ACADEMIC CURRICULA

POST GRADUATE DEGREE PROGRAMMES

Master of Technology

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 24
Syllabi for School of Electrical Engineering Programmes

Professional Core and Elective Courses

SRM INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

Power Systems

Professional Core Courses

Regulations 2021

SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21EEC501J	Course Name	MODERN POWER SYSTEM ANALYSIS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*represent and formulate the power system network*
CLR-2:	*apply different power flow methods for planning and operation of the power system*
CLR-3:	*analyze symmetrical and unsymmetrical faults in power system*
CLR-4:	*assess the security and reliability of the power system*
CLR-5:	*evaluate the transient stability of the power system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*develop the mathematical modeling of power system components and network*	*3*	*-*	*3*
CO-2:	*analyze the power system parameters using power flow studies*	*3*	*2*	*3*
CO-3:	*solve fault analysis in power system using suitable methods*	*3*	*2*	*3*
CO-4:	*perform the contingency and reliability analysis*	*3*	*2*	*3*
CO-5:	*apply the various methods to solve transient stability analysis*	*3*	*2*	*3*

Module 1- Mathematical Modeling of Power Networks	***15 Hour***
Per Unit Quantities, Modeling of power system components, Off nominal tap settings, Equivalent circuit of transformer and phase-shift transformer, Nodal Admittance Matrix, Basic Concept of Nodal Admittance Matrix, Formulation and Modification of Nodal Admittance Matrix, Solution to Electric Network Equations, Gauss Elimination Method, Triangular Decomposition and Factor Table, Sparse technique and near optimal ordering scheme, Nodal impedance matrix, Nodal impedance matrix using admittance matrix and branch addition method, Case study on admittance matrix and impedance matrix formation in IEEE test systems ***Laboratory Practice:*** *Ybus and Zbus formation using software tool, Triangular decomposition and gauss elimination method*	
Module 2 – Power Flow Analysis	***15 Hour***
Power system network model, Power flow analysis using Newton Raphson method, Decoupled and Fast decoupled methods, Control of voltage profile, System design and operation, static security analysis and compensation methods, DC power flow analysis, Outage analysis by DC load flow method, Computations of slack bus power, transmission losses, and power flow in power system, Power flow analysis in distribution networks, Case study on power flow studies in IEEE transmission and distribution systems ***Laboratory Practice:*** *Power flow analysis using simulation software coding and investigations*	
Module 3 – Symmetrical and Unsymmetrical Fault Analysis	***15 Hour***
Transients in RL series circuit, Voltage of loaded machine under fault condition, Symmetrical fault analysis using bus impedance matrix, Symmetrical components and sequence networks, Analysis of unsymmetrical fault at generator terminals, Analyzing unsymmetrical faults occurring at any point in a power system, Short circuit KVA, importance of short circuit current, Reactors construction and classification, Generator reactor, Feeder reactor, Bus bar reactor, Case study on selection and design of circuit breakers and relays ***Laboratory Practice:*** *Symmetrical and unsymmetrical fault analysis using simulation softwares*	
Module 4 – Security and Reliability Analysis	***15 Hour***

Factors effecting power system security, Contingency analysis, Zbus Methods in Contingency Analysis, Analysis of single contingencies and multiple contingencies in power system, calculation of bus voltages due to addition / removal of one line, Case study on AC power flow security analysis including contingency, concentric relaxation method, boundary area method, Basic concepts of probability theory, Probability of Stochastic Events, Random Variables and its Distribution, Numeral Character of Random Variable, Convolution of Random Variables, Several Usual Random Variable Distributions, Markov Process, Probabilistic Model of Power Systems, Fundamental Theory of Monte Carlo Simulation Method.   ***Laboratory Practice:*** *Contingency analysis in test systems using simulation tool, Monte carlo simulation analysis using simulation tool*
Module 5 – Transient Stability Analysis — ***15 Hour***
Numerical methods of Transient Stability analysis, Relationship between network and dynamic devices, Modeling of switching and faults, Numerical integration methods for transient stability analysis, Transient stability analysis with FACTS devices, Case study on Explicit integration techniques and Implicit integration techniques, Sequence impedances of synchronous machines, Direct method of transient stability analysis, Transient stability enhancement methods.   ***Laboratory Practice:*** *RK and Eulers method using simulation softwares, Equal area criterion analysis using simulation models*

Learning Resources	1. *D.P.Kothari, I J Nagrath, R K Saket, Modern Power System Analysis, 5th Edition, Tata McGraw Hill, 2022.* 2. *John J Grainger, William D Stevenson, Power System Analysis, Tata McGraw Hill 2017* 3. *Hadi Saadat, Power System Analysis, Tata McGraw Hill, 1998.*	4. *R.Jegatheesan, K.Vijayakumar, Modern Power System Analysis with MATLAB applications, Pearson India Education Services Pvt.Ltd, 2020* 5. *Pai, Chatterjee, Computer Techniques in Power System Analysis, 3rd Edition, Tata McGraw Hill, 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life Long Learning CLA-2- Practice (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	-	10%	20%	-
Level 2	*Understand*	30%	-	-	10%	30%	-
Level 3	*Apply*	30%	-	-	20%	30%	-
Level 4	*Analyze*	20%	-	-	20%	20%	-
Level 5	*Evaluate*	-	-	-	20%	-	-
Level 6	*Create*	-	-	-	20%	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Sudarshan, Schneider Electric	*1. Dr. K. Shanthi Swarup, IIT Madras*	*1. Dr C Nithya, SRMIST*
2. Mr. Saravanan, L &T	*2. Dr.D.Devaraj, Kalasalingam Academy of Research and Education*	*2. Dr. J.Preetha Roselyn, SRMIST*

Course Code	21EEC502J	Course Name	ADVANCED TOPICS IN OPERATION AND CONTROL OF POWER SYSTEMS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*examine the economic operation of power system*
CLR-2:	*illustrate the voltage and frequency control for secure operation of power system*
CLR-3:	*apply different methods to solve security constrained optimal power flow problem*
CLR-4:	*solve and interpret the state estimation and load forecasting problem*
CLR-5:	*outline the operation of deregulated power system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze and distinguish the problem methodologies associated with economic load dispatch, hydro thermal scheduling and unit commitment*	*3*	*-*	*2*
CO-2:	*develop the static and dynamic model for automatic voltage and frequency control*	*3*	*1*	*2*
CO-3:	*illustrate the importance of contingency analysis and to evaluate the solution for optimal power flow problem*	*3*	*3*	*2*
CO-4:	*formulate and solve problems related to state estimation and load forecasting*	*2*	*2*	*1*
CO-5:	*elucidate the framework and operation of modern energy market*	*2*	*-*	*1*

Module 1 - Optimal Generation Scheduling	***17 Hour***
Economic load dispatch, Economic load dispatch using Lagrange multiplier method, penalty factor, economic load dispatch with network losses, hydrothermal coordination with and without losses, cascaded and pump storage plant scheduling, unit commitment, unit commitment solution methods. ***Laboratory Practice****: Simulation/ Programming to solve Economic load dispatch problem with and without losses, Hydrothermal scheduling problem, Unit commitment*	
Module 2 - Generation Control	***18 Hour***
Plant and system level controls, types of alternator exciters, automatic voltage regulators for generator excitation control, static and dynamic performance of AVR loop, automatic load frequency control, primary automatic load frequency control loop, secondary automatic load frequency control loop, extension of automatic load frequency control loop to multi area systems, tie line power flow model. ***Laboratory Practice****: Simulation of Automatic Load frequency control in single area system and two area system and Automatic voltage regulator*	
Module 3 - Optimal Power Flow	***15 Hour***
Security analysis, security assessment, contingency analysis, algorithm to determine system security using contingency analysis, security assessment using AC power flow model, security analysis using concept of performance index, introduction to optimal power flow solution using Newton Raphson method, Security constrained Optimal Power Flow, Interior point algorithm. ***Laboratory Practice****: Contingency and Optimal Power flow solution for standard IEEE systems using simulation tools*	
Module 4 - State Estimation and load forecasting	***15 Hour***

Methods of state estimation – least square and weighted least square estimation, bad data detection and suppression of bad data, load forecasting, load forecasting techniques – methods of extrapolation and correlation, estimation of average and trend terms of deterministic part of load – limitation of the method, prediction of deterministic load, generalized load modeling, estimation of periodic components, estimation of stochastic part of load – time series approach. ***Laboratory Practice**: State estimation and load forecasting using simulation tools*
Module 5 – Operation of Modern Power System ***10 Hour***
Introduction to smart grid and deregulated markets, Principle of economics, utility functions, power exchanges, electricity market models, market power indices, ancillary services, transmission and distribution charges, principles of transmission charges, transmission pricing methods, demand-side management, regulatory framework. ***Laboratory Practice:** OPF in deregulated power system including congestion and bidding cost*

Learning Resources	1. *Elgerd O.I. Electric Energy Systems Theory – An Introduction, 2nd Edition., Tata McGraw-Hill Publishing Company Limited, 2017.* 2. *Nagrath I. J. and Kothari D. P., Power System Engineering, 3rd Edition. Tata Mc-Graw Hill Publishing Company, 2019.* 3. *Wood A. J. and Wollenberg B. F., Power Generation, Operation and Control, 3rd Edition, Willey – Inter Science Publications, 2013.*	4. *Kundur P. and Balu N. J., Power System Stability and Control, 1st edition, McGraw-Hill International Book Company, 2006.* 5. *Hadi Saadat., Power System Analysis,3rd edition, Tata McGraw-Hill Publishing Company Limited, 2010.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2- Practice (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	-	20%	20%	-
Level 2	Understand	20%	-	-	20%	20%	-
Level 3	Apply	30%	-	-	20%	30%	-
Level 4	Analyze	30%	-	-	20%	30%	-
Level 5	Evaluate	-	-	-	10%	-	-
Level 6	Create	-	-	-	10%	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Bhaskarsahu, Schneider Electric Ltd.	1. Dr. K. S. Swarup, IIT Madras	1. Dr. D.Suchitra, SRMIST
2. Mr. K.Senthilkumar, CPCL	2. Dr. C.Nayanatara, Sai Ram Engineering College	2. Dr. J.Preetha Roselyn, SRMIST

Course Code	21EEC503J	Course Name	ADVANCED PROTECTION SCHEMES IN POWER SYSTEMS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	**Data Book / Codes / Standards**	*National Electrical Code of India, ANSI Standards*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*illustrate the principle of digital protection in power system*
CLR-2:	*develop a comprehensive understanding of overcurrent protective devices, coordination strategies, and relevant standards*
CLR-3:	*analyze various relaying scheme for digital protection of transformer, generator and busbar*
CLR-4:	*examine and configure protective schemes for transmission lines*
CLR-5:	*familiarize with the advanced protection in power system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*familiarize the operation of static and numerical relay*	*2*	*2*	*2*
CO-2:	*demonstrate the fundamental principles and techniques of overcurrent protection*	*3*	*2*	*2*
CO-3:	*illustrate the application of differential protection scheme for transformers, generators and bus bar*	*3*	*2*	*3*
CO-4:	*implement distance and carrier-aided protection for transmission lines*	*3*	*-*	*3*
CO-5:	*investigate different issues in digital protection systems*	*2*	*-*	*2*

Module 1 – Overview of Static and Numerical Relays ***15 Hour***

Introduction and Philosophy of a Protective Relaying System, Characteristic functions of protective relays, Basic relay terminology, Introduction to Static Relays, Advantages of static relays over Electromagnetic Relays, Limitations, Basic construction of static relays, Practical non-critical switching circuits and critical level detectors, Influence of protective relays on associated equipment, Amplitude Comparator, Phase Comparator, Duality Between Amplitude and Phase Comparators, Performance and operational characteristics of digital protection, Basic structure of digital relays, Mathematical background to protection algorithms, Basic elements of digital protection, Numerical Relay, Comparison between electromechanical relay and numerical relay, Block Diagram of Numerical relay, Data Acquisition System, Numerical Relaying Algorithms, Numerical Overcurrent Protection, Numerical Distance Protection, Numerical Differential Protection, Microprocessor based Numerical Protective Relays, Artificial Intelligence based Numerical Protection, Introduction to IEC61850, Substation Automation Systems.

