart power grid renewable energy systems, Ali Keyhani, Wiley IEEE, 2016, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/108/104/108104052/

EE5312	ADVANCED CONTROL SYSTEMS	3-0-0: 3

Pre-Requisites: Basic Control Systems

Course Outcomes (COs):

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

CO1	Understand the representation of dynamic system and its behaviour.
CO2	Synthesize advanced PID controller for load frequency control in Micro Grid.
CO3	Design and evaluate optimal and adoptive control schemes for different power engineering applications.
CO4	Design and analyse nonlinear controllers for load frequency and voltage control in Microgrid.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Preliminaries: System representation- Review of Classical Control: P, PI, PID control- Review of modern control: State and state variables - State transition matrix (STM) – Controllability and observability- State variable feedback - Pole placement – Luenberg observer design-Reduced order observer-Stability and Detectability- Kalman Decomposition theorem- Stability in the sense of Lyapunov (Direct Method).

Advanced PID control: The PID controller-Filtering the derivative- Setpoint weighting- Integrator Windup- Controller degrees of freedom- Model based Design methods: Direct Synthesis (DS) method, Internal Model Control (IMC) method- Stability analysis- Robustness Measures-Feedforward design: Inversion based method- Cascade Control- Fractional PID- Case Study: Load frequency control (LFC) in Micro grid system.

Optimal Control: Cost function- Linear Quadratic regulator (LQR)-Algebraic Riccatti Equation (ARE)- Discrete time systems-Development of Kalman Filter: Predictor and Corrector form- Predictive Control: Dead Beat control, Generalized Predictive Control (GPC), Model Predictive Control (MPC): Problem formulation- Recursive feasibility-Stability of MPC- Case Study: Application of MPC to Micro Grid droop control.

Introduction to Nonlinear System and its control: Characteristics of nonlinear systems- Autonomous and Non-autonomous systems- Phase Plane analysis- Classification of Equilibrium Points- Limit Cycles Existence and its condition- Existence of Periodic Orbits- Lyapunov Stability– Nonlinear controller design: Feedback Linearization- Back stepping- Case Study: Nonlinear Load Frequency control design in Microgrid.

Learning Resources:

Text Books:

1. Linear System Theory and Design, C.T. Chen, Oxford University Press, 2013, 4th Edition.
2. Advanced PID Control, K. J. Astrom, T. Hagglund, ISA Publisher, 2006, 1st Edition.

Reference Books:

1. Nonlinear Systems, Hassan K Khalil, Prentice - Hall International (UK), 2002, 3rd Edition.
2. Model Predictive Control, E.F. Camacho, C.A.Bordons, Springer-Verlag London, 2007, 2nd Edition.
3. Optimal Control Systems, D. Subbaram Naidu, CRC Press, 2002, 1st Edition.
4. Modern Control Systems Theory, M. Gopal, New Age International Private Limited, 2014, 3rd Edition.
5. Predictive Control for linear and Hybrid Systems, F. Borrelli,A. Bemporad, M.Morari, Cambridge University Press, 2017, 1st Edition.

EE5313	ENERGY STORAGE SYSTEMS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand the characteristics of energy storage devices
CO2	Model and simulate the characteristics of energy storage systems
CO3	Explore the possibilities of deployment of energy storage systems in smart cities and electric vehicles.
CO4	Evaluate and suggest an efficient storage system in electric transportation.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1	1	3	
CO2	3	1	2	3	2	
CO3	3		3	3	3	3
CO4	3	2	3	2	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Impacts and requirements of Electrical Energy Storage system, Classification of Energy Storage Systems, Energy costs and load analysis. Grid Applications of Energy Storage systems, Ancillary Services from Energy storage. Traditional generation costs and optimizations. Power flow and energy balancing in a wide area network. Economics of energy and power, tied electrical rates and demand response. Role of energy storage system in handling uncertainties with Renewable systems and in microgrids.

Electrochemical Energy Storage: Batteries: Introduction to battery storage including lead acid, lithium ion, flow, and emerging battery technologies. Comprehensive analysis of design considerations and application specific needs. Impacts on system cost in terms of life cycle, environmental, and reliability of the end solutions.

Ultra-Capacitors: Introduction to ultra-capacitors including operation, applications, and emerging technologies. Topics include the usage in mobile applications and close proximity to renewable energy sources. Discussion of primary target market usage in today's energy and power sectors.

Super Conducting Magnetic Energy Storage (SMES): Introduction to Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage and emergent research, with focus on large utility scale energy storage facilities.

Mobile and Fixed Energy Storage: Advantages and disadvantages of mobile vs. stationary energy storage, with focus on vehicle to grid applications and opportunities to leverage existing and emergent technology to provide additional grid support functions.

Concept of time-of-day metering for storage planning and management.

Mechanical Energy Storage

Pumped Hydro: Models for pumped hydro capacity and availability, System cost, capacity, conversion efficiency, and siting.

Compressed Gas: Compressed gas storage technologies as bulk energy storage. Models for compressed gas capacity, efficiency, and availability, System cost, capacity, conversion efficiency, siting and associated barriers, possible applications in carbon capture and appropriation.

Flywheel: Flywheel energy storage system, Models for flywheel capacity, availability, efficiency, and self-discharge, Applications in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage, Selection and design of flywheels for safety and availability in various applications.

Thermal: Introduction to thermal storage in residential and utility scale applications including molten salts, cold reservoirs, and phase change materials, Analysis of design considerations, material selection, and application specific constraints, Applications in renewable energy at utility scale solar and geothermal power production.

Learning Resources:

Text Books:

1. Microgrids and Active Distribution Networks, S. Chowdhury, S. P. Chowdhury, P. Crossley, IET Power Electronics Series, 2012.
2. Integration and Control of Renewable Energy in Electric Power System, Ali Keyhani Mohammad Marwali and Min Dai, John Wiley publishing company, 2010, 2nd Edition.

EE5314	NUMERICAL OPTIMIZATION	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand the concepts of convex sets, convex functions and optimization problems, the concept of Duality, Lagrange dual problems, optimality condition.
CO2	Study few basic algorithms such as Descent methods, Newton's method, Conjugate direction methods, barrier method, Primal-dual methods
CO3	Analyse the mixed integer non-linear problem-solving methodologies, convex relaxation of non-linear non-convex problems.
CO4	Investigate the applications of the optimization for power system problems such as unit commitment, economic load dispatch, optimal power flow, security constrained optimal power flow and state estimation problem

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	2	1	
CO4	3	2	3		1	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Convex sets, function and optimization problems

Affine, convex sets, operations that preserve convexity, generalized inequalities, hyperplanes, basic convex function properties, conjugate functions, quasi-convex functions, convexity with respect to generalized inequalities. Linear optimization problems, quadratic optimization problems, geometric programming, vector optimization.

Duality

The Lagrange dual function, Lagrange dual problem, Geometric interpretation, Saddle-point interpretation, Optimality conditions, Perturbation and sensitivity analysis.

Algorithms

Unconstrained problems: Descent methods, Gradient descent method, Steepest descent method, Newton's method, Self-concordance, Conjugate direction methods.

Equality constrained problems: Newton's method with equality constraints, infeasible start Newton method

Inequality constrained problems: Logarithmic barrier function and central path, barrier method, Feasibility and phase I methods, Complexity analysis via self-concordance, Primal-dual methods

Mixed Integer programming and Convex relaxations

Condensed formulation, Smooth and disjunctive reformulations: Disjunctive constraints, Big M method, smooth binary formulation, convex hull methods, Block-separable splitting-schemes: MINLP splitting- schemes, MIQQP splitting-schemes, Convexification of non-convex problems, SDP relaxation, SOCP relaxation, QCQP relaxation.

