PANDIT DEENDAYAL ENERGY UNIVERSITY, GANDHINAGAR

SCHOOL OF TECHNOLOGY

COURSE STRUCTURE FOR M. TECH. (POWER SYSTEM) IN ELECTRICAL ENGINEERING

Semester I			M. Tech. in Electrical Engineering										
Sr. No.	Course/Lab Code	Course/Lab Name	Teaching Scheme					Examination Scheme					
			L	T	P	Hrs	C	Theory			Practical		Total
								MS	IA	ES	LW	LE/ Viva	Marks
1	20MA503T	Advanced Numerical Techniques and Computer Programming	3	1	0	4	4	25	25	50	--	--	100
2	20MA503P	Advanced Numerical Techniques and Computer Programming	0	0	2	2	1	--	--	--	50	50	100
3	20EE501T	Advanced Power System Protection	3	0	0	3	3	25	25	50	--	--	100
4	20EE501P	Advanced Power System Protection – Lab.	0	0	4	4	2	--	--	--	50	50	100
5	20EE502T	Modern Power Systems Operations and Control	3	0	0	3	3	25	25	50	--	--	100
6	20EE502P	Modern Power Systems Operations and Control - Lab.	0	0	2	2	1	--	--	--	50	50	100
7	20EE503T	Advanced Power Electronics	3	0	0	3	3	25	25	50	--	--	100
8	20EE503P	Advanced Power Electronics – Lab.	0	0	2	2	1	--	--	--	50	50	100
9	20EE504T	Open Elective 1	3	0	0	3	3	25	25	50	--	--	100
		Total	**15**	**1**	**10**	**26**	**21**	**125**	**125**	**250**	**200**	**200**	**900**

IA- Internal Assessment, MS-Mid Semester; ES – End Semester Exam

20MA503T					Advanced Numerical Techniques and Computer Programming					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs. / Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	1	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand and acquaint the concept of various numerical methods.
2. To develop numerical skills in solving problem of engineering interest.
3. To enrich the concept of finite element techniques.
4. To extract the roots of a polynomial equation.

UNIT 1 EIGEN VALUES/ VECTORS AND INTERPOLATION **10 Hrs.**

Role of computer and software, Numerical evaluation of largest as well as smallest (numerically) Eigen values and corresponding Eigen vectors. Curve fitting, Least square approximations (discrete and continuous data), Introduction to interpolation, Newton Gregory Forward Interpolation Formula, Newton Gregory Backward Interpolation Formula, Central difference interpolation formula, Lagrange's Interpolation Formula for unevenly spaced Formula, Error in interpolation, Newton's Divided Difference Formula, cubic spline interpolation, surface interpolation.

UNIT 2 NUMERICAL SOLUTION OF NON-LINEAR EQUATIONS AND POLYNOMIAL **08 Hrs.**

Introduction, Solution of nonlinear simultaneous equations, Descarte's Sign rule, Horner's method, Lin-Bairstow's method, Graeffe's root squaring method, Muller's method, Comparison of various methods.

UNIT 3 NUMERICAL SOLUTION OF ODEs AND PDEs **14 Hrs.**

Mathematical modelling and engineering problem solving, Taylor's method, Euler's method, Runge-Kutta methods of various order, Modified Euler's method, Predictor corrector method: Adam's method, Milne's method. Solution of Boundary value problems using finite differences. Finite difference approximation of partial derivatives, Classification of 2nd order PDEs, different type of boundary conditions, solutions of Elliptic, parabolic and hyperbolic equations of one and two dimensions, Crank- Nicholson method, ADI method.

UNIT 4 INTRODUCTION TO FINITE ELEMENT METHOD **08 Hrs.**

Introduction, Method of Approximation, The Rayleigh-Ritz Method, The Galerkin Method, Application to One dimensional/ two-dimensional problems.