Laboratory Practice: *Study of Protection philosophy and protection scenario in India, Testing and Maintenance aspects of Digital relays, Case study on Testing standards for relays.*

Module 2 – Overcurrent Protection Schemes ***15 Hour***

Time-current characteristics, Current Setting, Time Setting, Overcurrent Protective Schemes, Reverse Power/Directional Relay, Directional Overcurrent Relay, Protection of Parallel Feeders and Ring Mains, Earth Fault and Phase Fault Protection, Combined Earth Fault and Phase Fault Protection Schemes, Directional Earth fault Relay, Static Overcurrent Relays, Numerical Overcurrent Relays, Overcurrent Relay Coordination, Relay Coordination with Fuse, National Electrical Code of India, IEC standards, ANSI Standards for Protection system.

Laboratory Practice: *Modeling and Analysis of Overcurrent Relay, Design of Overcurrent Relay Coordination for a sample system, Case study on difference between 0.2 and 0.2S Class Accuracy of Current Transformer and Potential Transformer.*

Module 3 - Differential Protection Schemes ***18 Hour***

Transformer Protection: Faults in Transformer, Inrush phenomenon, High resistance Ground Faults in Transformers, Inter-turn faults in transformers, Incipient faults in transformers, Phenomenon of over-fluxing in transformers, Transformer protection schemes, Overcurrent protection, Protection Percentage Differential Protection, Digital Protection of Transformer. Generator Protection: Complexities of

generator protection, Electrical circuit of the generator, Faults in Generator, Stator Faults, Transverse Differential Protection, Rotor Faults, Abnormal operating conditions in generator, Generator protection schemes, Differential Protection of generators, Merz-Price Protection, Digital Protection of Generator. Busbar Protection: Differential Protection of Busbars, External and Internal Fault, Behaviour of Protective CT, Circuit Model of saturated CT, External Fault with One CT Saturated, Need for High Impedance Busbar Protection, Minimum Internal Fault detection by High Impedance Busbar Differential Scheme, Stability Ratio of High Impedance Busbar Differential Scheme, Supervisory Relay, Protection of Three-phase Busbars, Numerical Example on Design of High Impedance Busbar Differential Scheme. ***Laboratory Practice:*** *Testing of Transformer Differential Protection Relay, Testing of Generator Protection Relay, Design of Bus Bar Protection scheme.*
Module 4 – Digital Distance Protection ***18 Hour***
Distance Protection, Drawbacks of Overcurrent Protection, Simple Impedance Relay, Reactance Relay, Mho Relay, Effect of arc Resistance on reach of Relays, Performance of Relays during Normal Load Flow and Power Swing, Comparison between Distance Relays, Distance Protection of Three-phase Line, Reasons for Inaccuracy in Distance Relay Reach, Three-stepped Distance Protection, Trip Contact Configuration - Three-stepped protection of three-phase line against all ten shunt faults - Three-stepped protection of double-end-fed lines - Need for Carrier-aided Protection – Various Options for a Carrier, Coupling and trapping carrier into desired line section, Unit type carrier-aided directional comparison relaying, Carrier-aided Distance schemes for acceleration of zone II, Phase Comparison Relaying (Unit Scheme), Travelling Wave Relays. ***Laboratory Practice****: Simulation and Testing of Distance Protection Relay, Distance Protection Schemes for Transmission Lines based upon fundamental signal, Digital Protection of EHV/UHV transmission Line.*
Module 5 – Advanced Protection ***9 Hour***
Use of communication networks in protection, Smart Grid implications, Cybersecurity considerations, Cyber physical system, Wide-Area Measurement Systems (WAMS) based protection schemes, Protection Coordination and Selectivity, Protection System Testing and Maintenance, Reliability and Security of protection systems, Protection issues due to integration of renewable energy sources, Human Factors in Protection Systems, Power Quality issues in protection schemes, Legal and Regulatory Aspects.

Learning Resources	1. *Y.G. Paithankar and S.R Bhide, Fundamentals of Power System Protection, Prentice-Hall of India, second edition, 2013.* 2. *Badri Ram and D.N. Vishwakarma, Power System Protection and Switchgear, McGraw Hill Education, second edition, 2017.*	3. *Salman K. Salman and A.T. Johns, Digital Protection for Power Systems, The Institution of Engineering and Technology, second edition, 2022.* 4. *T.S. Madhava Rao, Digital/Numerical Relays, Tata McGraw-Hill Pub. Co., 2005.* 5. *National Electrical Code of India.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 -Practice (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	20%	-	-	20%	20%	-
Level 2	*Understand*	20%	-	-	20%	20%	-
Level 3	*Apply*	30%	-	-	30%	30%	-
Level 4	*Analyze*	30%	-	-	10%	30%	-
Level 5	*Evaluate*	-	-	-	10 %	-	-
Level 6	*Create*	-	-	-	10%	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. G Hanmanthrao, CPCL*	1. *Dr. K. Shanthi Swarup, IIT Madras*	1. *Dr. R. Ramya, SRMIST*
2. *Mr. Pithani Chaitanya Prasad, CPCL*	2. *Dr. C. Nayanatara, Sri Sai Ram Engineering College*	2. *Mr. D. Ravichandran, SRMIST*

Course Code	21EEC504J	Course Name	POWER SYSTEM DYNAMICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*21EEC501J*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*illustrate the modelling of synchronous machine*
CLR-2:	*enumerate the modeling of excitation and speed governing systems for generator*
CLR-3:	*perform the small-signal stability analysis on single machine and multi machine system*
CLR-4:	*analyze the impact of small signal stability on single machine infinite bus system with AVR and PSS*
CLR-5:	*analyze the transient stability in power system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*formulate the mathematical representation for synchronous machine*	*3*	*-*	*3*
CO-2:	*model the excitation and speed governing systems*	*3*	*-*	*3*
CO-3:	*apply small signal stability analysis for single machine infinite bus system*	*3*	*-*	*3*
CO-4:	*develop small signal stability model for single machine infinite bus system with AVR and PSS*	*3*	*2*	*3*
CO-5:	*explain the effect of subsynchronous oscillations in power system*	*3*	*2*	*3*

Module 1 - Synchronous Machine Theory and Modeling — ***15 Hour***

Basic concepts, Definitions and classifications, Rotor angle stability, Voltage stability and voltage collapse, Mid- Term and Long-Term stability, Synchronous Machine-Schematic Diagram, Physical Description, Armature and field structure, machines with multiple pole pairs, MMF waveform due to single and number of coils, MMF wave shapes on stator and rotor, Mathematical Description of a Synchronous Machine, Basic equations of a synchronous machine, Voltage and inductance equations on stator and rotor, Stator and rotor flux linkages in dq0 components, Per Unit system representation for stator and rotor, Equations of Motion: Swing equation, Representation in system studies, Synchronous Machine Representation in Stability Studies: Neglecting the effect of speed variations on stator voltages, Determination of synchronous machine parameters, Reactive capability limits of synchronous machines., simplified model with amortisseurs neglected, constant flux linkage model.

Laboratory Practice: *Determination of synchronous machine parameters in SMIB system, Swing equation calculations in SMIB system under different conditions*

Module 2 – Modelling of Excitation Systems — ***15 Hour***

Excitation System Requirements, Elements of an Excitation System, Types of Excitation System, DC excitation system, AC excitation System, Dynamics performance measures with excitation system, Control and protective functions: AC and DC regulators, Excitation system stabilizing circuits, Power System Stabilizer, Underexcitation limiter, Overexcitation limiter, volts-per-hertz limiter and protection, Load compensation, Field shorting circuits, Modelling of excitation systems: Per unit system with numerical examples, AC exciters and excitation system stabilizing circuit, Detailed excitation system model, IEEE type DC1A and AC1A excitation system models, Hydraulic turbines and governing systems, Hydraulic turbine transfer function, Case study on governors for hydraulic turbine, Steam turbines and governing systems, Modelling of steam turbine, Steam turbine controls.

Laboratory Practice: *Simulation of steam turbine governor model, Simulation of hydraulic turbine governor model, Simulation of DC, AC and IEEE excitation systems*

Module 3 – Small Signal stability in SMIB System — ***15 Hour***

Fundamental Concepts of Stability of Dynamic Systems, State space representation, Stability of dynamic system, Linearization and analysis of stability, Eigen properties of the state matrix, Eigenvalues, eigenvectors and Modal matrices, Eigenvalue and stability, Mode shape, eigenvalue sensitivity and participation factor, The concept of complex frequency, Relation between Eigen properties and transfer function, Numerical

examples of Eigen properties of the state matrix, Numerical examples of Eigenvalues based stability analysis, Single-Machine Infinite Bus (SMIB) Configuration, Classical Machine Model stability analysis, Numerical examples of SMIB classical model stability analysis, Stability analysis of SMIB including effect of field flux, Expression for the K constants in the expanded form, Special techniques for analysis of very large systems **Laboratory Practice:** Simulation of small signal stability analysis of classical SMIB system, Simulation of small signal stability analysis of SMIB system including field flux, Simulation of modal and eigen value analysis in power system
Module 4 – Small signal stability in SMIB including AVR and PSS **15 Hour**
Effects of Excitation System, Equations with definitions of appropriate K-constants, Simple Thyristor excitation system, AVR modelling, Analysis of excitation system with AVR, Numerical example for excitation system with AVR, Principle of Power System Stabilizer, Block diagram with the excitation system, Analysis of effect of AVR on synchronizing and damping components, Illustration of principle of PSS application with numerical example, Block diagram with AVR and PSS, Block diagram of PSS with description, System state matrix including PSS, Multi-Machine Configuration: Equations in a common reference frame, Equations in individual machine rotor coordinates, Illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines, Power System Stabilizer on SSS, Delta omega Stabilizer on SSS, Stabilizer based on shaft speed signal, Delta-P omega stabilizers. **Laboratory Practice:** Simulation of small signal stability analysis in SMIB including AVR, Simulation of small signal stability analysis in SMIB including AVR and PSS, Study of Delta omega and Delta P omega stabilizers
Module 5 – Subsynchronous Oscillations in Power Systems **15 Hour**
Turbine generator torsional characteristics, Torsional interaction with power system controls: Generator excitation, speed governors, Subsynchronous resonance, Characteristics of series compensated transmission systems, Self excitation due to induction generator effect, Torsional interaction, Countermeasures to SSR problems, Impact of network switching disturbances, Hydro generator torsional characteristics. **Laboratory Practice:** Simulation of series compensated transmission networks, Simulation of Torsional interaction with power system control

Learning Resources	1. Prabha Kundur, Power System Stability and Control, 1st Edition, Tata McGraw Hill, 2006. 2. Ramnujam R, Power System Dynamics: Analysis and Simulation, PHI Learning Pvt Ltd, 2009 3. Jan Machowski, Zbigniew Lubosny, Janusz W Bialek, James R Bumby, Power System Dynamics: Stability and Control, 3rd Edition, Wiley, 2020.	4. Peter W Sauer, M A Pai, Joe H Chow, Power System Dynamics and Stability, 2nd Edition, Wiley, 2017. 5. Abhijit Chakrabarti, Power System Dynamics and Simulation, PHI Learning Pvt Ltd, 2013

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life Long Learning CLA-2- Practice (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	-	10%	20%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	30%	-
Level 5	Evaluate	10%	-	-	10%	-	-
Level 6	Create	-	-	-	10%	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr N Vedachalam, NIOT	1. Dr. K. Shanthi Swarup, IIT Madras	1. Dr. J.Preetha Roselyn, SRMIST
2. Mr. D Sudharsan, Schneider Electric	2. Dr.D.Devaraj, Kalasalingam Academy of Research and Education	2. Dr K Vijayakumar, SRMIST