Power System Optimization

Unit commitment, Economic load dispatch, Optimal power flow, Security constrained optimal power flow, State estimation problems.

Learning Resources:

Text Books:

1. Convex Optimization, S. Boyd, L. Vandenberghe, Cambridge university press, 2004, 1st Edition.
2. Linear and Nonlinear Programming, David G. Luenberger, Yinyu Ye, Springer Media, LLC, 2008, 3rd Edition.

Reference Books:

1. Relaxation and Decomposition Methods for Mixed Integer Nonlinear Programming, Nowak, Birkhäuser Verlag, 2005, 1st Edition.
2. Optimization of Power System Operation, J. Zhu, Wiley IEEE Press, 2nd Edition, 2015.

Online Resources:

1. http://videolectures.net/stanfordee364aw08_convex_optimization1/
2. https://web.stanford.edu/class/ee364a/lectures.html

EE5315	SIGNAL PROCESSING TECHNIQUES	3-0-0: 3

Pre-Requisites: Signals and Systems

Course Outcomes (COs):

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

CO1	Understand the applications of Digital signal filtering techniques in power systems
CO2	Apply estimation techniques to evaluate power system parameters
CO3	Analyse different signal decomposition techniques
CO4	Evaluate the WAMS signal processing

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1		2	
CO2	2	1	2		1	
CO3	2		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Power Systems signals in terms of Smart Grid

Need for Signal Processing in Basics of power quality issues, Inrush Current in Power Transformers; Over-Excitation of Transformers; Transients in Instrument Transformers; Frequency Variation; Voltage Magnitude Variations; Voltage Frequency Variations, power system protection, Wide area dynamic analysis.

Power Systems and signal processing

Stochastic gradient based algorithms – LMS algorithm, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Mean-squared error behaviour, Convergence analysis, Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms- GRLS, Gauss-Newton and RM.

Basic Digital System, Parametric Notch FIR Filters; Sine and Cosine FIR Filters, Parametric Filters applications in smart grid,

Filters and Electrical Parameters Estimation

Forward and backward linear prediction, prediction error filters, AR lattice and ARMA Lattice – Ladder filters, Kalman filters, Wiener filter, Least Square methods for system modelling & Filter Design. Recursive least squares algorithms, Matrix inversion lemma, Spectrum estimation.

Estimation of autocorrelation. Periodogram, Nonparametric and Parametric methods. Estimation Theory; Least-Squares Estimator; Frequency Estimation; Phasor Estimation; Phasor Estimation in Presence of DC Component; Spectrum Estimation; Windows; Frequency-Domain Windowing; Interpolation in Frequency Domain: Multitoned Signal.

Time-Frequency Signal Decomposition
Short-Time Fourier Transform; Sliding Window DFT; Filter Banks; Pattern Recognition, Feature Extraction on the Power Signal; Signal Detection for Electric Power Systems; Detection Theory.

Signal Processing Techniques Applications
Concepts of wavelet, s-transform, heartly s-transforms; Hillbert transform; Gabor transform and applications in power fluctuations: load fluctuations, wind farm power fluctuations and smart microgrid, Asset Management.

Learning Resources:

Text Books:

1. Advanced Digital Signal Processing, J.G.Proakis, M. Salehi, 1992, McGraw –Hill.
2. Power Systems Signal Processing for Smart Grids, P. F. Ribeiro, C. A. Duque, P. Marcio da Silveira and A. S. Cerqueira, John Wiley and Sons Ltd., 2014, 2nd Edition.

Reference Books:

1. Adaptive Filter Theory, S. Haykin, Prentice Hall, 2001, 2nd Edition.
2. Signal Processing: The Model Based Approach, J. V. Candy, McGraw-Hill Book Company, 1987.
3. Statistical Digital Signal Processing and modeling, M. H. Hayes, John Wiley & Sons, 1996.
4. Handouts on DSP Processors.
5. Digital Signal Processing – A computer Based Approach, S. K. Mitra, MGH, 2001, 2nd Edition.

EE5101	ANALYSIS OF POWER CONVERTERS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Select appropriate switching devices for power converters
CO2	Analyse and design power converter configurations for specific applications
CO3	Select control techniques for low and medium power converters
CO4	Design power electronic converters to improve power quality

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	3	1	2	2
CO2	2	0	3	1	2	2
CO3	2	0	3	1	2	2
CO4	2	0	3	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT, MOSFET, IGBT, GTO, Wide band gap devices (GaN, SiC) - Design of driver and snubber circuit

DC-DC Converters: Non-isolated DC-DC converters: buck, boost, buck-boost, CUK converters under continuous and discontinuous conduction operation - Isolated DC-DC converters: forward, fly-back, push-pull, half-bridge and full-bridge converters - Relationship between I/P and O/P voltages- design of filter inductor and capacitors

Inverters: Single-phase and three-phase inverters- PWM techniques: single, multiple and sinusoidal PWM techniques- selective harmonic elimination, space vector modulation, current source inverter- High power inverters: Multi-pulse inverters, multi-level inverters - Diode-clamped, cascaded and Flying capacitor types, Carrier and Vector based multi-level modulation schemes -Concept of active power filters

Front-End (AC-DC) Converters: Conventional methods of power factor improvements: Semi-converter, extinction angle control, symmetrical angle control – active front-end converters- Single phase: Boost, voltage doubler and PWM rectifiers –voltage and current controlled three-phase PWM rectifiers

Learning Resources:

Text Books:

1. Power Electronics Handbook, M.H. Rashid, Butterworth-Heinemann, 2017, 4th edition.
2. Power Electronics: Converters, Applications & Design, N Mohan, T.M. Undeland, WP.Robbins, John Wiley & Sons, 2003, 3rd edition.

Reference Books:

1. Power Electronics: Essentials and Applications, Umanand, L, John Wiley India, 2009, 1st Edition.
2. Fundamentals of Power Semiconductor Devices, Jayant Baliga B, Springer, 2008, 1st Edition.

EE5103	APPLICATIONS OF DIGITAL SIGNAL PROCESSORS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Develop Assembly Language Programs for the Digital Signal Processors
CO2	Configure and use Digital Input / Output lines and ADCs
CO3	Configure and use Interrupts and Event Managers for PWM generation
CO4	Employ DSPs & FPGAs for the real time control of Power Electronic Converters

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	1	3	2
CO2	3	0	3	1	3	2
CO3	3	0	3	1	3	2
CO4	3	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

TMSLF2407 DSP Controller: Brief Introduction to Peripherals - Types of Physical Memory - Software Tools.

C2XX DSP CPU and instruction set: Introduction to the C2xx DSP Core and Code Generation - The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory -Memory Addressing Modes -Assembly Programming Using the C2xx DSP Instruction Set.

Parallel and Serial Data Transfer: Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports.

Interrupt system of TMS320LF2407: Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software, real time control with interrupts.

The analog-to-digital converter (ADC): ADC Overview - Operation of the ADC and programming modes.

Event Managers (EVA, EVB): Overview of the Event Manager (EV) - Event Manager Interrupts - General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry - General Event Manager Information - PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSP TMSLF2407A.
Introduction to TMS320F28335 DSP Controller, Architecture, Peripherals and Interrupts.

Field Programmable Gate Arrays: Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP)- HDL programming –overview of Spartan 6 & ISE Design Suite, Implementation of PWM technique with SPARTAN-6 FPGA.

Learning Resources:

Text Books:

1. Tolyat: DSP based Electromechanical Motion Control, Hamid A., CRC press, 2003, 1st ed.
2. FPGA based system design, Wayne Wolf, Pearson Education, 2005,1st ed.