40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Apply a suitable numerical technique to extract approximate solution to the problem whose solution cannot be obtained by routine methods.
CO2 - Analyse the accuracy of numerical methods by estimating error.
CO3 - Analyse / interpret the achieved numerical solution of problems by reproducing it in graphical or tabular form.
CO4 - Evaluate a polynomial on which operations like division, differentiation and integration can be done smoothly from the data generated by performing an experiment or by an empirical formula.
CO5 - Evaluate a sufficiently accurate solution of various physical models of science as well as engineering interest whose governing equations can be approximated by linear/nonlinear ODEs or PDEs or system of ODEs or PDEs.
CO6 - Design /develop an appropriate numerical algorithm for various problems of science and engineering.

TEXT/REFERENCE BOOKS

1. B.S. Grewal, Numerical Methods in Engineering and Science with Programs in C & C++, Khanna Publishers, 2010.
2. S.S. Sastry, Introductory Methods for Numerical Analysis, 4th ed. Prentice Hall of India, 2009.
3. M.K. Jain, S.R.K. Iyengar & R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 5th ed., New Age International, 2007.
4. C F Gerald and P O Wheatley, Applied Numerical analysis, 7th ed., Pearson education, 2003.
5. Erwin Kreyszig, Advanced Engineering Mathematics, 9th ed., Wiley publication, 2005.
6. R.K. Jain& S.R.K. Iyengar, Advanced Engineering Mathematics, 3rd ed. Narosa, 2002.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs.

Part A: 6 questions of 4 marks each 24 Marks

Part B: 6 questions 8 marks each 48 Marks

Part C: 2 questions 14 marks each 28 Marks

20MA503P					ADVANCED NUMERICAL TECHNIQUES AND COMPUTER PROGRAMMING					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs. /Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	---	---	---	50	50	100

List of Simulations

Computer program (in MATLAB) of following topics/methods will be discussed and executed in the lab.

1. Evaluation of largest as well as smallest (numerically) Eigen values and corresponding Eigen vectors.
2. Curve fitting,
3. Newton Gregory Forward Interpolation Formula,
4. Newton Gregory Backward Interpolation Formula,
5. Lagrange's Interpolation Formula for unevenly spaced Formula,
6. Newton's Divided Difference Formula, cubic spline interpolation.
7. Graeffe's root squaring method,
8. Euler's method,
9. Runge-Kutta methods,
10. Modified Euler's method,
11. Predictor corrector method: Adam's method, Milne's method.
12. Solution of Boundary value problems using finite differences.
13. Solution of tridiagonal system,
14. Solution of elliptic, parabolic and hyperbolic equations of one and two dimensions,
15. Crank- Nicholson method.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100
Continuous evaluation 50 marks
End semester examination and Viva-voce 50 marks

20EE501T					ADVANCED POWER SYSTEM PROTECTION					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce the students with basic concepts of power system protection
2. To appreciate and understand scientific concepts underlying engineering and technological applications
3. To educate the basic concepts and new developments in protection against transients & surges
4. To emphasize the significance of auto reclosing, synchronizing & system response to severe upsets

UNIT I PROTECTIVE RELAYING FUNDAMENTALS **10 Hrs.**

General Background, Zones of Protection, Requirements of Protection System, Unit and Non-unit Protection, Primary and Back-up Protection, Historical Development of protection, Classification of Protective Relays, Electro-mechanical (Electromagnetic) Relays (Thermal relay (Electromagnetic) Relays, Attracted Armature Relay, Induction Relays, Induction Disc Relay, Induction Cup Relay, Balance Beam Relay, Universal Torque Equation), Solid State Relays (Introduction, Comparison between Static and Electromechanical Relays, Classification of Static Relays, Generalized Static Time-Over current Relays), Digital Relaying(Merits and Demerits of Digital Relay, Generalized Block Diagram of Digital Relay, Sampling and Data Window), Tripping Mechanism of Relay, Different Relay Algorithms(Algorithms assuming pure sinusoidal relaying signal, Algorithms based on solution of system differential equations, Algorithms Applicable to Distorted Relaying Signals), Concept of Adaptive Relaying