Course Code	21EEC505T	Course Name	ADVANCED TOPICS IN POWER SYSTEMS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*21EEC501J*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*classify and comprehend the different aspects of voltage stability in transmission line*
CLR-2:	*summarize the generation and load aspects in voltage stability*
CLR-3:	*impart in-depth knowledge on the voltage instability mechanisms and analytical methods*
CLR-4:	*acquire knowledge on voltage stability assessment and enhancement methods*
CLR-5:	*get insight on the impact of renewables on power system stability*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze the power system stability and transmission aspects in power systems*	*3*	*-*	*3*
CO-2:	*evaluate the generator stability for various load model*	*3*	*-*	*3*
CO-3:	*infer the performance of power system under instability conditions using different analytical methods*	*3*	*-*	*3*
CO-4:	*examine the preventive and control actions during instability conditions in power system*	*3*	*2*	*3*
CO-5:	*analyze the power stability aspects with the inclusion of renewable energy in power system*	*3*	*2*	*3*

Module 1 - Stability Classifications and Transmission Aspects of Voltage Stability	***9 Hour***
Power system stability classification, Maximum deliverable power in SMIB, Power voltage relationships, Characteristics of voltage instability, Generator reactive power requirement in uncompensated line, Effect of compensation, Expression of maximum power angle at voltage stability limit, Voltage regulation of transmission line, VQ curves, Effect of tap changing transformers, Factors affecting voltage stability, medium and long term voltage stability, Voltage collapse, Voltage security.	
Module 2-Generation and Load Aspects of Voltage Stability	***9 Hour***
Review of synchronous machine theory, Frequency and voltage controllers, Limiting devices affecting voltage stability, Voltage reactive power characteristics of synchronous generators, Capability curves, Effect of machine limitations on deliverable power, Constant power model, Polynomial and Exponential loads, Voltage dependency of loads, Load restoration dynamics, Induction motors, Thermostatic load recovery, Generic aggregate load models, HVDC links, Effect of system reactance and load power factor on voltage stability.	
Module 3 – Instability Mechanisms and Analytical Methods	***9 Hour***
Differential equations, Bifurcation analysis, Differential algebraic equations, multiple time scales, Time scale decomposition, Equilibrium equations of voltage stability, Loadability limits, Sensitivity analysis, Eigen vector and singular vector properties, Static analysis methods for voltage stability: Eigen value analysis, Sensitivity analysis, Bifurcation analysis, Static analysis indices of voltage stability, Continuation power flow analysis, Transient voltage stability: Time domain simulation method, Energy function method, Non linear dynamic model, Contingency ranking methods for voltage stability studies.	
Module 4 – Voltage Stability Assessment and Enhancement	***9 Hour***
Stability criteria, critical load demand and voltage collapse, Analysis of medium and long term voltage stability scenarios, countermeasures to short term voltage stability, countermeasures to long term voltage stability, Contingency evaluation, loadability limit computation, Reactive power compensation of transmission systems, Preventive and Corrective control of voltage stability, Adaptive load shedding for stability improvement, Effect of FACTS devices on voltage stability, Voltage stability assessment using synchrophasor technology.	
Module 5 – Impact of Renewables on Power System Stability	***9 Hour***

Induction generators coupled to the grid, Fault behavior of induction generators, Influence of wind generators on power system stability, Inertia in conventional power system, Virtual inertia, Impact of renewables integration on system inertia, Impact of solar PV and wind systems integration on voltage stability.

Learning Resources	*1. Cutsem T.V. and Vournas C., Voltage Stability of Electric Power Systems, springer media LLC, 2008* *2. Kundur P,Om P Malik, Power System Stability and Control, 2nd edition, McGraw-Hill professionals ,2023.* *3. Ramanujam R., Power System Dynamics, Analysis and Simulation, PHI Learning, New Delhi, 2010.*	*4. Padiyar K. R., Power system dynamics: stability and control, BS publications, 2002.* *5. Abhijit Chakrabarti, D.P. Kothari, A.K. Mukhopadhyay and Abhinandan De, An Introduction to Reactive Power Control and Voltage Stability in Power Transmission Systems, PHI Learning Private Ltd., 2010.* *6. Yong Tong, Voltage stability analysis of power system, Springer, 2021.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr.N.Vedachalam, NIOT	*1. Dr.Shanti Swarup, IIT Madras*	*1. Dr.R.Rajarajeswari, SRMIST*
2. Mr.D.Sudharshan, Schneider Electric	*2. Dr. V.Gomathi, College Of Engineering Guindy, Anna University*	*2. Dr J Preetha Roselyn, SRMIST*

ACADEMIC CURRICULA

Power Systems

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21EEE621T	Course Name	MODERN OPTIMIZATION TECHNIQUES IN POWER SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*develop a comprehensive understanding of optimization techniques*
CLR-2:	*analyze the optimization approach in power system operation*
CLR-3:	*evaluate control and stability of power system using optimization approach*
CLR-4:	*analyze the multi objective optimization problem using modern optimization approaches*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*comprehend the mathematical optimization techniques*	*2*	-	-
CO-2:	*apply optimization models in operation of power systems*	*3*	*2*	-
CO-3:	*apply intelligent models in power system stability and control*	*3*	*2*	*3*
CO-4:	*acquire knowledge of multi-objective optimization in power system problems*	*3*	*2*	*3*

Module 1 - Optimization Techniques ***9 Hour***

Optimization techniques, Unconstrained and Constrained optimization, Conventional Techniques, Definition of optimization problems and Classification of optimization problems, Pontryagin's Maximum Principle, Optimality conditions, Linear programming, Nonlinear programming, Quadratic programming, Mixed integer programming, Classical OPF, Classical unit commitment, Simulated annealing, Tabu search algorithm, Drawbacks in conventional methods, Fundamentals of Evolutionary algorithms, Evolutionary Strategy and Evolutionary Programming, Genetic Algorithm: Solution coding, Fitness Function, Genetic Algorithm operators: Selection, Crossover, Mutation, Constraint handling, Issues in GA implementation, Particle Swarm Optimization, Ant Colony Optimization

Module 2 – Optimization Approach in Power System Operation ***12 Hour***

Problem statement of Economic dispatch and unit commitment, GA for economic dispatch, PSO for unit commitment, Tabu search for unit commitment, OPF problem formulation: Objective functions and constraints, Cost minimization and active loss minimization using evolutionary approach, Generation scheduling using GA/PSO, Hydrothermal scheduling formulation using evolutionary models, Case study on OPF using evolutionary model

Module 3 – Optimization Approach in Power System Control and Stability ***12 Hour***

Transmission system expansion planning using optimization, Load frequency control and voltage controllers optimal tuning using GA, Angle stability improvement using optimal design of PSS parameters, Distribution network optimal reconfiguration, optimal capacitor placement and sizing in distribution systems, Optimal design of controllers for voltage stability improvement

Module 4 – Multi Objective Optimization for Power System ***12 Hour***

Basic concept of Multi objective analysis- Conventional approaches for MOOP, Concept of Pareto optimality, Multi objective GA, Problem formulation, Fitness assignment, Sharing function, Economic Emission dispatch using MOGA, Multi objective PSO, Dynamic neighborhood PSO, Vector evaluated PSO, Non dominated sorting GA, Multi objective OPF formulation, Generating Nondominated Set, Weighting method-, Hierarchical Cluster technique, Case Study on MOOP in OPF problem using MOGA

Learning Resources	*1.James A. Momoh, Mohamed E. El-Hawary, Electric Systems, Dynamics, and Stability with Artificial Intelligence Applications, Power Engineering – CRC Press, 2000.* *2.Erik Cuevas, Emilio Barocio Espejo, Arturo Conde Enríquez., Metaheuristics Algorithms in Power Systems, Springer International Publishing, 2019*	*3.Ahmed F. Zobaa, Alfredo Vaccaro, Computational Intelligence Applications in Smart Grids_ Enabling Methodologies for Proactive and Self-Organizing Power Systems, Imperial College Press, 2015* *4.Kalyanmoy Deb, Multi objective optimization using Evolutionary Algorithms, John Wiley and Sons, 2008.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Muralikrishnan, Edutech India Pvt Ltd	*1. Dr. Somasundaram, Anna University*	*1. Dr. D.Sattianadan, SRMIST*
2. Deb Singdeo, Mathworks	*2. Dr. Shanti Swarup, IIT Madras*	*2. Dr. J. Preetha Roselyn, SRMIST*

Course Code	21EEE622T	Course Name	RESTRUCTURED ELECTRICAL POWER SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*describe the behavior of deregulated markets in power system*
CLR-2:	*describe the technical and non-technical issues in deregulated power industry.*
CLR-3:	*identify the methods of local marginal prices calculation in transmission and the function of financial transmission*
CLR-4:	*analyze the energy and ancillary services management in deregulated power industry.*
CLR-5:	*discriminate the restructuring framework in Indian and other power sectors*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	*Program Outcomes (PO)*		
		1	*2*	*3*
CO-1:	*describe the requirement for deregulation of the electricity market and the principles of market models in restricted power systems.*	*3*	*-*	*-*
CO-2:	*analyze the methods of congestion management in restricted power systems.*	*3*	*3*	*2*
CO-3:	*analyze the locational marginal pricing and financial transmission rights in restricted power systems.*	*3*	*2*	*2*
CO-4:	*analyze the ancillary services management in restricted power systems.*	*3*	*2*	*2*
CO-5:	*differentiate the framework of Indian and other power sectors*	*3*	*-*	*-*

Module 1 - Introduction to Restructuring of Power Industry	***6 Hour***
Reasons for restructuring, Understanding the restructuring process, objectives of deregulation of various power systems across the world, Consumer behavior, Supplier behavior, Market equilibrium Short-run and Long-run costs, Various costs of production.	
Module 2 - Transmission Congestion Management	***9 Hour***
Importance of congestion management in deregulated environment, Classification of congestion management methods, Calculation of ATC, Non-market methods, Market based methods, Nodal pricing - Inter-zonal Intra-zonal congestion management, Price area congestion management, Capacity alleviation method.	
Module 3 - Locational Marginal Prices and Financial Transmission Rights	***10 Hour***
Fundamentals of locational marginal pricing, Lossless DCOPF model for LMP calculation, Loss compensated DCOPF model for LMP calculation, ACOPF model for LMP calculation, Risk Hedging Functionality of financial Transmission Rights, FTR issuance process, Treatment of revenue shortfall, Secondary trading of FTRs, Flow Gate rights, FTR and market power	
Module 4 - Ancillary Service Management and Pricing of Transmission Network	***10 Hour***
Types of ancillary services, Load-generation balancing related services, Voltage control and reactive power support services, Black start capability service, Mandatory provision of ancillary services, Markets for ancillary services, Co-optimization of energy and reserve services, International comparison, Pricing of transmission network: wheeling, principles of transmission pricing, transmission pricing methods, Marginal transmission pricing paradigm, Composite pricing paradigm -loss allocation methods.	
Module 5 – Market Evolution	***10 Hour***
The Philosophy of Market Models, Market models based on contractual arrangements, Market architecture, *US Markets, The ERCOT Market, Standard Market Design (SMD), PJM market, Nordic power market, Comparison of power markets, Framework of Indian power sector, Reform initiatives during 1990-1995, Availability based tariff (ABT), Electricity Act 2012, Open Access issues, Power exchange*	

Learning Resources		
Learning Resources	1. *Kankar Bhattacharya, Math H.J.Boolen, and JaapE. Daadler, Operation of restructured power systems, Kluwer Academic Pub., 2001.* 2. *Paranjothi, S.R., Modern Power Systems The Economics of Restructuring, New Age International Publishers, First Edition: 2017.* 3. *Sally Hunt, Making competition work In electricity,John Willey and SonsInc,2002.*	4. *Steven Stoft, Power System Economics: Designing Markets for Electricity, Wiley IEEE Press, 2002.* 5. *A. Khaparde, A. R. Abhyankar, Restructured Power Systems, NPTEL Course, https://nptel.ac.in/courses/108101005/.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1.Dr.S.Sambath, TANGEDCO	1. Dr Shanti Swarup, IIT Madras	1. Dr.C.Subramani, SRMIST
2. Dr N Vedachalam, NIOT	2. Dr. R,Ramesh, Anna University,	2. Dr.S.Vidyasagar, SRMIST