Reference Books:

1. FPGA Design, Philip Andrew Simpson, Springer Nature; 2nd ed., 2015.
2. FPGA-Based Embedded System Developer's Guide, A. ArockiaBazil, Raj, CRC Press, 2018, 1st ed.
3. Application Notes from Texas Instruments
4. Spartan-6 FPGA Configurable Logic
5. Xilinx Spartan 6 Data sheets

EE5202	DATA SCIENCE APPLICATIONS IN POWER ENGINEERING	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Distinguish between Algorithmic based methods and Knowledge based Methods
CO2	Able to distinguish between Artificial Neural Networks and Fuzzy Logic
CO3	Adopt Soft Computing techniques for solving Power Engineering Problems
CO4	Apply appropriate AI frame work for solving Power Engineering Problems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	0	0	3	0	0	0
CO2	3	0	0	0	0	0
CO3	3	0	3	0	0	0
CO4	3	0	3	3	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Artificial Neural Networks (ANN):

Introduction to Artificial Neural Networks - Definition and Fundamental concepts -Biological Neural Network – modelling of a Neuron -Activation functions – initialization of weights - Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – XOR Problem - ADALINE and MADALINE

ANN Paradigms:

Multi – layer perceptron using Back propagation Algorithm (BPA) -Self – Organizing Map (SOM) -Learning Vector Quantization (LVQ) - Radial Basis Function Network -Functional link network -Hopfield Network -Bidirectional Associate Memory (BAM)

Deep Learning:

Deep Architectures – Convolutional Neural Networks – Convolutional Layer – Pooling Layer – Normalization Layer- Fully Connected Layer – Deep belief Networks

Fuzzy Logic:

Introduction – Classical and Fuzzy sets- Properties, Operations and relations-Fuzzy sets – Membership function – Basic Fuzzy set operations -Properties of Fuzzy sets – Fuzzy Cartesian Product - Operations on Fuzzy relations – Fuzzy logic – Fuzzy Cardinalities - Fuzzy Logic Controller (FLC): Fuzzy Logic System Components: Fuzzification - Inference Engine - Defuzzification methods

Applications of ANN and Fuzzy Logic:

Load flow studies - Economic load dispatch - Load frequency control – Single area system and two area systems - Reactive power control - Speed control of DC and AC Motors - Fuzzy control applications in wide area control – ANN in hybrid state estimation – ANN applications for power system protection.

Learning Resources:

Text Books:

1. Neural Networks, Fuzzy Logic & Genetic Algorithms, S. Rajasekaran and G.A.V. Pai, PHI, New Delhi, 2008.
2. Fuzzy Logic with Fuzzy applications, T.J. Ross, Mc Graw Hill Inc, 1997.

Reference Books:

1. Neural Networks: A Comprehensive Foundations Simon Haykin, Pearson Edition, 2003.
2. Fuzzy sets, Uncertainty and Information, G.J.Klir and T.A.Folger, PHI, Pvt.Ltd,1994.
3. Neural Network & Fuzzy System, Bart Kosko, Prentice Hall, 1992.
4. Neural Computing Theory & Practice, P. D .Wasserman, Van Nostrand Reinhold, New York, 1989.

EE5215	MACHINE LEARNING AND APPLICATIONS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand basic concepts of Machine Learning Techniques
CO2	Distinguish between supervised learning, unsupervised learning and reinforced learning
CO3	Develop the skills in using machine learning software for solving practical problems
CO4	Apply Machine Learning Algorithms for Electrical Engineering problems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	3	2	0
CO4	3	0	3	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

NEURAL NETWORKS:

Introduction to Neural Networks, Models of Neuron Network, Architectures – Knowledge representation, Artificial Intelligence and Neural Networks – Learning Process, Error Correction Learning, Multi-layer perceptron using Back Propagation Algorithm (BPA)

LEARNING THEORY:

Introduction to Machine Learning: What is Learning – Learning Objectives – Data needed – Bayesian inference and Learning – Bayes theorem – inference – naïve Bayes – Regularization – Bias-Variance Decomposition and Trade-off – Concentration Inequalities – Generalization and Uniform Convergence – VC –dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning

SUPERVISED LEARNING:

Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis, Naïve Bayes – Kernel Method: Support Vector Machine (SVM) – Kernel function – Kernel SVM - Gaussian Process – Tree Ensembles: Decision Trees- Random Forests – Boosting and Gradient Boosting

UNSUPERVISED LEARNING (CLUSTERING):

–means Clustering Algorithm – Gaussian Mixture Model (GMM) – Expectation Maximization (EM) – Variational Auto Encoder (VAE) – Factor Analysis – Principle Components Analysis (PCA) – Independent Component Analysis (ICA)

REINFORCEMENT LEARNING:

Markov Decision Processes (MDP) – Bellman's Equations- Value Iteration and Policy Iteration - Value Function Approximation – Q – Learning

Applications of ML:
Load Forecasting – Energy Market forecasting – Fault identification and localization – Renewable Uncertainty estimation

Learning Resources:

Text Books:

1. Pattern Recognition and Machine Learning, Christopher Bishop, Springer, 2011.
2. Machine Learning, E. Alpaydin, MIT Press, 2010.

Reference Books:

1. Machine Learning, Tom M. Mitchell, McGraw Hill International Edition, 1997.

EE5351	SMART GRID PROTECTION	3-0-0: 3

Pre-Requisites: Power System Protection

Course Outcomes (COs):

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

CO1	Understand basic concepts of advanced protection systems
CO2	Design relay algorithms and associated hardware
CO3	Understand the principles of modern protection systems for substation, transformer, generator and motor
CO4	Evaluate the impact and influence of PMUs on the Protections schemes

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	2		1	2	1	1
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Advanced Protection Systems

Basics of Electrical Protection systems, Short-circuit analysis, Protection system in Smart Grid, Importance and challenge of protective devices in smart grid.

Relays and Hardware Consideration

Basics of digital protection and relays, Advantage of microprocessor technology and its application to protection, subsystem of digital relay, Numerical relays, Protection of substation, transformer, generators and motors. Analogue signal conditioning, low pass filters, DSP based general purpose hardware, Microcontrollers and digital relay implementation procedures.

Relaying Algorithms

Classification of relaying algorithms, Algorithms for digital relaying, Full cycle and half cycle Fourier algorithms, -, least square fitting algorithm, Kalman filtering algorithm, Digital harmonic filter algorithms.

Wide Area Protection

Differential Protection of Transmission Lines, Distance protection of Transmission Lines, Distance Relaying of Multiterminal Transmission Lines, Adaptive Protection, Adaptive Out-of-Step Protection, Security Versus Dependability, Transformer, Adaptive System Restoration, Control of Backup Relay Performance, Hidden Failures, Intelligent Islanding, Supervisory Load Shedding, Concept of integrated wide area monitoring and protection (WAM &WAP).

SIPS architecture, SIPS data archival system, SIPS applications, Data protocols, SIPS monitoring and testing functions, Example of SIPS application based on PMU technology

Advanced Protection for Smart Grid

Impact of Renewables Integration on Protection Systems, Distribution Grid Protection in

Smart Grid Environment, Protection Needs for Modern Distribution Systems, Adaptive relay protection, Protection of Microgrids.

Learning Resources:

Text Books:

1. Computer Relaying for Power systems, G. Phadke and James S. Thorp, John Wiley and Sons, 2009, 2nd Edition.
2. Wide Area Monitoring, protection and control systems the enabler for smarter grids, Vaccaro, Alfredo Zobaa, Ahmed. F, IET publisher, 2016, 1st Edition.
3. Fundamentals of Power System Protection, Y. G. Paithankar and S. R. Bhide, Prentice Hall of India, 2010, 2nd Edition.