UNIT II PROTECTION OF LINES **20 Hrs.**

PROTECTION OF TRANSMISSION LINES: Introduction, Various Types of Transmission Line Faults, Overview of Over Current Protection of Transmission Lines, Over View of directional Protection Relay, Modern Digital/Numerical Over current & Earth Fault Relay, Over Current Relay Coordination in an Interconnected Power System (Introduction, LINKNET Structure, Determination of Primary/Back-Up Relay pairs) **DISTANCE RELAYING**: Introduction, Transmission Line Protection, Distance Protection, Reach of Distance Relay, Selection of Measuring Unit, current and Voltage Connections, Problems & Remedies in Distance Protection(Close-in fault, Fault Resistance, Remote In-feed, Mutual Coupling, Series Compensated Transmission Lines, Power Swing, Overload, Transient Condition), Examples on Setting of Distance Protection, Symmetrical Component Based Distance Relay, Digital Distance Relaying Scheme. **PILOT RELAYING SCHEMES FOR TRANSMISSION LINE**: Introduction to Pilot Protection System, Circulating Current Based Wire Plot Relaying Scheme, Carrier Current Protection Scheme(Phase Comparison Scheme, Directional Comparison Scheme, Blocking and Unblocking Carrier aided Distance Scheme, Carrier Blocking Scheme, Carrier Unblocking Scheme, Transfer Tripping Carrier aided Distance Scheme, Under Reach Transfer Tripping Scheme, Over Reach Transfer Tripping Scheme)

UNIT III PROTECTION AGAINST TRANSIENTS & SURGES **06 Hrs.**

Introduction, Sources of Transients or Surges in EHV Line, Switching of Transmission Line, Switching of Capacitor Bank, Switching of Coupling Capacitor Voltage Transformer (CCVT), Switching of Reactor, Arcing Ground, Lightning Strokes, Overvoltage Phenomenon due to Lightning and Switching, Surges and Travelling Waves, Wave Propagation on Transmission Line, Reflection and Attenuation, Reflection, Attenuation of Transients, Attenuation of Transients Using Filter, Attenuation of Transients Using Isolation Transformer, Neutral Grounding, effects of Ungrounded Neutral on System Performance Methods of Neutral Grounding, Solid Grounding, Resistance Grounding, Reactance Grounding, Resonant Grounding, Grounding Practices, Protection against Transients and Surges, Protection against Lightning, Earthing Screen (Overhead Shielding), Overhead Ground Wires, Surge Modifier or Absorber, Lightning Arrester (Surge Diverter), Types of Lightning Arresters, Rod Gap Arrester, Horn Gap Arrester, Multi Gap Arrester, Expulsion Type Arrester, Valve Type Arrester, Silicon Carbide (SiC) Lightning Arrester, Metal Oxide (MO) Lightning Arrester, Selection Procedure for Lightning/Surge Arresters, Common Ratings of Lightning/Surge Arresters

UNIT IV AUTORECLOSING AND SYNCHRONIZING & SYSTEM RESPONSE TO SEVERE UPSETS **06 Hrs.**

AUTORECLOSING AND SYNCHRONIZING: Introduction, History of auto reclosing, Advantages of auto reclosing, classification of auto reclosing Relay, auto reclosing based on number of phases, auto reclosing based on number of attempts, auto reclosing based on speed, Sequence of Events of a Typical Single-shot auto reclosing Scheme, Factors to be considered during Reclosing(Choice of zone in case of distance relay, Dead time/ De ionizing time, Reclaim Time, Instantaneous Lock out, Intermediate Lock Out, Breaker supervision function), Synchronism Check(Phasing Voltage Method, Angular Method, Automatic Synchronizing)**SYSTEM RESPONSE TO SEVERE UPSETS:** Introduction, Nature of system response to severe upsets, System Response to Islanding Conditions (Under generated Islands, Over generated Islands, Reactive Power Balance, Power Plant Auxiliaries, Power System Restoration), Load Shedding, Factors to be considered for Load Shedding Scheme(Maximum Anticipated Overload, Number of Load Shedding Steps, Size of Load Shed at Each Step, Frequency Setting, Time Delay), Rate of Frequency Decline, Frequency Relays, Islanding(Issues with Islanding, Methods of Islanding Detection**)**