Course Code	21EEE623T	Course Name	TRANSIENTS IN POWER SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*outline the concepts of travelling wave phenomena and the effects of over voltages*
CLR-2:	*analyze the parameters of overhead lines and underground cables under transient conditions*
CLR-3:	*impart knowledge in modelling of power system transients*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply the knowledge to analyze issues on travelling wave phenomena, lightning, switching and temporary over voltages*	*3*	*2*	*3*
CO-2:	*develop the model and analyze the performance of overhead lines parameters and underground cables parameters*	*3*	*2*	*3*
CO-3:	*analyze the different features and capabilities of power system transients using electromagnetic transient analysis*	*3*	*2*	*3*

Module 1 - Travelling wave and Transients	***18 Hour***
Basic Concepts and Switching Transients, Travelling Waves, Velocity of travelling waves and characteristic impedance, Energy of travelling waves, Attenuation and distortion of electromagnetic waves, Telegraph equations, Forward and backward travelling waves, Wave propagating in distortionless line, Reflection of travelling waves in transformer windings, Reflection of travelling waves in generator windings, Origin of transient recovery voltages, Switching overvoltages, Resistance switching, Load switching, Interrupting capacitive currents, Back-to-back switching, Capacitor switching for voltage regulation, Interrupting small inductive currents, Transformer inrush current, Line fault, Lightning induced transients, Mechanism of lightning, Waveshape of lightning current, Direct lightning stroke in transmission line towers, Direct lightning stroke in transmission lines, Interaction between lightning and power network, Case study on misoperation of proactive and switching equipment during source-side fault and transients in bank to bank capacitor switching.	
Module 2 – Transients on Overhead Transmission Lines, Underground Cables and Transformer	***18 Hour***
Transients in Overhead line parameters, Line parameters for simple configurations, Series resistance in transmission line conductor, Series inductance in single conductor, two conductor and multi conductor lines, Shunt capacitance in two-conductor line, Modal propagation in transmission lines, Analysis of modal propagation in transposed multiphase transmission lines, α-β-0 transformation and modal transformation equations, Normalization of transformation from α-β-0 transformation, Transients in underground cables parameters, Technical features of underground cables, Electrical parameters in underground cables, Series impedance and shunt admittance matrix of coaxial cable, Impedance and admittance matrices for three phase system in three single core self-contained cables, Earth return impedances estimation in self and mutual impedance matrices, Transformer modeling during transient phenomena, Resistance-Inductance ([R]-[ω]) model for single phase transformer, Resistance-Inverse Inductance ([R]-[ω]-1) model for single phase transformer, Generalization of ([R]-[ω]) model for N- coil transformer, Generalization of ([R]-[ω]-1) model for N- coil transformer. Case study on transient behavior of transformer coil and internal resonance in transformer winding.	
Module 3 – Electromagnetic Transient Analysis	***9 Hour***
Introduction to EMTP for Modeling and simulation, Simulation techniques for computation of transients, Modeling capabilities of EMTP in series RLC, and π circuits, Simulation capabilities of EMTP: Steady state solution model and time step solution module, Transient associated with electric circuits, lightning and switching, Line parameter evaluation program using EMTP, Constructional features that affect transmission line parameters, Shunt capacitance matrix evaluation program, Line parameters for equivalent phase conductors, Elimination of ground wires aspect for parameter evaluation, Bundling of phase conductors aspect for parameter evaluation, Steady state solution method in EMTP, Features and applications of EMTP, Transient studies using EMTP, Case study on travelling waves using EMTP concept, Case study on Transients in overhead transmission lines using EMTP concept	

Learning Resources	1. *Allan Greenwood, Electrical Transients in Power System, 2nd Edition, Wiley & Sons Inc. New York, 2018.* 2. *R.Ramanujam, Computational Electromagnetic Transients, Dreamtech Press D, New Delhi, 2019.* 3. *Akihiro Ametani, Naoto Nagaoka, Yoshihiro Baba, Teruo Ohno, Koichi Yamabuki, Power System Transients: Theory and Applications, 2nd Edition, CRC Press, Taylor & Francis Group, 2016*	4. *Indulkar C.S, Kothari D.P, Ramalingam R, Power System Transients: A Statistical Approach, PHI Learning Pvt. Ltd., 2010* 5. *Akihiro Ametani, Numerical Analysis of Power System Transients and Dynamics, IET power and energy series 78, CPI Group (UK) Ltd, Croydon, UK, 2015*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Ganesh, TANGEDCO	1. Dr. R,Ramesh, Anna University	1. Dr. C.S.Boopathi, SRMIST
2. Dr N Vedachalam, NIOT	2. Dr D Devaraj, KARE	2. Dr. D.Sattianadan, SRMIST

Course Code	21EEE624T	Course Name	STABILITY STUDIES IN INTEGRATION OF RENEWABLE ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the principles, benefits, and technical requirements for integrating renewable energy sources into the grid.*
CLR-2:	*analyze the technical challenges associated with integrating renewable energy into the grid and explore strategies to mitigate these challenges.*
CLR-3:	*understand and analyze different types of stability in power systems along with renewables*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify the technical standards and requirements for renewable energy integration into the grid*	*2*	*2*	*2*
CO-2:	*evaluate the impact of renewable energy integration and possible strategies of mitigation*	*3*	*3*	*2*
CO-3:	*assess the impact of renewable energy on voltage, frequency and rotor angle stability in the context of renewable energy integration.*	*3*	*3*	*2*

Module 1 – Introduction and Grid Code Requirements for Renewable Energy Integration	***10 Hour***
Overview of Renewable Energy Technologies, Importance and benefits of grid integration, Current Trends and Future Outlook in Renewable Energy, Variability and intermittency of renewable energy sources, Solar Power: Photovoltaic and Concentrated Solar Power (CSP) Systems, Wind Power: Onshore and Offshore Wind Turbines, Hydropower: Run-of-the-River, Storage, Pumped Storage Biomass Power: Types and Characteristics, Geothermal Power: Resource Characteristics and Power Generation, Grid Protection and Safety Requirements, Technical Standards for Grid Connection, Frequency Control Requirements, Voltage Control Requirements, Fault Ride-Through Capabilities, Reactive Power Support.	
Module 2 – Technical Challenges in Grid Integration of Renewable Energy	***16 Hour***
Specific Requirements for Renewable Energy Integration, Challenges in Weak Grids, Strategies to Mitigate congestion and Strengthen Weak Grids, Impact of Intermittent Renewable Sources, in Power Quality Issues, Effects on Grid Stability and Performance, Variability of renewable production, Protection issues, Change of short circuit levels, Challenges due to bidirectional power flow, reverse power flow, Lack of sustained fault current and islanding, Bidirectional power flow in distribution network, localized voltage stability problems, Fault ride-through for wind and solar PV farms - real and reactive power regulation, voltage and frequency operating limits, solar PV and wind farm behavior during grid disturbance, Hybrid and isolated operations of solar PV and wind systems. General Grid Applications of BESS, Technical Requirements: Round-Trip Efficiency, Response Time, Lifetime and Cycling, Sizing. Case Study on Integration of renewable energy into the power system	
Module 2 –Stability Analysis in Renewable Energy Integration	***19 Hour***
Impact of renewable energy on voltage stability: Solar PV, Wind, Biomass, Mitigation Strategies in Voltage Stability Issues, Impact of Renewable Energy on Frequency Stability, Frequency Response and Inertia in renewable energy integrated systems, Advanced frequency control Techniques: Synthetic Inertia, Fast Frequency Response, Impact of Renewables on Synchronous Generator Dynamics, Transient Stability Analysis Techniques with renewables, FRT based transient stability in grid integrated system, Enhancing rotor angle stability: using Power System Stabilizers, FACTS Devices and renewables integration, Case Studies on voltage stability with high renewables penetration	

Learning Resources	1. *Lawrence E. Jones, "Renewable Energy Integration: Practical Management of Variability, Uncertainty, and Flexibility in Power Grids" 2nd Edition, Elsevier, 2017.* 2. *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces (IEEE 1547-2018).* 3. *M. Kathiresh, A. Mahaboob Subahani and G.R Kanaga Chidambaresan, "Integration of Renewable Energy Sources with smart grid", 1st Edition, John Wiley, 2021.*	4. *Power System Stability and Control, NPTEL course content, http://nptel.iitm.ac.in.* 5. *Kundur, Prabha S., and Om P. Malik, "Power System Stability and Control, Second Edition," McGraw-Hill, 2022.* 6. *Machowski, Jan, Janusz W. Bialek, and James R. Bumby, "Power System Dynamics: Stability and Control, Third Edition," Wiley, 2020.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20%	-
Level 2	Understand	30%	-	30%	-	30%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	20%	-	30%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr.A.Kannan, Seshasayee Paper Mills Ltd, Tirunelveli*	1. *Dr Chitti Babu, IIITDM*	1. *Dr. K.Selvakumar, SRMIST*
2. *Mr. K.Kumaresan, Senior Manager, NTPC*	1. *Dr. B. Bijukumar, NIT Karaikkal*	2. *Dr. J. Preetha Roselyn, SRMIST*

Course Code	21EEE625T	Course Name	MODELING AND CONTROL OF SUSTAINABLE ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*impart in-depth knowledge on sustainable energy systems*
CLR-2:	*demonstrate the electrical models and associated controls for solar PV and wind energy systems*
CLR-3:	*summarize the modeling associated with energy storage systems*
CLR-4:	*identify the control concepts of microgrid and smart grid environment*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*enumerate the working and applications of various sustainable energy systems*	*2*		*-*
CO-2:	*develop electrical and aerodynamical models of solar PV and wind energy systems with suitable control schemes*	*3*	*2*	*2*
CO-3:	*formulate the model design involved in battery and fuel cell systems*	*3*	*2*	*2*
CO-4:	*enumerate the concepts of control techniques suitable for a micro grid and smart grid*	*3*	*2*	*2*

Module 1 – Sustainable Energy Systems	***5 Hour***
Review of sustainable energy sources, Types of renewables, Solar PV characteristics and power generation, Wind power generation and aerodynamics characteristics, Energy Storage – Batteries, Lead acid, Lithium ion, Nickel Cadmium and Sodium ion: Characteristics and Functioning, Fuel cells, Ultracapacitors, Supercapacitors, Flywheel storage, Wave energy-based power generation, Hydro power generation	
Module 2 – Modelling and Control of Solar PV Systems	***10 Hour***
Introduction to PV systems, Maximum power point tracking, Stand-alone PV systems, Grid connected PV systems, System presizing, PV array modelling, Power Converter Technology for PV Systems, Transformer less AC and DC Module Inverters, Transformer less Single-Stage String Inverters, Double-Stage PV Systems, PV Inverter Structures, Three-Phase PV Inverter Topologies, Control Building Blocks for PV Inverters, Modulation Strategies for Three-Phase PV Inverters, Grid Synchronization, Implementation of PLLs for Grid Synchronization	
Module 3 – Modelling and Control of Wind Energy Systems	***10 Hour***
Wind power development, Wind turbine generator technology, Challenges with wind power integration, Generator Selection for Small-Scale Wind Energy Systems, Turbine Selection for Wind Energy , Aerodynamic modelling of wind systems, Rankine Froud Actuator disc model, Betz limit, Angular momentum wake rotation theory, Aerofoil sections and their characteristics, Estimation of power output and energy production, Modelling of wind generators: Self-Excited Induction Generators, Permanent Magnet Synchronous Generators, Doubly fed Induction Generator	
Module 4 – Modelling and Control of Energy Storage Systems	***10 Hour***
Lithium-ion battery and lead acid battery technology, battery working mechanism, lithium-ion and lead acid battery characteristics, battery aging behavior analysis, battery electrical equivalent circuit modelling and parameter estimation methods, battery state estimation for SoC & SoH calculations, Basics of Fuel cell, fuel cell auxiliary components model, Compressor model, lumped model of the manifold dynamics, thermodynamics of gas mixtures, air cooler model, humidifier model, fuel cell stack model: stack voltage model, cathode flow model, anode flow model, membrane hydration model, Analysis of fuel cell system model- humidifier and hydrogen flow controls, steady state analysis	
Module 5 – Control of Microgrids with Sustainable Energy Systems	***10 Hour***
Introduction to Microgrids and Smart grid, Difference between Microgrids and Smart grid, Overview of phasor measurement units, Wide area monitoring and control, modelling and simulation of microgrid, smart grid infrastructure, control scheme for real and reactive power, Current reference computations, DC voltage regulator, Current loop control, phase lock loop, Voltage modulation, IEC 61850, IEC 62056, IEC 61334 standards of grid integration	