Reference Books:

1. Microgrids: Operation, Control, and Protection, E. Amir, LAP Lambert Academic Publishing, 2014, 1st Edition.
2. Power System Protection and Switchgear, Badriram and V. Kharma, TMH, 2011, 2nd Edition.
3. Protection and Switchgear, B. Bhalja, R. P. Maheshwari and N. G. Chothani, Oxford University Press, 2011, 1st Edition.
4. Static Relays with Microprocessor Application, T.S. Madhava Rao, TMH, 2009, 2nd Edition.

EE5352	WIDE-AREA MONITORING AND CONTROL	3-0-0: 3

Pre-Requisites: Basics of Power Systems, Signals and Systems

Course Outcomes (COs):

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

CO1	Understand the concepts of Phasor measurements in power system.
CO2	Understand monitoring a wide area power system using synchronized measurements and data obtained from PMUs
CO3	Evaluate the modifications in power systems operation with introduction of PMUs
CO4	Analyze wide area power system dynamics and global control.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	2	1	1		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Phasor measurement units

Importance of PMUs, Phasor Measurement Units and Phasor Data Concentrators
Wide Area Monitoring: WAMS concept, data collection, WAMS architecture, Monitoring systems placement, Advanced data processing.

Time-frequency representation: Hilbert–Huang analysis, Wavelet analysis, Dynamic harmonic regression,
Multivariant multi scale analysis: Multi-signal Prony analysis, Data fusion principles

Monitoring Power system status

Power system reliability and Stability, three defence line in power system, Power system DC state estimation, AC state estimation, Hybrid state estimation with PMU data.

Power system health monitoring, Disturbance and anomaly detection, Modal-based health monitoring methods, Wide-area inter-area oscillation monitoring, High-dimensional pattern recognition-based monitoring, Voltage and reactive power monitoring, benefits of WAMS in Congestion Management, Contingency Analysis, RE Integration

Power System Stability

Concepts of stability of dynamic system, Eigen properties of the state matrix, small signal stability of SMIB system, effect of excitation system, power system stabilizer, system state matrix with amortises, small signal stability of multimachine systems, characteristics of small signal stability problem.

Wide Area Control

Basic Framework and Operating Principle of Wide-Area Damping Control, Coordinated Design of Local PSSs and Wide-Area Damping Controller, Assessment and Choice of Input Signals for Multiple Wide-Area Damping Controllers.

Learning Resources:

Text Books:

1. Wide Area Monitoring of Interconnected Power Systems, R. Messina, IET publisher, 2015, 1st Edition.
2. Interconnected Power Systems Wide-Area Dynamic Monitoring and Control Applications, Yong Li, D. Yang, Fang Liu, Y. Cao, Springer-Verlag Berlin Heidelberg, 2016, 1st Edition.
3. Power System Stability and Control, Prabha Kundur, McGraw Hill Education, 2006, 1st Edition.

Reference Books:

1. Power system wide-area stability analysis and control, Ma, Jing, Wiley Blackwell, Science press, 2018, 1st Edition.
2. Wide area monitoring, protection and control systems the enabler for smarter grids, Alfredo Vaccaro, and Ahmed F Zobaa, IET publisher, 2016, 1st Edition.
3. Synchronized Phasor Measurements and Their Applications, Arun G. Phadke, James S. Thorp, Springer International Publishing AG, 2017, 2nd Edition.

EE5353	SMART GRID COMMUNICATIONS AND PROTOCOLS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand the role of communication networks in Smart Grid systems
CO2	Analyse the architectures of the network communications
CO3	Evaluate advanced communication protocols for power system automation
CO4	Analyse system network security and data management.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Power system Automation

Evolution of power system Automation, SCADA System, Elements of Communication Networking**;** Control in Traditional Power Networks; Distributed Generation and Active Control; Communications Challenges in Active Control

Elements of Communication Networking for Power System Practitioners:

Elements of Data Communication Networks; Protocols and Protocol Layers; OSI Reference Model; TCP Reference model; Practical Protocol Layering in Network; Data Networking Technologies; Different network topologies and Classification of communication network.

Communication Network Architecture

Architecture Framework; Core-Edge Architecture; Smart Grid Network Protocols; Smart Grid Domains and Smart Grid Communication Network; WAN Architecture; WAN over Network Service Provider; Local Traffic Aggregation; Putting It All Together; Field Area Networks; FAN Protocol Options; Summary of FAN Networking Technologies; Logical End-to-End Connectivity (A Few Examples); Automated Demand Response; Volt, VAR, Watt Control in Distribution System; Wide Area Situational Awareness and Control.

Network Security

Importance of Smart Grid Security; Regulations, Standards, and Best Practices; Smart Grid Security Architecture; Security Zones; Transmission Zone; Distribution SCADA Zone; Distribution Non-SCADA Zone; Interconnect Zone; Additional Security-Related Operations.

Smart Grid Data Management

Characterization of Smart Grid Data; Technology Challenges; Secure Information and Data Management Architecture; Design Requirements; Secure Data Management; Secure End-to-End Protocols; Data Management Platform; Applications of Smart Grid Data; Utility-Centric Applications; Consumer-Centric Analytics; Market-Centric Analytics; Power Line Communication.

Smart Grid Protocols

Modbus; Modbus message frame; Protocol architecture, IEC 60870-5-101/103/104; Distributed network protocol 3; Inter-control center protocol; Ethernet; IEC 61850, Synchrophasor standard; Wireless technologies for home automation; Protocols in the power system communication: Deployed and evolving such as LPWAN, 5G etc. for network; Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR) may be included/added.

Learning Resources:

Text Books:

1. Communication Networks for Smart Grids, Kenneth C. Budka, Jayant G. Deshpandeand Marina Thottan, Springer London Heidelberg New York Dordrecht, 2014, 1st Edition.
2. Power system SCADA and smart grid, Mini. S. Thomas and John D. McDonald, CRC Press Taylor & Francis Group, 2015, 1st Edition.

Reference Books:

1. Communication Challenges and Solutions in the Smart Grid, F. Bouhafs, M. Mackay and M. Merabti, Springer New York Heidelberg Dordrecht London, 2014, 1st Edition.
2. Simulation-Based Validation for Smart Grid Environments: Framework and Experimental Results, Wonkyu Han, Mike Mabey, Gail-Joon Ahn and Tae Sung Kim, Springer International Publishing Switzerland, 2014, 1st Edition.