TOTAL HOURS **42 Hrs.**

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand protective relaying fundamentals
CO2 – Analyze protective relaying schemes for Transmission lines
CO3 – Choose / determine suitable protective relaying scheme for Transmission lines
CO4 – Estimate relay settings for protective relaying schemes for Transmission lines
CO5 – Understand the basics of protection against transients & surges
CO6 – Illustrate& summarize concepts of auto reclosing, synchronizing and system response to severe upsets

TEXT/REFERENCE BOOKS

1. Oza, Nair, Mehta, Makwana, "Power System Protection and switchgear",TMH.
2. Stanley H. Horowitz, Arun G. Phadke, "POWER SYSTEM RELAYING"-Third Edition,2008 Research Studies Press Limited. ISBN: 978-0-470-05712-4
3. J. Lewis Blackburn, Thomas J. Domin, "Protective Relaying Principles and Applications" –Third Edition, CRC Press, Taylor & Francis, 2006.
4. C. Russell Masson, "Art And Science Of Protective Relaying"
5. Y. G. Paithankar and S. R. Bhide, "Fundamentals Of Power System Protection" 2nd edition, PHI
6. Bhavesh Bhalja, Nilesh Chothani, "Protection and switchgear", Oxford Publication 2011
7. B. Ram, "Power System Protection" TMH Publication

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Q.1 (A) Logical Reasoning Question from Unit-I ----- (09) (B) Descriptive Question from Unit-I--------------- (15) 24
Q.2(A) Logical Reasoning Question from Unit-II-----------(15) (B) Descriptive Question from Unit-II-------------------(12) 52
(C) Examples / Numerical from Unit-II---------- (25)
Q.3 (A) Logical Reasoning Question from Unit-III ------ (06) (B) Descriptive Question from Unit-III---------------- (06) 12

Q.4 (A) Logical Reasoning Question from Unit-IV ------ (06)(B) Descriptive Question from Unit-IV----------------- (06) 12

20EE501P					ADVANCED POWER SYSTEM PROTECTION – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
-	-	4	2	4	-	-	-	50	50	100

COURSE OBJECTIVES

1. To impart the practical knowledge about the control & Power circuits of Industrial grade Protection panels
2. To learn about operation & control of basic protective devices (Fuse, MCB, ELCB)
3. To compare the construction, Operating Principles & working of different types of relays
4. To choose relay setting and verify the correct operations for various protective schemes

List of Experiments:

1. Introduction & familiarization with the laboratory.
2. Study of control and power circuit diagrams for MCB,ELCB,FUSE simulation panel
3. Study & Performance of MCB,ELCB,FUSE & plotting their performance characteristic
4. Study of control and power circuit diagrams for radial feeder protection simulation panel
5. Study of the construction & Operation of Electromechanical Relay
6. Testing, Calibration of Electromechanical Over Current Relays (Normal Inverse, Very Inverse & Extreme Inverse Characteristics)
7. Principles of Radial feeder Protection – Calculations, Relay Settings
8. Principles of Radial feeder Protection –Verifications through Hardware Simulations
9. Study of control and power circuit diagrams for OVUV protection simulation panel
10. Study & familiarization of Numerical Relay
11. Principles of Over Voltage & Under voltage Protection – Calculations, Relay Settings
12. Principles of Over Voltage & Under voltage Protection – Verifications through Hardware Simulations
13. Study of control and power circuit diagrams for Parallel feeder protection simulation panel
14. Principles of Parallel feeder Protection - Calculations, Relay Settings
15. Principles of Parallel feeder Protection– Verification through Hardware Simulations
16. Study of control and power circuit diagrams for distance protection simulation panel
17. Principles of Transmission Line Protection (Distance Protection) – Calculations , Relay Settings & Verification through hardware simulations
18. Principles of Transmission Line Protection (Carrier Current Protection) – Calculations , Relay Settings & Verification through hardware simulations
19. Principles of Induction Motor Protection- Calculations , Relay Settings & Verification through hardware simulations
20. Principles of Generator Protection- Calculations & Relay Settings
21. Principles of Generator Protection -Verification through hardware simulation