Learning Resources	1. *Wang, L. ed., Modeling and control of sustainable power systems: Towards smarter and greener electric grids, Springer Science & Business Media, 1st edition, 2011.* 2. *Rekioua, D. and Matagne, E., Optimization of photovoltaic power systems:modelization, simulation and control, Springer Science & Business Media, 1st edition,2012.* 3. *Wu, Qiuwei, and Yuanzhang Sun, Modeling and modern control of wind power, John Wiley and Sons,1st edition, 2018*	4. *Pukrushpan, J.T., Stefanopoulou, A.G. and Peng, H., Control of fuel cell power systems: principles, modeling, analysis and feedback design, Springer Science and Business Media, 1st edition, 2004.* 5. *Wang, S., Fernandez, C., Chunmei, Y., Yongcun, F., Wen, C., Stroe, D.I. and Chen, Z., Battery System Modeling, Elsevier, 1st edition, 2021.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	*35%*	-	*30%*	-
Level 2	*Understand*	*35%*	-	*35%*	-	*30%*	-
Level 3	*Apply*	*25%*	-	*20%*	-	*20%*	-
Level 4	*Analyze*	*10%*	-	*10%*	-	*20%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Srikanth Vasamshetti, CSIR-CSIO*	1. *Dr. D. Devaraj, KARE*	1. *Dr. U. Sowmmiya, SRMIST*
2. *Dr. S. Archana, Valeo India Pvt Ltd*	2. *Dr.R. Geetha, Vellammal Engg Coll*	2. *Dr. J. Preetha Roselyn, SRMIST*

Course Code	21EEE626T	Course Name	POWER SYSTEM PLANNING AND RELIABILITY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize the basic concepts of power system planning and reliability*
CLR-2:	*learn security analysis and contingency approaches with environmental considerations*
CLR-3:	*explore distribution system design and protective device coordination*
CLR-4:	*comprehend and enrich reliability basics, maintenance approaches*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*implement reliability-based planning criteria and risk analysis*	*3*	*2*	*-*
CO-2:	*apply security analysis methodologies and approaches*	*3*	*2*	*-*
CO-3:	*develop distribution systems and optimize protection coordination*	*3*	*2*	*3*
CO-4:	*utilize advanced reliability evaluation techniques and maintenance approached in real-world scenarios*	*3*	*2*	*3*

Module 1 –Power System Planning and Reliability	***12 Hour***
Basic concepts and importance of power system planning, Historical perspective and evolution of power system planning, Concepts of transmission, distribution planning and reliability, Introduction to power system reliability, Basic notions of power system reliability, Reliability indices, Outage classification, Need for load forecasting, Factors affecting load patterns, Applications of load forecasting, Types of load forecasting, Methods of Load Forecasting, Impact of renewable energy variability on load forecasting, Industry trends and innovations in load forecasting, Standards and regulations, Applications of reliability tools in power systems, Risk analysis in power system planning, Case study on load forecasting, demand feasibility study using simulation tools	
Module 2 –Contingency and Security Analysis for Power System Reliability	***11 Hour***
Basic concepts of security analysis, Static security analysis at control centers, Contingency analysis, Contingency selection, Features of the contingency approach, Advantages and disadvantages of contingency approach, Deterministic contingency analysis, Advantages of contingency analysis, Probabilistic load flow, Probabilistic transmission system reliability analysis, Transmission system reliability evaluation, Environmental and social considerations, Case study on advanced security and contingency analysis techniques using simulation tool	
Module 3 – Distribution System Protection	***11 Hour***
Distribution substations, Design of primary system, Design of secondary systems, Distribution system protection, Brief description of various distribution system protection, Coordination of protective devices, Radial configurations, Conditional probability approach, System point indices, Load point indices, Application to practical systems, Data requirements for composite system reliability, Integration of distributed energy resources, Microgrid planning and operation, Impact of DERs on distribution system reliability, Integration of modern technologies, IEEE 1584/519, Use of AI in load forecasting, Case study on protection coordination using software simulation.	
Module 4 – Reliability Evaluation and Risk Assessment	***11 Hour***
Basic reliability concepts, General reliability function, Markov chains and processes, Applications of Markov chains and processes, Simple series system models, Simple parallel system models, Procedure followed for integrating transmission, Radial networks, Additional interruption indices, Application to radial systems, Extension of radial systems, Effect of lateral distributor protection, Effect of disconnects, Protection failures, Risk assessment methodologies, Probabilistic risk assessment, Failure modes and effects analysis (FMEA), Reliability-centered maintenance (RCM), Modern risk assessment methodologies, IEC standards, Case study on protective device failures.	

Learning Resources		
	1. *Billiton Roy& Allan Ronald, Reliability of Power system, Pitman Pub. 2013* 2. *Richard Elect. Brown, Electric Power Distribution Reliability, CRC Press,2002*	3. *R.L. Sullivan, Power System Planning, Tata McGraw Hill Publishing Company Ltd,2012.* 4. *T. Gonen, Electrical Power Distribution Engineering, McGraw Hill Book Company,2014.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	20%	-	30%	-
Level 2	Understand	30%	-	20%	-	30%	-
Level 3	Apply	20%	-	30%	-	20%	-
Level 4	Analyze	20%	-	30%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr.Panneerselvam, TANGEDCO	1. Dr.K. Keerthivasan, HCT, Oman	1. Mr.D.Ravichandran, SRMIST
2. Mr.N.Ravi, BHEL.	2. Dr.K.S.Swarup, IIT Madras	2. Dr. D. Sattianathan, SRMIST

Course Code	21EEE627T	Course Name	WIDE AREA MONITORING AND CONTROL IN SMART GRID	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*IEC 61850*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*analyze the Synchrophasor Measurement Concepts*
CLR-2:	*understand the PMU implementation and analyze the state estimation*
CLR-3:	*develop wide area measurement systems in smart grid*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand Synchrophasor Measurement Techniques*	*1*	*1*	*2*
CO-2:	*implementation of PMUs and state estimation in smart grid*	*1*	*1*	*2*
CO-3:	*realize and test wide area measurement system in smart grid*	*1*	*2*	*2*

Module 1 – Phasor Measurement Techniques	***12 Hour***
Basic concepts and definition, Synchrophasors, Frequency and ROCOF, Phasor representations of sinusoids, Phasor estimation of nominal frequency signals, Updating phasor, Phasor estimation at off-nominal frequency signals, Types of frequency excursions found in power system, Frequency estimates from balanced and unbalanced three-phase inputs, Steady-state and Dynamic conditions of power systems, Classical phasor versus dynamic phasor, Basic definition of accuracy indexes, Methods to calculate synchrophasor's based on steady-state model, Methods based on a dynamic signal model, Evaluation of frequency and ROCOF, Dynamic behavior of phasor measurement algorithms.	
Module 2 – Phasor Measurement Units and Phasor Data Concentrators	***12 Hour***
International standards for instrument transformers, Accuracy of instrument transformers, Instrument transformers technologies, Transducer impact on PMU accuracy, PMU architecture, Data acquisition system, Synchronization of sources, Communication and data collector, Distributed PMU, Synchrophasor standards, Synchrophasors and IEC 61850, Case study on steady-state testing of PMU in an electrical substation, Functional requirements of PMU and PDC, Evolution of synchrophasor standards and file structures, PDC files.	
Module 3 – State Estimation and PMUs	***12 Hour***
Formulation of the state estimation problem, State estimation measurement models, Weighted least square, Static state estimation, Bad data detection, State estimation with phasor measurements, linear state estimation, Role and impact of PMU in state estimation, PMU-based transmission and distribution system state estimation, Optimal PMU placement, State estimation applications, Automation architecture with integrated PMU measurements for state estimation	
Module 4 – Wide Area Measurement Systems Applications	***9 Hour***
Voltage stability assessment based on Thevenin approach and synchrophasor measurements, Voltage stability assessment based on Modal approach and synchrophasor measurements, Adaptive under-frequency load shedding and under-voltage load shedding, Estimation of grid parameters, Structure of WAMS integrated in control and management systems, Software platform for real-time monitoring platform, Monitoring application, Distributed system state estimation, Case study on real-life examples of wide-area measurement systems, Managing oscillations in power systems, Managing disturbances, Constraint relief in transmission and distribution system.	

Learning Resources	1. *Antonello Monti, Carlo Muscas, Ferdinanda Ponci, Phasor Measurement Units and Wide Area Monitoring Systems, Academic Press, 2016* 2. *A.G. Phadke, J.S. Thorp, Synchronized Phasor Measurement and Their Applications, Springer2008* 3. *Yong Li, Dechang Yang, Fang Liu, Yijia Cao, Christian Rehtanz, Interconnected Power Systems: WideArea Dynamic Monitoring and Control Applications, Springer, 2015*	4. *Ma J., Makarov Y., Dong Z, Phasor Measurement Unit and its Applications on Modern Power Systems, Springer, 2010* 5. *IEEE Power & Energy Society, IEEE Standard for Synchrophasor Data Transfer for Power Systems, IEEE New York, 2011* 6. *Xu B, Abur A, Optimal Placement of Phasor Measurement units for State Estimation, PSERC, Final Project Report, 2005*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Sudarshan, Schneider Electric*	1. *Dr. D. Devaraj, KARE*	1. *Dr. C. Nithya, SRMIST*
2. *Mr. Saravanan, L &T*	2. *Dr.K.S.Swarup, IIT Madras*	2. *Dr. J. Preetha Roselyn, SRMIST*

ACADEMIC CURRICULA

Power Electronics and Drives & Power Systems

Common Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21EEE501T	Course Name	FLEXIBLE AC TRANSMISSION SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*impart in-depth knowledge on working and its characteristics of FACTS devices*
CLR-2:	*get insight of the mathematical representation of compensation techniques*
CLR-3:	*interpret the implementation of suitable FACTS controllers in real time applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*enumerate the operation, types and benefits of FACTS controllers*	*3*	*1*	*3*
CO-2:	*develop the modeling of compensators for different power system studies*	*3*	*1*	*3*
CO-3:	*interpret the functions of emerging FACTS controllers and its real time applications*	*3*	*2*	*1*

Module 1 - FACTS Concepts ***18 Hour***

Basics of power transmission networks, Uncompensated transmission lines, Flow of power in an ac system (parallel path and meshed system), Criteria for loading capability, power flow considerations, Dynamic stability considerations of a transmission interconnection, Importance of controllable parameters, Basic types of FACTS controllers, Application of FACTS controllers in distribution systems - HVDC and FACTS, Objectives of shunt compensation, Methods of controllable VAR generation, SVC, STATCOM, GCSC, TSSC, TCSC, SSSC, UPFC, IPFC, NGH SSR damper, TCBR, Case study on implementation of FACTS controller in distribution system and analyze small signal stability of the system

Module 2 - Modeling of Compensators ***15 Hour***

Modelling of compensators for studies: load flow, small and large disturbance, sub-synchronous resonance, electromagnetic transients and harmonics performance, Modeling of multi-functional single converter FACTS: STATCOM, SSSC, SVC and TCSC, Modeling of multi-converter FACTS: UPFC and IPFC in nonlinear interior point optimal power flow analysis, Case study on open loop simulation of FACTS devices in transmission system