EE5354	SMART GRID PROTECTION LAB	0-1-2: 2

Pre-Requisites: Power system Protection

Course Outcomes (COs):

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

CO1	Determine the characteristics of power system protection devices and Relays
CO2	Determine the performance of different protection relays
CO3	Understand the importance of wide area protection
CO4	Realize the fault ride through capabilities of renewable energy systems

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Study and testing of following relays
    i. Overcurrent relay
    ii. Over voltage relay
    iii. Under Voltage relay
2. Relay coordination in smart grid protection scheme for Radial Circuit Topology
3. Relay coordination in smart grid protection scheme for Bidirectional Circuit Topology
4. Study and testing of islanding protection in microgrids
5. Protection of active distribution network
6. Programmable Relay design and operation of relay with PMU data extracted from PDC in HIL- PMU environment
7. Protection of distributed generation sources (wind and solar power generators)
8. Testing of Fault Ride Through (FRT) capability of wind energy source
9. Testing of Fault Ride Through (FRT) capability of solar energy source
10. Islanding detection in an active distribution system

EE5355	SMART ELECTRIC GRID SIMULATION LAB	0-1-2: 2

Pre-Requisites: Basic of Power Systems, Signals and Systems

Course Outcomes (COs):

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

CO1	Understand the PMU monitoring and data visualization
CO2	Understand the role of PMUs and PDCs in wide area monitoring, protection and control
CO3	Demonstrate and suggest an optimal PMU positioning for the system observability
CO4	Understand the possibility of cyber-threats in smart grids

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Optimal PMU placements for proper monitoring of power system
2. DC state estimation
3. Hybrid state estimation
4. Design of virtual PMU in MATLAB
5. Data capturing from PMU using HIL- PMU setup using C-37 protocol
6. PMU data-based power system health monitoring
7. Programmable Relay design and operation of relay with PMU data extracted from PDC in HIL- PMU environment
8. Wide area control of Two area Kundur system
9. Real time wide area control of two area system
10. Attack Detection using DC state estimation

EE5398	SEMINAR – II	0-0-2: 1

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Identify and chose appropriate topic of relevant to the Smart Electric Grid
CO2	Assimilate literature on technical articles of specified topic
CO3	Write technical report.
CO4	Present a technical talk on the chosen topic

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	1		1	
CO2	3	3	2		1	
CO3	3	2	3	2	1	
CO4	3	3	3		1	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

There is no specific syllabus for this course. Student can choose any topic, of his / her choice, pertaining to Smart Electric Grid. Topic should be a relevant and currently researched one. Students are advised to refer articles published in current journals in the area of Smart Grids for choosing their seminar topics. Student should review minimum of 10 to 15 research papers relevant to the topic chosen, in addition to standard textbooks, codebooks, etc. Students are required to prepare a seminar report, in the standard format and give presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. It is mandatory for all the students to attend the presentations of their classmates.

Learning Resources:

1. IEEE Electrical Engineering Journals.
2. Research Articles / Industrial Reports available on Internet.
3. Smart Electric Grid Textbooks, Handbooks and Codebooks.

EE5361	GRID INTEGRATION OF ELECTRIC VEHICLES	3-0-0: 3

Pre-Requisites: Dynamics of Renewable energy sources

Course Outcomes (COs):

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

CO1	Understand the Electric Vehicle concepts and its importance in power system.
CO2	Assess the role of EV in modern distribution system and smart grids
CO3	Analyse the technology, design methodologies and control strategy of hybrid electric vehicles
CO4	Investigate the operation and importance of EVs in Grid Applications, grid balancing, ancillary services and demand response

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fundamentals of Electric Vehicles (EV)

Introduction to Electric Vehicle technology – Types –Fundamental issues related to electric vehicles (EVs) and hybrid electric vehicles (HEVs) – Interdisciplinary Nature of EVs – State of the Art of EVs – Advantages and Disadvantages – Challenges and Key Technologies of EVs – Challenges for EV Industry in India

Electric Vehicle Batteries

Electric vehicle battery efficiency – type – capacity –charging/discharging –technical characteristics – performance – testing, EV battery for stationary applications (B2U).

Charging Techniques

Architecture/Components of EV charging station –EVSE (Electric Vehicle Supply Equipment) – Type of EV Chargers – Charging Methods – Automotive networking and communication, EV and EV charging standards.

Grid Applications

Concept of Vehicle to Grid (V2G/G2V)–Ancillary Services – peak saving – load-generation balance – Demand Response – Energy time shift – Energy Management strategies and its general architecture – integration of EVs in smart grid, social dimensions of EVs.

Advanced Topics

Different design and control aspects of electric drives and chargers for EVs and HEVs, Battery Charger Topologies, and Infrastructure for Plug-In-Electric and Hybrid Vehicles – Impact of Plug-in Hybrid Electric Vehicles on smart Grid/Distribution Networks – Sizing Ultra capacitors for Hybrid Electric Vehicles, concept of vehicle to Home (V2H), Effect of charging infrastructure on grid protection and control, Role of AMI/Smart Meters in EV Management.

Learning Resources:

Text Books:

1. Electric Vehicle Technology Explained, James Larminie, John Lowry, Wiley-Blackwell, 2012, 2nd Edition.
2. Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Sheldon S. Williamson, Springer, 2016, 1st Edition.

Reference Books:

1. Electric Vehicle Battery Systems, Sandeep Dhameja, Elsevier, 2012, 1st Edition.
2. Advanced Electric Drive Vehicles, Ali Emadi, CRC Press, 2017, 1st Edition.
3. Electric & Hybrid Vehicles Design Fundamentals, Iqbal Hussain, CRC Press, 2011, 2nd Edition.
4. Hybrid electric Vehicles Principles and applications with practical perspectives, Chris Mi, M. Abul Masrur, D. Wenzhong Gao, A Dearborn, John Wiley & Sons Ltd. , 2017, 2nd Edition.
5. The automobile, In Electric Vehicles: Prospects and Challenges, T. Muneer and I. Illescas García, Elsevier, 2017, 1st Edition.
6. Plug in Electric Vehicles in Smart Grids, S. Rajakaruna, F. Shahnia, and A. Ghosh, Springer Singapore, 2015, 1st Edition.
7. Vehicle-to-Grid: Linking electric vehicles to the smart grid, J. Lu, and J. Hossain, IET, 2015, 1st Edition.

EE5362	ADAPTIVE AND ROBUST CONTROL SYSTEMS	3-0-0: 3

Pre-Requisites: Control Systems

Course Outcomes (COs):

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

CO1	Understand the fundamental concepts of adaptive and Robust control system
CO2	Design of MRAS and STR adaptive controllers
CO3	Suggest robust control and design robust droop controller using loop shaping methods
CO4	Design and apply Sliding Mode Control with suitable and efficient control approach

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction

Overview of Adaptive Control-Adaptive Schemes-Formulation of Adaptive Control problem-Preliminaries: Lyapunov stability-Parameter Estimation**:** Least squares and Regression models- Recursive least squares (RLS)- Estimating parameters in Dynamic systems-Convergence of Parameter Estimation algorithms- Prediction error (PE) model structures-One step ahead PE method.

Self Tuning Regulator (STR)/ Model Reference Adaptive Systems (MRAS)

Certainty Equivalent Principle-Pole placement design- direct self-tuning regulators -Indirect self tuning regulators, continuous time self-tuners, Hybrid self tuners- disturbances with known characteristics- The MIT rule- Determination of Adaptation gain- Design of MRAS using Lyapunov theory- Relationship between MRAS and STR.

Auto Tuning and Gain Scheduling

Auto tuning Principle and Techniques, Transient response methods- Methods based on Relay feedback- Relay Oscillation- Gain scheduling: the principle - Design of Gain scheduling controllers- Case Study: Adaptive droop control of Microgrid.

Robust Control

Types of Uncertainty -Kharitonov Theorem: Applications to Robust PI/PID controller design-Robust Stability /Performance Condition- H2 and H∞ norms-Concept of Loop shaping-Controller design using the loop shaping methods: H∞ Control, Quantitative feedback theory (QFT)- Case Study: Loop shaping methods to Robust droop control of Microgrid.

Sliding Mode Control (SMC)

Motivation-Matched and Unmatched Uncertainty-Sliding surface design- Stability of SMC-Equivalent control concept- Integral Sliding Mode Control (ISMC)- Composite nonlinear feedback (CNF) controller- Application of SMC to Load frequency control in Microgrid.

Learning Resources:

Text Books:

1. Adaptive Control, K.J. Astrom, B. Wittenmark, Addison-Wesley, 2nd Edition, 1995.
2. Multivariable Feedback control: Design and Analysis, I. Postlethwaite, S.Skogestad, Wiley Publisher, 2014, 2nd Edition.