COURSE OUTCOMES

On completion of the course, student will be able to;

CO1 – Understand the control & power circuit diagrams of Industrial grade panels
CO2 – Compare the performance characteristics of FUSE, MCB, and ELCB
CO3 – Understand construction, working, operation of Electromechanical / Electromagnetic & Numerical relays
CO4 – Evaluate and validate relay settings for the over current & earth fault protections as applied to radial feeder & parallel feeder
CO5 – Evaluate and validate relay settings for the distance protection scheme for transmission lines
CO6 – Observe & Understand basics of the carrier current protection scheme for transmission lines & distance protection of transmission lines

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100

Continuous evaluation	50 marks
End semester examination and Viva-voce	50 marks

Pandit Deendayal Energy University **School of Technology**

20EE502T					MODERN POWER SYSTEM OPERATION AND CONTROL					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce optimization techniques in power system to achieve optimal and secure operation of power systems
2. To introduce restructured power system and discuss issues in operating power system in new framework of deregulations
3. To explore methods of congestion management in restructured power system to achieve perfect power market
4. To perform load frequency control in conventional and restructured power system

UNIT I: ECONOMIC DISPATCH (ED) AND OPTIMAL POWER FLOW (OPF) **14 Hrs**

ED problem with equality and inequality constraints, lambda iteration method, penalty factors, B-coefficients, derivation of loss formula, difference between ED and OPF, OPF applications, OPF solution techniques, Gradient and Newton method for OPF, Linear Sensitive Methods, Linear Programming and Interior Point methods for OPF, SCOPF

UNIT II: AUTOMATIC GENERATION CONTROL **06 Hrs**

Basic voltage and frequency control loops for generator, mathematical model of speed governing system, prime mover, generator, load and speed droop characteristic for load frequency control, and its importance. Automatic generation control in single area and multi area without and with secondary frequency controller, tie-line bias control, AGC in restructured power system

UNIT III: POWER SYSTEM SECUIRTY AND CONGESTION MANAGEMENT **14 Hrs**

Reasons for restructuring / deregulation of power industry, Consumer behavior, Supplier behavior, Market equilibrium, Relationship between short-run and long-run average costs, Perfectly competitive market, Market models based on contractual arrangements, Market architectureFunctions of power security, optimal-secure dispatch, factors affecting security, derivation of generation shift factors and line outage distribution factors, contingency analysis using sensitivity factors, PTDF, contingency selection, congestion management, available transfer capability, locational marginal prices, nodal pricing, inter-zonal and intra-zonal congestion management

UNIT IV: POWER SYSTEM STATE ESTIMATIOM **06 Hrs**

Need of state estimation, Power system state estimation using least square methods, application of state estimation, derivation of Hessian matrix

TOTAL HOURS **40 Hrs**

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Operate power systems in most economical way by adopting optimization techniques considering various equality-inequality constraints and generation limits

CO2 – Perform optimal and secure operation of interconnected power systems using optimal power flow techniques

CO3 – Model power system components for frequency control in power system

CO4 – Formulate techniques for power system security analysis and apply sensitivity factors for contingency analysis in conventional and deregulated power system

CO5 – Manage congestion in restructured power system using different methods of ATC, OPF and nodal pricing