Module 3 - Applications of Emerging FACTS Controller ***12 Hour***

Impact of FACTS devices on power system voltage stability, Congestion management and loss minimization, Power flow control in energy markets, Non-Intrusive System Control for regular and contingency operation, Autonomous Systems for Emergency and Stability Control, Impact of FACTS devices in Wide Area Monitoring and Control, Impact of FACTS installation and choice on small signal stability analysis and Transient stability analysis

Learning Resources

1. *Mohan Mathur, R. and Rajiv K. Varma, Thyristor Based FACTS Controller for Electrical Transmission Systems, Second Edition, Wiley Inderscience, 2016.*
2. *Narain G. Hingorani and Laszlo Gyugyi, Understanding FACTS – Concepts & Technology of Flexible AC Transmission Systems, Second Edition, Standard Publishers, New Delhi, 2011.*
3. *X.P. Zang, C. Rehtanz and B. Pal, Flexible AC Transmission Systems: Modeling and Control, Birkhauser, 2014.*
4. *K R Padiyar, FACTS Controllers in Power Transmission and Distribution, Second Edition, New Age, 2021.*
5. *Yong Hua Song and Allan T. Johns, Flexible Ac Transmission Systems (FACTS) The Institution of Engineering and Technology, 2008.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	*30%*	-	*30%*	-
Level 2	*Understand*	*30%*	-	*30%*	-	*30%*	-
Level 3	*Apply*	*20%*	-	*20%*	-	*20%*	-
Level 4	*Analyze*	*20%*	-	*20%*	-	*20%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. S. Saravanan, S&S Engineering	*1. Dr. P. Bhuvaneswari P, Sri Venkateswara College of Engineering & Technology, Chittoor*	1. *Dr. A. Geetha, SRMIST*
2. Mr. Francis Suresh Balan, CGS Green Sustainergy Pvt. Ltd	2. *Dr. M. Durairasan, University College of Engineering, Thirukkuvalai*	2. *Dr. S. Usha, SRMIST*

Course Code	21EEE502T	Course Name	HIGH VOLTAGE DIRECT CURRENT TRANSMISSION SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*IEEE 1378-2022; IEC TR 63127; IEC 61975*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the need and selection of HVDC system for bulk power transmission*
CLR-2:	*analyze the operation of converter for HVDC system*
CLR-3:	*describe the control and recent trends in HVDC transmission systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*illustrate HVDC system structure and components*	2	2	-
CO-2:	*demonstrate the converter topology and its characteristics*	2	3	2
CO-3:	*explain the control and recent trends of HVDC*	3	2	2

Module 1 – HVDC Power Transmission ***5 Hour***

Overview of HVDC transmission, Comparison between DC and HVDC systems, HVDC standard transmission voltage, Need for power system interconnections, Evolution of AC and DC transmission systems. Comparison of EHV AC and DC transmission, description of DC transmission systems, modern trends in AC and DC transmission; Components of HVDC transmission system, Case study on comparison between traditional and modern HVDC systems

Module 2 – HVDC Converters and Control ***20 Hour***

Analysis of HVDC Converters, Rectifier and Inverter operation of Graetz circuit configurations, Choice of converter configuration, 6-pulse and 12-pulse rectifiers and inverters and their characteristics, Operation principle of VSC based HVDC Transmission, Comparison of Line Commutated Converter and Voltage Source Converter, Standards-IEEE 1378-2022, IEC TR 63127, Design of HVDC converter station, Components and functions, Design factors and challenges, Equivalent circuit of HVDC link, DC link control, Converter control characteristics, Types of control techniques for HVDC system, Constant current control, Constant excitation angle control, Constant ignition angle control, Individual phase control and equidistant pulse control, Valve blocking and by-passing, Starting, stopping and power flow reversal, Higher level controllers, Case study on performance analysis of HVDC converter system

Module 3 – Design, Testing of HVDC System and Recent Trends ***20 Hour***

Harmonics in HVDC system, Harmonics Filters, EMI Filters, Design of AC filters and DC filters, Power loss analysis of HVDC system, Efficiency improvement for long distance transmission, HVDC system testing, Standards-IEC 61975, Types of HVDC system testing, Converter maloperations, Faults in HVDC System and their protection, Recent developments in HVDC systems, Issues encountered in traditional systems, Multi Terminal DC systems, HVDC Light technology, Growth of HVDC market, HVDC Transmission market size and industry analysis, HVDC in future sustainable energy system, Renewable energy source interconnection, Design of VSC based HVDC with Offshore Wind Farms, Modeling and simulation studies to facilitate offshore wind and HVDC Systems, Case study on HVDC project, planning and analysis

Learning Resources		
	1. K. R. Padiyar, HVDC Power Transmission Systems: Technology and System Reactions, New Age International, third edition, 2017. *2. Arrillaga, Jos, and Jos Arrillaga. High voltage direct current transmission, Vol. 29. Iet, Second Edition, 1998.* *3. S. Rao, EHVAC and HVDC Transmission Engineering and Practice, third Edition, Khanna Publisher,1993*	*4. R. D. Begamudre, Extra High Voltage AC Transmission Engineering, Third Edition, New Age Publishers, 2009* *5. Kamakshaiah, S and Kamaraju, V, HVDC Transmission, First Edition, Tata McGraw Hill Education (India), New Delhi 2011.*

Learning Assessment							
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	30%	-	30%	-	30%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	20%	-	20%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Jason Manoraj, L&T Technology Services Limited	1. Dr. P. Thamizhazhagan, University college of Engineering, Tindivanam	1. Dr. A. Lavanya, SRMIST
2. Mr. Sitangshu Sekhar Biswas, Department of Atomic Energy	2. Dr. A. Venkadesan, NIT Puducherry	2. Dr. J. Divya Navamani, SRMIST

Course Code	21EEE503T	Course Name	APPLICATIONS OF MACHINE LEARNING FOR ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*identify the concepts of renewable energy systems and need for machine learning*
CLR-2:	*develop in-depth knowledge on statistical machine learning concepts*
CLR-3:	*demonstrate the forecasting models of power generation and load availability of energy systems*
CLR-4:	*formulate and classify the faults involved in solar and wind energy systems*
CLR-5:	*summarize switching device characteristics involved in advanced solid-state switches*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*enumerate the concepts of renewable energy systems*	*2*	*-*	*2*
CO-2:	*summarize the concepts behind statistical machine learning techniques*	*2*	*-*	*1*
CO-3:	*demonstrate the forecasting methods for power generation and load availability through learning algorithms*	*2*	*1*	*2*
CO-4:	*develop fault classification models for solar and wind energy systems*	*2*	*1*	*2*
CO-5:	*formulate the switching device design involved for advanced solid-state devices*	*2*	*1*	*2*

Module 1 – Electrical Energy Systems ***5 Hour***

Conventional source of electrical energy, Basic layout of thermal power generation and its setbacks, Basic layout of sustainable energy resources, Importance of Solar PV and wind energy systems, Electrical characteristics of solar PV, Modeling of solar cells including the effects of temperature, shadow effects and mitigation techniques, Significance of MPPT and types of MPPT, Solar PV based grid tied systems and integration issues; Principles of wind energy conversions and components of WECS, Aerodynamic modeling and wind characteristics, HAWT, VAWT, Wind energy based islanded and grid tied systems and related issues

Module 2 – Statistical Machine Learning ***10 Hour***

Statistical terminology for model building and validation, Machine Learning, Machine learning model development and deployment, Linear Regression, Logistic Regression, Bias versus variance trade-off, Train and test data, Machine learning losses, Feature Selection and Extraction, Explicit Semantic Analysis, Non-Negative Matrix Factorization, Singular Value Decomposition and Principal Component Analysis, Convergence Criteria, Train and test validation, Cross-validation and its techniques, K-Fold, Grid Search, Performance Metrics

Module 3 – Power Generation & Load Forecasting for Energy Systems ***10 Hour***

Power generation and load forecasting, Types of data: Sensor/SCADA/Simulation based dataset, Solar irradiance data (GHI, DNI, Diffuse), Wind energy data, Data visualization, Energy demand model, Forecast methods based on physical, numerical weather prediction, Persistence/Statistical Forecasting, Short term forecasting methods: similar day approach, time series approach, auto regression and moving average models, ARMA, ARIMA, ARIMAX , Simple and multivariant regression, SVM, Markov chain models, ensemble methods, hybrid methods, Case Study on Solar PV Power Generation Forecasting, Load Forecasting for Islanded systems with solar PV, Wind

Module 4 – Fault Study in Energy Systems ***10 Hour***

Introduction to faults in solar PV and wind energy systems, Types of faults, Faults in Solar PV based islanded and grid tied systems, Faults in wind energy based islanded and grid tied systems, Regression based classifier, Bayes based classifier, k-NN based classifier, Random forest classifier, Support vector machine based classifier, Condition monitoring of energy system - Reactive maintenance, Preventive maintenance, Predictive maintenance, Case Study on Prediction and classification of faults in solar PV and wind energy systems

Module 5 – Characteristic study of Advanced Power Devices ***10 Hour***

Recent advancements in power switching devices, SiC Device: Construction and Characteristics, GaN Device: Construction and Characteristics, Panasonic Device: Construction and Characteristics, Transform Device: Construction and Characteristics, Comparison of all devices, Collection of device data, Data processing, analytics and visualization, Device capability check using regression model, Bayes model, kNN, SVM, Single variant and Muti-variant analysis, Case Study on prediction of power losses in power switches

Learning Resources	1. *Rai G.D., non-conventional energy resources, Khanna publishers, 2019.* 2. *Wadwa. C.L., Electric Power Systems, Fifth Edition, Wiley Eastern Ltd, New Dellhi 2017.* 3. *Tom M. Mitchell, Machine Learning, First Edition, McGraw-Hill Education (India) Private Limited, 2017.*	4. *Ethem Alpaydin, Introduction to Machine Learning (Adaptive Computation and Machine Learning), Third Edition, The MIT Press 2020.* 5. *Stephen Marsland, Machine Learning: An Algorithmic Perspective, Second Edition, CRC Press, 2015*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*40%*	-	*40%*	-	*40%*	-
Level 2	*Understand*	*40%*	-	*40%*	-	*40%*	-
Level 3	*Apply*	*10%*	-	*10%*	-	*10%*	-
Level 4	*Analyze*	*10%*	-	*10%*	-	*10%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Srikanth Vasamshetti, CSIR-CSIO*	1. *Dr. D. Devaraj, KARE*	1. *Dr. U. Sowmmiya, SRMIST*
2. *Dr. S. Archana, Valeo India Pvt Ltd*	2. *Dr.R. Geetha, Vellammal Engineering College*	2. *Dr. J. Preetha Roselyn, SRMIST*

Course Code	21EEE504T	Course Name	POWER QUALITY ASSESSMENT AND ENHANCEMENT	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*identify the fundamental concepts, and industry standards of power quality*
CLR-2:	*provide the knowledge to assess power quality in industrial applications*
CLR-3:	*explain the importance of mitigating methods to enhance power quality*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*enumerate power quality terms, IEEE regulations, standards and recommended practices*	*3*	*-*	*-*
CO-2:	*analyze power quality in various industrial applications*	*3*	*2*	*3*
CO-3:	*apply the different mitigating technologies to enhance power quality*	*3*	*2*	*3*

Module 1 – Fundamentals and Standards of Power Quality ***9 Hour***

Overview of power quality terms, Types of Power Quality Disturbances: Harmonic Distortion, Voltage Sag and Swell, Interruptions, Transients, Effects of poor power quality on equipment and economics, Power quality standards and key standards: IEEE 519, IEC 61000, EN 50160, Power quality indices: THD, Voltage Flicker, Voltage Sag and Swell Indices, Interruption Indices, Overview of power quality measuring instruments, Impact of renewable energy sources on power quality, Power quality challenges and solutions.

Module 2 – Power Quality Assessment in Industrial Applications ***18 Hour***

Industrial Power Factor Correction, Power quality in Smart grids, Microgrids, Electric vehicles and Data centers, Impact of non-linear loads, Energy storage impact on power quality, Power quality and energy efficiency, Economic impact of power quality problems, Power quality audits, Principles of operation and performance analysis of harmonics filters, Proactive and passive compensation, Advanced software tools for power quality assessment, IoT-based power quality monitoring, Flicker assessment in critical process industries, Motor staring analysis, Power quality challenges in industrial automation and process control, Advanced power quality monitoring techniques, Case study on examination of power quality issues in various manufacturing plants, hands-on practice with power quality analyzers.