Reference Books:

1. Robust Adaptive Control, P.A. Ioannou, J. Sun, Dover Publications, 2013, 2nd Edition.
2. Sliding Mode Control: Theory and Applications, C. Edwards, S.K. Spurgeon, Taylor and Francis Publisher, 1998, 1st Edition.
3. Adaptive Control: Algorithms, Analysis and Applications, I.D. Landau, R. Lozano, and M. M'Saad, A. Karimi, Springer, 2011, 2nd Edition.

EE 5363	SMART APPLIANCES AND INTERNET OF THINGS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand and evaluate the characteristics of smart home appliances.
CO2	Understand the behaviour of IoT and their applications
CO3	Manage smart communication systems with multiple sensors and protocols
CO4	Design and simulate smart homes and smart cities with IoTs and cloud computing

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Modern Domestic Appliances

Solid State Lamps: Introduction - Review of Light sources - white light generation techniques- Characterization of LEDs for illumination application. Power LEDs- High brightness LEDs- Electrical and optical properties. LED driver considerations-Power management topologies - color issues of white LEDs- Dimming of LED sources, BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment.

IoT Communication Technologies

Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications. Interoperability in IoT.

IoT Control Technologies and Programming

Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems. Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

IoT Cloud Computation and Applications

Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring, Role of ML and AI in IoT.

Learning Resources:

Text Books:

1. Fundamentals of Solid-State Lighting, Vinod Kumar Khanna, CRC press, 2014, 1st Edition.

2. Permanent Magnet Brushless DC Motor Drives and Controls, Chang-liang Xia, John Wiley & Sons Singapore Pte. Ltd., 2012, 1st Edition.
3. IoT for Smart Grids Design Challenges and Paradigms, K. Siozios, D. Anagnostos, D. Soudris, E. Kosmatopoulos, Springer, 2019, 1st Edition.

Reference Books:

1. Advanced Lighting Controls: Energy Saving Productivity, Technology & Applications, Craig Di Louie, Fairmont Press, Inc., 2006, 1st Edition.
2. Lighting Control: Technology and Applications, Robert S Simpson, Focal Press, 2003, 1st Edition.
3. Introduction to solid state lighting, Arturas Zukauskus, Michael S. Shur & Remis Gaska, Wiley- Interscience, 2002, 1st Edition.
4. Power Electronics: Converters, Applications and Design, Mohan, Undeland and Robbins, John Wiley and Sons, 1989, 1st Edition.

Online Resources:

1. www.aboutlightingcontrols.org.
2. www.ti.com

EE 5364	SMART GRID RESILIENCY AND CYBER SECURITY	3-0-0: 3

Pre-Requisites: Power system Analysis

Course Outcomes (COs):

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

CO1	Understand the key technical threat types, communication protocols and resilient smart grid architectures
CO2	Deploy risk management, operational security and secure development of Smart Grid.
CO3	Assess static and dynamic security analysis techniques to validate
CO4	Verify smart grid security and resiliency

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	2	3		2	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Basic Concepts:
Smart Grid communication, physical and network, introduction to SCADA, MTU, HMI, PLCs, RTU, Physical communications and protocols, Power system observability, bad data detection and identification using state estimation results, Zero injection measurements, pseudo measurements for improving observability.

Power system contingency:
Contingency, security assessment and ranking metrics: using conventional load flow, DC sensitivity factors GSF, LODF (for line overloading), 1P and 1Q method (for voltage violations), Concentric relaxation method, using voltage sub network, and system equivalencing, Security constrained Optimal power flows, n-1 and n-1-1 contingency operations

Reliability Vs Resilience: contingency Vs resiliency analysis: need of resiliency, Elements of Power System Resilience, metrics for system resiliency, EXTREME EVENTS MODELING: WEATHER-RELATED EVENTS, CYBER-ATTACKS, Generic Framework for Resilience Analyses, Damage Prevention, System Recovery, Survivability, enhancing power system resiliency.

Smart Grid Security Challenges
Security Goals and Challenges, Importance of security, Classification of the threats, Security Analytics for AMI and SCADA, Security Analytics for EMS Modules, Overview of SMT and Probabilistic Model Checking.

Security and Data Privacy in Smart Grid
Security Challenges in Smart Grid Implementation, Legal Protection of Personal Data in Smart Grid and Smart Metering Systems, Phases of smart grid system development cycle, Smart Grid Security and Privacy of Customer-Side Networks, Smart Grid Security Protection against

False Data Injection (FDI) Attacks, Smart Grid Security, Secure V2G Connections, End-to-End security with devices/equipment, sensors, controllers, actuators, communication and systems.

Smart Grid Threat and Cross-Domain Risk
Smart Grid threat Landscape, Smart Grid Risk Assessment, Challenges and solutions, Emerging methods and techniques for the smart grid security.

Smart Grid Resiliency and Cyber attack
Types of physical attack on smart grid devices, Hardware security modules, Analytics for Smart Grid Security and Resiliency, Cyber security solutions for control and monitoring system, Control centric security tools and risk assessment methodology, Secure Communications in Smart Grid: Networking and Protocols, Ukraine power plant cyberattack case study, European ENTSO-E cyberattack case study

Learning Resources:

Text Books:

1. Security and Resiliency Analytics for Smart Grids, Al-Shaer, Ehab, Rahman and Mohammad Ashiqur, Springer Intr., 1st Edition, 2016.
2. Smart Grid Security, S. Goel, Y. Hong, V. Papakonstantinou, D. Kloza, Springer-Verlag, 2015, 1st Edition.

Reference Books:

1. Security and Privacy in Smart Grid, A. Abdallah and X. Shen, *Springer Intr.*, 2018, 1st Edition.
2. Smart grids security challenges: Classification by sources of threat, Abdul Rahaman, Journal of Electrical Systems and Information Technology, 2018.
3. Power System State Estimation: Theory and Implementation, A. Abur and A. G. Exposito, CRC Press, 2004, 1st Edition.
4. Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers, Roy D. Yates, David J. Goodman, Wiley, 2014, 3rd Edition.
5. Smart Grid: Fundamentals of Design and Analysis, J. A. Momoh, Wiley India, 2015, 1st Edition.

Online Resources:

1. https://freevideolectures.com/course/4286/nptel-computer-aided-power-system-analysis/64

EE 5365	CLOUD COMPUTING & BIG DATA ANALYTICS IN SMART GRIDS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Enumerate research integrating cloud computing and big data applications for smart grid
CO2	Analyze the benefits of cloud computing and big data analytics for smart grid technology
CO3	Explore applications of big data and cloud computing
CO4	Evaluate current status of smart grid simulation tools

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction

Introduction to Cloud Computing in Smart Grid - Introduction to Big Data Analytics - Fundamental Mathematical Prerequisites, Big Data Era, General Security Challenges

Cloud Computing Applications for Smart Grid

Cloud computing in smart grid, Cloud computing architecture, Demand Response - Geographical Load- Balancing - Dynamic Pricing - Virtual Power Plant - Advanced Metering Infrastructure - Cloud-Based Security and Privacy

Smart Grid Data Management and Applications

Pricing and energy forecasting in Demand Response, case study on Energy Forecast, Smart Meter Data Management -PHEVs: Internet of Vehicles - Smart Buildings.