CO6 – Estimate the state of power systems and explore its application to enhance system security

TEXT/REFERENCE BOOKS

1. Allen J Wood and Bruce F Woolenberg, ***"Power Generation, Operation and Control"***, John Wiley & Sons
2. Hadi Sadat, "***Power System Analysis***", Tata McGraw Hill
3. A R Abhayankar and S A Khaparde, ***"Restructured Power Systems"***, Narosa Publications, 2011
4. J.D. Glover, M.S. Sharma and T.J. Overbye, "***Power System Analysis and Design***", 6th Edition, Cengage Learning
5. John J. Grainger and William D. Stevenson, "***Power System Analysis***", McGraw-Hill, 1994
6. J S Dhillon and D P Kothari, ***"Power System Optimization"***, PHI Learning, 2004
7. NPTEL Web Course on Restructured Power Systems by Prof. S A Khaparde
8. N V Ramana, "***Power System Operation and Control",*** Pearson Education India, 2010

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Derivation/long questions of 5-8 Marks 70 Marks

Numerical of 5-8 Marks 30 Marks

20EE502P					MODERN POWER SYSTEM OPERATION AND CONTROL – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To solve optimization problem for power system and use of power simulation software
2. To solve problems on power system security and manage congestion management
3. To model power system component to carry out frequency control

LIST OF SIMULATIONS

1. To solve constrained parameter optimization with equality constraints using Newton's method
2. To solve ED problem of thermal generating units using lambda iteration method
3. To solve ED problem of thermal generating units considering generation limits
4. To simulate frequency control in single-area power system
5. To simulate automatic generation control in two-area power system
6. To simulate automatic generation control in multi-area power system for restructured power system
7. To simulate Optimal Power Flow (OPF) for interconnected power systems
8. To simulate and compare multi-area optimization problem as ED, OPF and Security Constrained Optimal Power Flow (SCOPF)
9. To simulate contingency analysis considering single/multiple outage of line or generators from interconnected power system
10. To use sensitivity factors for contingency analysis
11. To use locational marginal price (LMP) to identify congestion in power systems
12. To simulate available transfer capability for congestion management in power system
13. To carry out state estimation of power system

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Operate simulation software to analyze power systems operations
CO2 – Write programs for power system optimization, operation and control
CO3 – Simulate interconnected power system for ED-OPF and differentiate both solutions
CO4 – Solve contingency analysis and apply sensitivity factors to identify different state of power system operation
CO5 – Simulate frequency control in single-area and two-area power system
CO6 – Solve state estimation problem in power system

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**
Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE503T					ADVANCED POWER ELECTRONICS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To review the operation and applications of power semiconductor switches and power converters
2. To analysethe recent developments in power semiconductor switches and power converters
3. To explore the applications of advanced power converters in electric power systems

UNIT I: REVIEW OF POWER SEMICONDUCTOR SWITCHES AND POWER CONVERTERS **08 Hrs**

Review of Power Semiconductor Switches and Power Converters, Advancements in Power Semiconductor Switches and Power Converters, Modern and Wide Band Gap Power Semiconductor Switches: Construction and Working.

UNIT II: ADVANCED POWER CONVERTERS **16 Hrs**

Multilevel Inverters: Significance, Classification, Operational Analysis of Neutral Point Clamped, Flying Capacitor and Cascaded Multilevel Inverters, Modulation Schemes. **Multi-pulse Rectifiers:** Significance, Operational Analysis of 12, 18 and 24 Pulse Rectifiers. **PWM Rectifiers:** Significance, Power and Control Structure, Operational Analysis. **Matrix Converters:** Features, Classification, Operational Analysis of Direct, Indirect and Sparse Matrix Converters, Modulation Techniques. **Active Bridge dc-dc Converters:** Working of Single and Dual Active Bridge dc-dc converters.