Module 3 – Power Quality Enhancement ***18 Hour***

Utility-Customer interface, Different configurations of harmonic filters: passive, active and hybrid filters, Different configurations of custom power devices: Network reconfiguring Devices, Operation and control, Distribution Static Compensator (DSTATCOM) for load compensation and voltage regulation, Series compensation with Dynamic Voltage Restorer (DVR), Unified Power Quality Conditioner (UPQC) for shunt and series compensation, Hybrid custom power devices, Power quality improvement in distribution systems, Renewable Energy in Power Quality Enhancement, Impact of smart grids and IoT on Power Quality, Software tools for designing the filters, Practice on design of passive filters and active filters, Case study on problem identification, analysis and implementation of custom power devices in manufacturing plant, challenges and mitigation strategies to enhancing power quality in renewable energy plants.

Learning Resources		
	1. Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., Power System Harmonic Analysis, Wiley India, 2nd edition, 2008. *2. Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System Quality, McGraw-Hill International Book Company, 2004*	*3. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Power Quality Problems and Mitigation Techniques, Wiley Publications, 2015.* *4. Arindam Ghosh and Gerard Ledwich, Power quality enhancement using custom power devices, Springer Science & Business Media, 2022.*

Learning Assessment							
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	20%	-	30%	-
Level 2	Understand	30%	-	20%	-	30%	-
Level 3	Apply	20%	-	30%	-	20%	-
Level 4	Analyze	20%	-	30%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Sridher, Schwing Stetter (India) Pvt. Ltd., Chennai	1. Dr. A Venkatesan, NITPY	1. Dr. T. M. Thamizh Thendral, SRMIST
2. Mr. K. Karthikeyan, BHEL-Trichy	2. Dr. Ganesh Kumar, Anna University	2. Mr. D. Ravichandran, SRMIST

Course Code	21EEE505T	Course Name	ELECTRIC VEHICLE AND ENERGY STORAGE SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*context of an electric vehicle architecture, configuration, and rationale policies and regulations*
CLR-2:	*enrich the knowledge of electric motor drives and their control techniques*
CLR-3:	*summarize the different energy storage systems and various modes of energy storage*
CLR-4:	*acquaint the electric vehicle charging systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*acquire knowledge of various parts of the electric vehicle and their functions*	*1*	*2*	*2*
CO-2:	*develop EV Traction Motors and their Control Techniques*	*2*	*3*	*3*
CO-3:	*analyze the characteristics and parameters of batteries, battery management systems, and Hydrogen Fuel Cell Technologies*	*3*	*3*	*3*
CO-4:	*comprehending Electric Vehicle Charging Systems, regulation and Adoptions*	*2*	*3*	*3*

Module 1 - Electric Vehicle and its Components, Rationale Policies and Regulations	***9 Hour***
Introduction to Electric Vehicle (EV), Comparison of EV with ICE based Vehicle, Outline to EV components and systems, Introduction of Driving Cycle, Vehicle Dynamics of EV, Problem Solving in Vehicle Dynamics - Fundamental of vehicle transmissions, and Trends in transmission design, Transmission losses and efficiency - Hybrid Electric Vehicle (HEV) and its Types, Fuel Cell Electric Vehicle (FCEV) - Economic rationale for EV policy and regulation, Environmental implications of EVs and regulatory responses- Government Policies and Incentives.	
Module 2 – Electric Vehicle Traction Motors and their Control Techniques	***12 Hour***
Introduction to EV Drive Train, EV Motor drive and load profile, Selection of traction Motor, Dynamics of Electric drives - Fundamental torque equations, Components of load torques - Selection of motor power rating, Thermal model of motor for heating and cooling - Classes of Power train motor configurations and components: Mid drive, hub, and In-wheel motor drive configuration - - Electrical Barking. Type of Motor drive: BLDC, PMSM mid-drive type, and Axial Flux PMSM, SRM Motor drive - Schematic motor controller, Modeling and control of advanced control techniques for EV drive motors - Testing: Thermal management testing for motors, Noise, vibration, and harshness (NVH) Durability and EMI reliability, IP65 and IP67 testing	
Module 3 – Energy Storage Systems in Electric Vehicle	***12 Hour***
Electrochemistry of the Cells and Batteries - General approach to modeling batteries - Traction battery pack design - Electrical Requirements, Thermal Requirements, Mechanical Requirements, Automotive Drive cycles - EV Batteries Specifications, Internal structure, Charging and Discharging of : Lithium Iron Phosphate Battery (LFP), Nickel Cobalt Aluminum Oxide (LNCA), Lithium Nickel Manganese Cobalt Oxide (LNMC), lithium iron phosphate battery (LiFePO 4), and Sodium Battery- Selection of battery for EVs and HEVs – Hydrogen Fuel Cell Technologies, Types of Fuel Cell and operations - Fuel cell and Battery (FC + B) - Fuel Cell + Ultra capacitor (FC + UC) - Fuel Cell + Battery + Ultra capacitor (FC + B + UC) - Battery state of charge estimation methods - Battery cell equalization problem - Thermal control - Energy and Power estimation - Battery management system: Definition, Parts: Power Module, Battery, DC/DC Converter, load - Communication channel - Battery pack safety - Battery standards and tests - Cell balancing: Causes of imbalance, Active Balancing, Passive balancing - Thermal Runway: High discharge rates, short circuits, charging and discharging - Environment and Human Health impact assessments of batteries	
Module 4 – Electric Vehicle Charging System	***12 Hour***
Types of EV supply equipment (EVSE), components of EV battery chargers, charging infrastructure challenges, classification based on charging levels (region-wise), modes, plug types, standards related to connectors, communication, supply equipment, EMI/EMC - Electric Vehicle (EV) Standards, Overview of international standards (ISO, IEC) for EV technology, National standards for EV technology in India, global standards (SAE, CHAdeMO, CCS) for EVs – Charging Modes: CV and CV - Onboard charging systems, types of AC-DC converters; working principles, modulation, design, and closed loop control of power factor correction converters (PFC): Boost type PFC, Totem-pole PFC, active front-end converter. Types of Off Chargers: AC chargers, DC chargers, and fast chargers – Wireless charging: Types, Operation, Control, and	

standards - Communication architecture for EV charging - -V2G, V2V connectivity, Criteria for connecting EV to the utility for AC level 1 and level 2 charging - Nature and scope of policies to stimulate widespread EV adoption - Policy formulation and implementation at various levels of government.

Learning Resources	*1. Ronald Jurgen, Electric and Hybric-Electric Vehicles: Fuel Cell Hybrid EVs SAE, First Edition, 2011.* *2. Mehrdad Ehsani, Yimin Gao, sebastien E. Gay and Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, First Edition, CRC Press, 2009* *3. Wu, Yuping, Lithium-ion Batteries Fundamentals and Applications, CRC Press, Taylor and Francis, first edition, 2015.* *4.San Ping Jiang, Fundamentals and Application of Lithium-ion Battery Management in Electric Drive Vehicles, Wiley, first edition, 2015.* *5. James Larminie, John Lowry, Electric Vehicle Technology Explained, John Wiley and Sons Ltd, second edition, 2012*	*6. Shuiwen Shen, Qiong-zhong Chen, Practical Control of Electric Machines for EV/HEVs Design, Analysis, and Implementation, Springer, first edition, September 2023* *7. Tiago, Traction Control in Electric Vehicles Paperback, Lambert Academic Publishing, first edition, 2017.* *8. Neeraj Priyadarshi, P. Sanjeevikumar, Farooque Azam,C. Bharatiraja, Rajesh Singh, Advanced Power Electronics Converters for Future Renewable Energy Systems, CRC Press, Taylor and Francis, first edition, 2023.* *9.Thandavarayan Maiyalagan, Perumal Elumalai, Chokkalingam Bharatiraja, Rechargeable Lithium-Ion Batteries Trends and Progress in Electric Vehicles, CRC Press, Taylor and Francis, first edition, 2020*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20%	-
Level 2	Understand	30%	-	10%	-	30%	-
Level 3	Apply	30%	-	20%	-	30%	-
Level 4	Analyze	20%	-	20%	-	20%	-
Level 5	Evaluate	-	-	20%	-	-	-
Level 6	Create	-	-	20%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Marrand, Expert Engineer-Volvo Group, India	1. Dr. Deepak Ronanki, IITM	1. Dr. C.Bharatiraja, SRMIST
2. Dr.Amit Kumar Gupta, Rolls-Royce-Electrical	2. Dr. Sheldon Williamson, University of Ontario	2. Dr. K.Vijayakumar, SRMIST

Course Code	21EEE506T	Course Name	ADVANCED DIGITAL SIGNAL PROCESSING	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electrical and Electronics Engineering	Data Book / Codes / Standards	Nil		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand advanced digital signal processing techniques*
CLR-2:	*apply advanced algorithms for real-time signal processing*
CLR-3:	*apply statistical methods to analyze random signals*
CLR-4:	*analyze advanced digital signal processing algorithms in practical scenarios*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply advanced methods for signal reconstruction, filtering and analyze in frequency domain*	*2*	*-*	*2*
CO-2:	*utilize Fast Fourier transform and wavelet transforms for signal analysis*	*2*	*-*	*3*
CO-3:	*apply estimation and probability theory to signal processing problems*	*2*	*1*	*3*
CO-4:	*analyze digital signal processing for image and video processing in communications and control systems*	*2*	*1*	*3*

Module 1 - Introduction to Digital Signal Processing	***12 Hour***
Fourier Transform: Continuous Fourier Transform, Discrete Fourier Transform and its properties, Fast Fourier Transform algorithms (Radix-2, Radix-4), Laplace Transform, Z-transform, Adaptive Filters: Least Mean Squares and Recursive Least Squares algorithms, Multirate Signal Processing: Decimation and interpolation, Polyphase filters and their design	
Module 2 – Signal Processing Techniques	***10 Hour***
FFT Algorithms: Split-radix FFT, Mixed-radix FFT, FFT for non-power-of-2 lengths: Bluestein's FFT algorithm, Prime-factor FFT algorithms, Wavelet Transforms: Continuous Wavelet Transform, Discrete Wavelet Transform, Wavelet packet decomposition and reconstruction, JPEG Compression: Discrete Cosine Transform, Quantization and encoding, MP3 Compression: Subband coding, Psychoacoustic modelling	
Module 3 - Statistical Signal Processing	***12 Hour***
Random Processes, Probability Distributions, Stationary and non-stationary random processes, Gaussian and non-Gaussian distributions, Markov processes and their properties - Parameter estimation: Maximum Likelihood Estimation, Bayesian estimation, Linear and non-linear least squares estimation, Cramer-Rao lower bound, Kalman Filtering, Kalman filter formulation and applications, Extended Kalman Filter (EKF) and Unscented Kalman Filter, Kalman filtering for state estimation and control.	
Module 4 - Digital Signal Processing Applications	***11 Hour***
Image Filtering: Spatial domain filtering (smoothing, sharpening), Frequency domain filtering (FFT-based filtering), Image Compression: Wavelet-based image compression techniques, JPEG2000 standard - Video Processing: Motion estimation and compensation, Video coding standards (H.264, HEVC), Speech and Audio Processing, Speech Recognition: Hidden Markov Models, Deep learning approaches (Recurrent Neural Networks), Audio Effects: Echo cancellation and noise reduction techniques, DSP in Communications, Digital Modulation Techniques: Amplitude Shift Keying, Frequency Shift Keying, Phase Shift Keying, Orthogonal Frequency Division Multiplexing, Equalization Techniques: Linear and non-linear equalization methods, Adaptive equalization algorithms.	