Smart Grid Design and Deployment

Attack detection, current problem and techniques, Secure Data Learning Scheme, Logical Security Architecture, Smart Metering Data Set Analysis—A Case Study, Security Schemes for AMI Private Networks, Simulation Tools- Worldwide Initiatives

Probability and Statistics

Random variable and sample space, empirical approach to probability - conditional probability - independent events - Bayes' Theorem, mathematical expectation - moment generating function - Chebyshev's inequality - Bernoulli trials - the Binomial, negative binomial, geometric, Poisson, normal, rectangular, exponential, Gaussian, beta and gamma distributions, sampling and large sample tests, chi- square test, theory of estimation, linear and polynomial fitting by the methods, correlation of bivariate frequency distribution.

Learning Resources:

Text Books:

1. Smart Grid Technology: A Cloud Computing and Data Management Approach, S. Misra and S. Bera, Cambridge University Press, 2018, 1st Edition.
2. Smart Grid Communication Infrastructure: Big Data, Cloud Computing and Security, F. Ye, Y. Qian and R.Q. Hu, Wiley IEEE Press, 2018, 1st Edition.

Reference Books:

1. Smart Grid: Fundamentals of Design and Analysis, James A. Momoh, Wiley India, 2015, 1st Edition.

EE 5366	TRANSACTIVE ENERGY MARKETS	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand Transactive Energy (TE)
CO2	Understand Transactive Energy Resources
CO3	Detail TE Techniques
CO4	Model TE and understand it's application

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		3	
CO2	3	1	2		2	
CO3	3		3	3	3	3
CO4	3	2	3		3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Transactive Energy (TE)
Potential impact of TE, Applications for Utilities and Distribution System Operators, Customer Applications

Renewable energy sources in a Transactive Energy market
Transactive Energy Products, Transactive Energy Market Participants, Transactive Energy Classification scheme for renewable market participants, Grid stability and protection, energy market management

Transactive Energy Techniques
Conceptual View of Distributed Power Generation and Management Transactive Energy Construct, End- to-End Transactions of Information, Prices and Power, Centralized and Decentralized Transactive Energy

Extension of Transactive Techniques from Wholesale to Retail
Price-based resource scheduling and dispatch, Congestion management, Transmission/distribution capacity auction, Market-clearing and pricing, End-to-End Transactive Solutions Closing the Gap between Wholesale and Retail.

Mathematical Modeling and Economic Interpretation of Transactive Energy-based distribution system, case studies

Transactive Energy Application to Modern Grid and concept of block chain techniques

Learning Resources:

Text Books:

1. eIoT: The Development of the Energy Internet of Things in Energy Infrastructure, S. O. Muhanji, A.E. Flint, A. M. Farid, Springer, 2019, 1st Edition.

EE5367	CHALLENGES AND SOLUTIONS IN RENEWABLE INTEGRATION	3-0-0: 3

Pre-Requisites: Dynamics of Renewable Energy Resources

Course Outcomes (COs):

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

CO1	Understand the available grid Codes for the renewable integration in multiple countries
CO2	Understand market and forecasting challenges due to uncertainties in renewables
CO3	Assess power quality and inertia issues with increased penetration of RES in electric grids
CO4	Evaluate solutions and apply for RES operational and uncertainty issues

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Energy System Challenges

Handling Renewable Energy Variability and Uncertainty in Power System Operation, short-term frequency response challenges in power systems with high nonsynchronous penetration levels, technical impacts of high penetration levels of wind power on power system stability, constraints to the transformation rate of global energy infrastructure, demand supply flexibility, Voltage control, inertia response

Overview of the grid codes, components of the grid codes, development of the grid codes, classification and specifications of the grid codes, anomalies in grid codes, Fault-Ride Through criterion.

Integration of Renewable Energy

The Indian Experience Policy initiatives, Regulatory initiatives, Transmission planning initiatives, Experience with RECs in India, Challenges

German Renewable Energy Sources Pathway: Increasing challenges of RES integration into the German electricity system.

Danish Case Study: The Danish markets for balancing the electricity system, making wind as a part of the balancing solution, an hour with negative prices for downward regulation, Challenges to participation in the tertiary reserve market, Decentralized combined heat and power plants of the balancing solution

Texas Case Study: Study of the impacts of wind generation on ancillary service, Ancillary service requirement methodology improvements to integrate wind generation resources, Regulation-up and - down reserve service

Photovoltaic Penetration in Distribution Network
Voltage imbalance sensitivity analysis, stochastic evaluation, Monte Carlo Evaluation, series and parallel custom power devices, dynamic and feasibility issues related to custom power, performance of grid connected solar photovoltaic system with MPPT controllers, mathematical model of grid connected three phase SPV system, performance evaluation of P&O and INC based MPPT algorithms, application of adaptive neuro fuzzy inference system (ANFIS) for control of DC-DC convertor for SPV system.

Market Operations and Forecasting Renewables
Analyzing the impact of variable energy resources on power system reserves, Advances in Market Management Solutions for Variable Energy Resources Integration, forecasting Renewable Energy for Grid Operations, Incorporating Forecast Uncertainty in Utility Control Center, Reserve Management for

Integrating Renewable Generation in Electricity Markets, Scandinavian Experience of Integrating Wind Generation in Electricity Market, Economics of renewable generation integration and long term power purchase agreements (PPA)

Solution for RES Uncertainties
Enabling and disruptive technologies for renewable integration, Enhancing situation awareness in power systems: overcoming uncertainty and variability with renewable resources, managing operational uncertainty through improved visualization tools in control centers with reference to renewable energy providers, Synchro phasors for distribution networks with variable resources, Monitoring and control of RES using synchronized phasor measurements.

Solution for Operational Issues
Virtual inertial, reactive power control in response to voltage deviations, use of energy storage systems, advanced control strategies to improve dynamic and transient response time, Derated operation of the renewable resources.

Learning Resources:

Text Books:

1. Renewable energy integration: Challenges and Solutions, J. Hossain and A. Mahmood, Springer- Verlag, 2014, 1st Edition.
2. Renewable Energy Integration Practical Management of Variability, Uncertainty, and Flexibility in Power Grids", Elsevier Inc., 2nd Edition, 2017.

Reference Books:

1. Integrating Variable Renewable Energy: Challenges and Solutions, L. Bird, M. Milligan, and D. Lew, Technical Report NREL/TP-6A20-60451 September 2013.
2. Challenges to Grid Integration of Renewable Energy in India, Akshay Urja, MNRE technical report, 2019.
3. Solar PV Integration Challenges, F. Katiraei and J. R. Aguero, IEEE Power and Energy Magazine, 2011.

EE5368	SMART ELECTRICAL DISTRIBUTION SYSTEM	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Understand structure and load patterns of a power distribution system
CO2	Model and analyse modern smart power distribution system
CO3	Analyse the performance of distribution power flow and short circuit studies
CO4	Suggest/follow Regulations and Market Models for Smart distribution system

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction

Fundaments of the Electrical Power Distribution System and feeder configuration, Distribution system loading, Load Characteristics, SAIDI, SAIFI, Distribution Transformer, Single phase and three Phase Transformer connections.

Distribution system Modeling

Impedance of distribution system, Modeling of distribution line, cables, Distribution Transformer, Distributed generation, loads and reactive power sources. Modeling and study of voltage regulators in distribution network.

Distribution System Analysis

Load flow for distribution system: Backward/forward method, Direct method, load flow application for weakly meshed distribution system, Short Circuit analysis: Sequence based, Thevenin Equivalent and Phase variable based, LG, LL, LLG, LLLG fault analysis and its applications.

Smart Distribution Technologies

Distribution automation, outage management systems, automated meter reading (AMR), automated metering infrastructure (AMI), Net Metering, Automated Fault Location, Isolation and Service Restoration, Outage Management Systems (OMS), Energy Storage, Renewable Integration, Microgrids. Impacts of microgrids, EV charging and roof top solar in smart electric distribution system.