UNIT III: COMPONENT DESIGN AND SOFT SWITCHING **08 Hrs**

Component Design: Components of Advanced Power Converters, Heat Sink Design, EMI Filter Design, Gate Driver ICs, High Frequency Magnetic Component Design, Bidirectional Power Semiconductor Switches, Protection Unit. **Soft Switching:** Hard Switching and its Effects, Soft Switching and its Application in Power Converters.

UNIT IV: APPLICATION OF POWER CONVERTERS IN POWER SYSTEMS **08 Hrs**

Role of Advanced Power Converters in FACTS, HVDC, Power Quality Enhancement, Distributed Generation, Control of Photovoltaic and Wind Energy Conversion Systems, Grid Integration, Electric Vehicles

TOTAL HOURS **40 Hrs**

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Review the operation of different types of power semiconductor switches and power converters
CO2 – Comprehend the construction, characteristics and features modern power semiconductor switches
CO3 – Analyse the power structure and operation of advanced ac power converters
CO4 – Analyse the power structure and operation of advanced dc power converters
CO5 – Design and select components required for the operation of power converters
CO6 – Examine the applications of power converters in the electric power systems

TEXT/REFERENCE BOOKS

1. M. H. Rashid, "Power Electronics: Circuits, Devices and Applications," Prentice Hall of India Ltd.
2. Ned Mohan, T. M. Undeland and W. P. Robbins, "Power Electronics: Converters, Applications and Design," Wiley India Ltd.
3. B. K. Bose, "Modern Power Electronics and ac Drives," Prentice Hall Inc.
4. L. Umanand, "Power Electronics Essential & Applications," Wiley India Pvt. Ltd.
5. Bin Wu, "High Power Converters and AC Drives," Wiley - IEEE Press.
6. Krishna Kumar Gupta and Pallavee Bhatnagar, "Multilevel Inverters: Conventional and Emerging Topologies and Their Control," Academic Press.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: 4 Questions, one from each unit, each carrying 20 marks 80 Marks
Part B/Question: 1 Questions from unit II carrying 20 marks 20 Marks

20EE503P					ADVANCED POWER ELECTRONICS – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To impart the practical knowledge about working of modern power semiconductor switches and advanced power converters
2. To understand the features, merits, demerits and applications of advanced power converters
3. To analyse the operation of advanced power converters through experimental and simulation studies

LIST OF SIMULATIONS AND EXPERIMENTS

1. To study the application of power converters in different applications.
2. To implement gate driver circuitry for IGBT/MOSFET with the help of commercially available gate driver IC.
3. To analyse the operation of wide band gap power semiconductor switches through experimental studies.
4. To analyse the operation of 3-phase controlled and uncontrolled rectifiers.
5. To analyse the operation of ac voltage controller and cycloconverter.
6. To analyse the operation of 3-phase voltage source inverter feeding an induction motor.
7. To design a dc-dc converter and validate the design through simulation studies.
8. To design a dc-dc converter and validate the design through experimental studies.
9. To analyse the impact of EMI filters on the operation of power converters
10. To analyse the power quality at the input of the 6-pulse rectifier and determine its impact on another load connected at the point of common coupling.
11. To analyse the power quality at the input of the 12-pulse rectifier and determine its impact on another load connected at the point of common coupling.
12. To demonstrate the operation of multilevel inverter and analyse the power quality at the output.
13. To simulate and analyse the operation of multilevel inverter.
14. To simulate and analyse the operation of multi-pulse rectifier.
15. To write a code for high frequency inductor design.
16. To write a code for high frequency transformer design.
17. To simulate matrix converter and analyse its operation.
18. To simulate and analyse hard switching and soft switching.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand the significance of modern power semiconductor switches and advanced power converters
CO2 – Experiment with modern power semiconductor switches to determine their characteristics and features
CO3 – Design the gate drive circuitry for power semiconductor switches using commercially available gate driver ICs
CO4 – Experimentally validate the performance of the advanced power electronic converters
CO5 – Validate the performance of the advanced power electronic converters through simulation studies
CO6 – Analyse the operation of advanced power converters and determine their advantages with respect to conventional power converters

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100

Continuous evaluation 50 marks
End semester examination and Viva-voce 50 marks

20EE504T					APPLICATIONS OF AI &OPTIMIZATION IN POWER SYSTEMS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	--	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To assist the student understand the mathematical formulation of different optimization problems in power systems
2. To equip the student with the knowledge of different conventional and AI-based optimization techniques.
3. To help the student in mapping different optimization techniques with power system problems.