Learning Resources		
Learning Resources	1. John G. Proakis and Dimitris G. Manolakis, Digital Signal Processing Principles, Algorithms, and Applications, 4th Edition, Pearsons, 2007. 2. Guy Nason, Wavelet Methods in Statistics with R, First Edition, Springer, 2006.	3. Monson H. Hayes. Statistical Digital Signal Processing and Modeling, Wiley, Third edition, 2012. 4. Bernard Sklar, Digital Communications: Fundamentals and Applications, Pearson Prentice Hall, third edition, 2017.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Ms.Nivedha, Infineon Technologies	1. Dr. Velmurugan P G S, Thiagarajar College of Engineering	1. Dr. Pradeep V, SRMIST
2. Mr.Ragul S, Temenos	2. Dr. Arvind R Singh, Shandong University	2. Dr. Sureshkumar A, SRMIST

Course Code	21EEE507T	Course Name	ENERGY AUDIT AND MANAGEMENT FOR ELECTRICAL SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*gain expertise in energy audit methodologies for enhancement and saving expenses*
CLR-2:	*develop electrical systems to improve efficiency and to effectively manage resources*
CLR-3:	*establish energy conservation measures by using practical approaches*
CLR-4:	*understand energy use trends to prioritize efficiency improvements*
CLR-5:	*present research results and execute economical strategies for energy management.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze energy usage and identify efficiency opportunities*	*2*	*2*	*1*
CO-2:	*optimize electrical systems for improved efficiency*	*2*	*2*	*1*
CO-3:	*implement energy conservation techniques in electrical systems.*	*2*	*2*	*1*
CO-4:	*apply energy audit methodologies and tools effectively*	*2*	*2*	*2*
CO-5:	*prepare comprehensive energy audit reports and implement cost-effective solutions.*	*2*	*2*	*3*

Module 1-Introduction to Energy Audit and Management	***9 Hour***
Energy Audit, Importance of Energy Audit, Objectives of Energy Audit, Types of Energy Audit, Preliminary Energy Audit, Detailed Energy Audit, Investment, Grade Audit, Energy Management, Concepts and Principles, Energy conservation versus energy efficiency, Energy policy and regulations, Energy management standards (ISO 50001), Industry trends and innovations in energy management	
Module 2- Energy Efficiency in Electrical System	***9 Hour***
Analyzing electrical systems, Load assessment and profiling, Load curve analysis, Demand factor determination, Power quality analysis, Voltage fluctuations, Harmonic distortion, Power factor improvement, Energy conservation opportunities, Energy efficient lighting solutions, Variable frequency drives (VFDs) for motors, Energy efficient HVAC systems, Energy efficient air compression system, Benchmarking, Industry practices in electrical system optimization, IEEE 519, IEC 61000-4-30	
Module 3- Energy Conservation Techniques in Electrical Systems	***9 Hour***
Implementing energy conservation measures, Lighting systems optimization, LED lighting retrofits, Daylight Harvesting Techniques, Lighting Control Systems, Motor and Drive System Efficiency, - Variable Speed Drives (VSDs), Motor Management Programs, HVAC System Equipment Selection, Building Automation Systems (BAS), HVAC Best Efficiency Practices, Renewable Energy Integration, Case study on energy efficiency, ASHRAE Standards: ASHRAE 90.1 - ISO standards	
Module 4 - Energy Audit Techniques and Tools	***9 Hour***
Energy Audit Methodologies, Measurement and Verification Techniques, Direct Measurement Techniques, Indirect Measurement Techniques, Energy Monitoring Systems, SCADA Systems, Smart Meters, Data Loggers, Energy Performance Indicators, Specific Energy Consumption, Energy Intensity Indicators, Energy Audit Instruments, Power Analyzers, Thermal Imaging Cameras, Energy Management Software, Hands-on training with energy audit instruments, Advanced Tools and Techniques in Energy Audits, ISO standards, Fluke Energy Analyze Plus	
Module 5- Energy Audit Reporting and Implementation	***9 Hour***
Reporting and Implementing Audit Findings, Energy Audit Report Preparation, Executive Summary, Energy Consumption Analysis, Energy Saving Recommendations, - Cost-Benefit Analysis - Payback Period Calculation, Return on Investment (ROI) Analysis, Life Cycle Costing, Prioritizing Energy Efficiency Measures, Project Management for Implementation, Post-Implementation Monitoring, Feedback Mechanisms, Assessing and evaluating performance of equipment, energy auditing in specific industries, Modern Reporting and Implementation Techniques, ISO standards	

Learning Resources	1. *Wayne C. Turner, Energy Management Handbook, The Fairmount Press, Inc, ninth edition, 2018.* 2. *Barney L. Capehart, Wayne C. Turner and William J. Kennedy, Guide to Energy Management, The Fairmont Press Inc., seventh edition, 2012.*	3. *Energy Manager Training Manual (4 Volumes) available at www.energymanager training.com, a website administered by the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, 2015*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. R. Viswanathan, Power Grid corporation	1. Dr.K. Keerthivasan, HCT, Oman	1. Dr. D.Ravichandran, SRMIST
2. Er.Mohanan Pillai , MAPS	2. Dr. A. Venkadesan, NIT Puducherry	2. Dr.V.Kalyanasundaram, SRMIST

Course Code	21EEE508T	Course Name	SOFT COMPUTING TECHNIQUES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the foundational concepts of soft computing and differentiate from hard computing*
CLR-2:	*explore artificial neural networks, architectures, learning algorithms, and applications in electrical engineering.*
CLR-3:	*gain insights into the applications of fuzzy logic and its operations in electrical engineering problems*
CLR-4:	*explore problem-solving using genetic algorithms, schema theorem, and applications of genetic algorithms in various fields*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify components and applications of soft computing techniques*	*2*	*2*	*2*
CO-2:	*modeling and implementation of artificial neural network models to solve problems in electrical engineering*	*2*	*3*	*3*
CO-3:	*apply fuzzy logic concepts to solve problems related to electrical engineering and design fuzzy logic controllers*	*3*	*3*	*3*
CO-4:	*analyze and apply genetic algorithms to optimize solutions in various fields*	*2*	*3*	*2*

Module 1 -Foundations of Soft Computing	***6 Hour***
Introduction to Computing Systems, Soft Computing versus Hard Computing, Characteristics and Importance of Soft Computing, Components of Soft Computing, Applications of Soft Computing Techniques	
Module 2 –Artificial Neural Networks and Applications	***13 Hour***
Biological neurons, Basic models of artificial neural networks, Connections, Learning, Activation Functions, McCulloch and Pitts Neuron, Hebb network, Perceptron networks, Learning rule, Training and testing algorithm, Adaptive Linear Neuron, Back propagation Network, Architecture, Training algorithm, supervised and unsupervised learning, Single-layer perceptron, Multi-layer perceptron, Back Propagation Neural network, Recurrent neural networks, Convolutional neural networks, Application of neural network in Electrical engineering.	
Module 3 –Fundamentals of Fuzzy Logic and Applications	***13 Hour***
Fuzzy logic, fuzzy sets, properties, operations on fuzzy sets, fuzzy relations, Logic operations on fuzzy relations, Fuzzy membership functions, fuzzification, Methods of membership value assignments, intuition, inference, rank ordering, Lambda, cuts for fuzzy sets, Defuzzification methods, Truth values and Tables in Fuzzy Logic, Fuzzy propositions, Formation of fuzzy rules, Decomposition of rules, Aggregation of rules, Fuzzy Inference Systems, Mamdani and Sugeno types, Neuro-fuzzy hybrid systems : Characteristics, classification, application of fuzzy logic controller in electrical engineering.	
Module 4 –Genetic Algorithms: Theory and Applications	***13 Hour***
Biological Background, Traditional optimization and search techniques, genetic algorithm and search space, genetic algorithm versus traditional algorithms, basic terminologies, simple genetic algorithm, general genetic algorithm, operators in genetic algorithm, stopping condition for genetic algorithm flow, constraints in genetic algorithm, problem solving using genetic algorithm, schema theorem, classification of genetic algorithm, Holland classifier systems, genetic programming, Multi-Objective Optimization applications of genetic algorithm.	

Learning Resources	1. *Pradhan, B. K., Soft Computing: Techniques and its Applications in Electrical Engineering, Pearson Education India, 2018.* 2. *Aggarwal, Charu C., Neural Networks and Deep Learning: A Textbook, Springer, 2018* 3. *Ross, Timothy J., Fuzzy Logic with Engineering Applications, Wiley-Blackwell, 2010.*	4. *Sivanandam, S. N., Sumathi, S., and Deepa, S. N., Introduction to Fuzzy Logic using MATLAB, Springer, 2007* 5. *Goldberg, David E., Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley Professional, 1989*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20%	-
Level 2	Understand	30%	-	30%	-	30%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	20%	-	30%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr.A.Kannan, Seshasayee Paper Mills Ltd, Tirunelveli	1. Dr . M.Balaji, SSN	1. Dr. K.Selvakumar, SRMIST
2. Mr. K.Kumaresan, Senior Manager, NTPC	2. Dr.B. Bijukumar, NITPY	2. Dr. R.Sridhar, SRMIST

Course Code	21EEE509T	Course Name	SPECIAL MACHINES AND THEIR CONTROLLERS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electrical and Electronics Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on permanent magnet brushless dc motor and its characteristics*
CLR-2:	*gain knowledge on the concepts of permanent magnet synchronous motor and its control.*
CLR-3:	*analyze the working principle, operation and control of axial flux permanent magnet machines*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze the working and control of permanent magnet brushless dc motor*	*3*	*2*	*2*
CO-2:	*illustrate the operation and characteristics of permanent magnet synchronous motor*	*3*	*2*	*2*
CO-3:	*interpret knowledge on control of axial flux permanent magnet machines*	*3*	*2*	*2*

Module 1 - Permanent Magnet Brushless DC Motor	***15 Hour***
Construction and operation of PMDC and BLDC motor with features, Comparison of mechanical and electronic commutation, permanent magnet materials, BLDC motor classifications, Rotor magnet design topology in BLDC motor, electronic commutation in Star and Delta connected stator winding - EMF and Torque Equation - Torque - speed characteristics, Controller Design-Transfer function, Sensor and Sensor-less control, computer aided design approach in surface mounted type BLDC motor for electric vehicle, Applications.	
Module 2 - Permanent Magnet Synchronous Motor	***15 Hour***
Characteristic features between square and sine wave machines, PMSM classifications, Rotor magnet design topology in PMSM motor, EMF and Torque equation, Torque - speed characteristics, Phasor representation, Control of PMSM: vector and self-control, Power controllers, evaluation of control characteristics- design of current and speed controllers, FEA design in interior type PMSM motor for electric vehicle, Digital controllers, Sensor and Sensor-less control, Applications.	
Module 3 – Axial Flux Permanent Magnet Machines	***15 Hour***
Features of Axial Flux Permanent Magnet Machines and its classifications, Development of Axial Flux Permanent Magnet Machines, Comparison with Radial Flux Machines- Topologies and Geometries, Axial magnetic field excited by PMs, Principle of Operation, Torque production, Performance characteristics, Design of Axial Flux machines with and without cores, FEM approach, Control of trapezoidal and sinusoidal AFPM machine, Sensor-less position control, Applications.	

Learning Resources		
	1. Jacek F. Gieras, Rong-Jie Wang Maarten J. Kamper, Axial Flux Permanent Magnet Brushless Machines, Springer Netherlands, 2008. *2. Ramu Krishnan, Permanent Magnet Synchronous and Brushless DC Motor Drives, First Edition, CRC Press, 2010.*	*3. E.G. Janarthanan, Special Electrical Machines, PHI Learning Private Limited, Delhi, Second Edition, 2014.* *4. T.J.E. Miller, Brushless magnet and Reluctance motor drives, Clarendon press, London, 1989.*

Learning Assessment							
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Sassikumar J – Ola Electric.	1. Dr.R.Ramesh, CEG - Anna University	1. Dr. M. Arun Noyal Doss, SRMIST
2. Mr. K.N. Balakrishnan, Magana Automotive	2. Dr.M.Sudhakaran, PEC	2. Dr.K.Mohanraj, SRMIST