Regulations and Market Models for Smart Distribution System

Demand Response, Tariff Design, Time of the day pricing (TOD), Time of use pricing (TOU), Consumer privacy and data protection, consumer engagement etc. Cost benefit analysis of smart grid projects.

Learning Resources:

Text Books:

1. Electric Power Distribution, A.S. Pabla, Tata McGraw Hill Publishing Co. Ltd., 2017, 4th Edition.

2. Electric Distribution Systems, Abdelhay A. Sallam and Om P. Malik, IEEE Press Series, 2019, 2nd Edition.

Reference Books:

1. Distribution System Modeling and Analysis, W. H. Kersting, CRC Press, 2017, 4th Edition.
2. Electric Power Substations Engineering, John D. McDonald (Editor), CRC Press, 2016, 3rd Edition.

EE5153	DIGITAL CONTROL SYSTEMS	3-0-0: 3

Pre-Requisites: Basic Control Systems

Course Outcomes (COs):

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

CO1	Evaluate the output of a digital system for a given input.
CO2	Describe the dynamics of a Linear, Time Invariant and Causal digital systems through difference equations.
CO3	Analyze digital systems using the Z-transformation.
CO4	Design digital controllers for Power Electronic Systems.

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	0	2	1	2	2
CO2	2	0	2	1	3	2
CO3	2	0	3	1	3	2
CO4	2	0	3	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Digital control systems - Quantizing and quantization error, Data acquisition, Conversion and distribution system

Z-Transform: Z-transform - Z-transforms of elementary functions, important properties and theorems, Inverse Z-transform, Z-transform method of solving difference equations

Z-Plane Analysis of Discrete-Time Control Systems: Impulse sampling and data hold, Pulse transfer function, Realization of digital controllers and digital filters, Mapping between s-plane and z-plane, Stability analysis of closed loop systems in z-plane, Transient and steady state analyses

State Space Analysis: State space representation of digital control systems - Solution of discrete time state space equations, Pulse transfer function matrix, Discritisation of continuous time state space equations, Lyapunov stability analysis

Pole Placement & Observer Design: Controllability, Observability

Quadratic Optimal Control Systems: Design via pole placement, State observers, Quadratic optimal control, Steady state quadratic optimal control, Quadratic optimal control of a servo system

Learning Resources:

Text Books:

1. M. Gopal: Digital control engineering, New Age Int. Ltd., 2nd Edition, 2014.
2. K. Ogata: Discrete time control systems, Pearson Education, 2nd Edition, 2006.

Reference Books:

1. Katsuhiko Ogata: Modern control Engineering, Pearson Education India, 5th Edition, 2015.
2. B.C. Kuo: Digital Control Systems, Oxford University Press, 2nd Edition, 2012.

EE5264	EVOLUTIONARY ALGORITHMS APPLICATIONS IN POWER ENGINEERING	3-0-0: 3

Pre-Requisites: None

Course Outcomes (COs):

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

CO1	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems
CO2	Examine the importance of exploration and exploitation of evolutionary algorithm to attain near global optimal solution
CO3	Distinguish the functioning of various evolutionary algorithms
CO4	Employ various bio-inspired algorithms for Power Engineering applications

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	0	3	0	0	0
CO2	3	0	3	0	0	0
CO3	3	0	3	0	2	0
CO4	3	0	3	0	0	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

FUNDAMENTALS OF SOFT COMPUTING TECHNIQUES- Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems

GENETIC ALGORITHM and PARTICLE SWARM OPTIMIZATION-Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem

ARTIFICIAL BEE COLONY ALGORITHM and DIFFERENTIAL EVOLUTION - Artificial bee colony (ABC) algorithms-binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units. The Motivation for Differential Evolution (DE), Introduction to Parameter Optimization, Single-Point, Derivative-Based Optimization, Local Versus Global Optimization, Differential Mutation, Recombination, Selection, Benchmarking Differential Evolution, DE Versus Other Optimizers, DE on Parallel Processors

SHUFFLED FROG-LEAPING ALGORITHM and BAT OPTIMIZATION ALGORITHM- Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation-

Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogs-comparison of memes and genes -memeplex formation- memeplex updation- BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem.

MULTI OBJECTIVE OPTIMIZATION- Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and applications.

Learning Resources:

Text Books:

1. Recent Advances in Swarm Intelligence and Evolutionary Computation, Xin-She Yang, Springer International Publishing, Switzerland, 2015, 1e
2. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley & Sons, 2001, 1e

Reference Books:

1. Swarm Intelligence-From natural to Artificial Systems, Eric Bonabeau, Marco Dorigo and Guy Theraulaz, Oxford university Press, 1999.
2. Swarm Intelligence, James Kennedy and Russel E Eberheart, The Morgan Kaufmann Series in Evolutionary Computation, 2001.
3. Artificial Intelligence and Intelligent Systems, N P Padhy, Oxford University Press, 2005.

EE6347	COMPREHENSIVE VIVA VOCE	2 Credits

Pre-Requisites: Both I & II Semester course work of I year

Course Outcomes (COs):

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

CO1	Assimilate knowledge of different courses studied.
CO2	Develop overall comprehension about Smart Electric Grids
CO3	Analyse real life Smart Electric Grid problems with knowledge learned
CO4	Interpret and Articulate solutions to practical Smart Electric Grid challenges

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		2	
CO2	3	1	2		1	
CO3	3		3	3	2	2
CO4	3	2	3		2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Entire course of study (All the required courses studied) up to II Semester of I Year

Learning Resources:

1. Reading Material of all the courses.
2. Case Studies/Industrial training reports.
3. Mini projects taken up.

EE6349	DISSERTATION PART – A	12 Credits

Pre-Requisites: Both I & II Semester course work of I year

Course Outcomes (COs):

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

CO1	Define Research Problem Statement.
CO2	Critically evaluate literature in chosen area of research & establish scope of work.
CO3	Develop a detailed study methodology.
CO4	Carry out mathematical and simulation study

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		3	
CO2	3	1	2	2	2	
CO3	3		3	3	3	2
CO4	3	2	3		3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

There is no prescribed syllabus. Students are required to search, collect and review various research articles published in chosen area of research. A student has to select a topic for his / her dissertation, based on his/her interest and the available facilities at the commencement of dissertation work. Students are required to submit a dissertation report on the research work carried out by him/her.

Learning Resources:

1. Journal Publications.
2. Conference / Seminar Proceedings.
3. Handbooks / Research Digests/Codebooks.

EE6399	DISSERTATION PART – B	20 Credits

Pre-Requisites: Both I & II Semester course work of I year, Dissertation Part-A

Course Outcomes (COs):

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

CO1	Expand on the defined Research Problem statement
CO2	Formulate the objectives and plan experimental / theoretical study.
CO3	Conduct Laboratory/analytical studies
CO4	Analyse Data, develop models and offer solutions

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		1		3	
CO2	3	1	2	2	2	
CO3	3		3	3	3	2
CO4	3	2	3		3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

There is no prescribed syllabus. Students are required to search, collect and review various research articles published in chosen area of research. A student has to select a topic for his / her dissertation, based on his/her interest and the available facilities at the commencement of dissertation work. Students are required to submit a dissertation report on the research work carried out by him/her.

Learning Resources:

1. Journal Publication.
2. Conference / Seminar Proceedings.
3. Handbooks / Research Digests/Codebooks.
4. Previous thesis books.

NOTE: Refer to the following link for the guidelines to prepare dissertation report:
https://www.nitw.ac.in/path/?dept=/nitwForms