UNIT 1 INTRODUCTION TO CONVENTIONAL OPTIMIZATION 08 Hrs.

Introduction to optimization; definition, formulation of optimization problems, objective functions, decision variables, unconstrained and constrained optimization problems, equality and inequality constraints, single and multi-variable optimization, classification of optimization problems; Linear programming (LP), Integer programming (IP), Mixed integer programming (MIP), Nonlinear programming (NP).

UNIT 2 APPLICATION OF CONVENTIONAL OPTIMIZATION TECHNIQUES ON POWER SYSTEM PROBLEMS 12 Hrs.

Application of LP on economic dispatch problem; Phasor measurement Units (PMU), Optimal placement of PMU for network observability using IP, Application of MIP in generation scheduling for a unit commitment problem; Optimal power flow problem using NP.

UNIT 3 INTRODUCTION TO ARTIFICIAL INTELLIGENCE TECHNIQUES 10 Hrs.

Non-traditional optimization techniques, population based search algorithms; Teaching Learning Based Optimization (TLBO) techniques, Particle Swarm Optimization technique; Differential Evolution; Genetic algorithm, Artificial Bee Colony technique.

UNIT 4 APPLICATION OF AI-BASED TECHNIQUES ON POWER SYSTEM PROBLEMS 10 Hrs.

Optimum load shedding problem; optimal sizing and placement of distributed generation; Optimal location for FACTS devices in EHV networks; Optimal sizing of capacitor-banks in LV networks, Optimal placement of capacitors in radial distribution systems.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Understand basic theory and concepts of optimization problems.
CO2 - Categorize different power system problems according to the type of optimization applicable.
CO3 - Build mathematical model of power system optimization problems.
CO4 - Analyse the feasibility of specific optimization technique in relevance to the power system problem at hand
CO5 - Apply appropriate optimization techniques and compare their performance.
CO6 - Recommend appropriate optimization models and techniques for power system related problems.

TEXT/REFERENCE BOOKS

1. S. S. Rao, Engineering Optimization", New Age International Publishers, India.
2. D. P. Kothari, J. S. Dhillon, Power System Optimization, PHI Learning Pvt. Ltd. India.
3. J. Zhu, Optimization of Power System Operation, John Wiley and Sons.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Derivation/Long Questions 70 Marks

Numerical/Flowchart of algorithms 30 Marks

PANDIT DEENDAYAL ENERGY UNIVERSITY, GANDHINAGAR

SCHOOL OF TECHNOLOGY

COURSE STRUCTURE FOR M. TECH. (POWER SYSTEM) IN ELECTRICAL ENGINEERING														
Semester II			M. Tech. in Electrical Engineering											
Sr. No.	Course/Lab Code	Course/Lab Name	Teaching Scheme					Examination Scheme						
			L	T	P	Hrs	C	Theory			Practical		Total	
								MS	IA	ES	LW	LE/Viva	Marks	
1	20EE505T	Grid Integration of Renewable Energy Sources	3	0	0	3	3	25	25	50	--	--	100	
2	20EE505P	Grid Integration of Renewable Energy Sources – Lab.	0	0	2	2	1	--	--	--	50	50	100	
3	20EE506T	Power System Dynamics and Stability	3	0	0	3	3	25	25	50	--	--	100	
4	20EE506P	Power System Dynamics and Stability – Lab.	0	0	2	2	1	--	--	--	50	50	100	
5	20EE507T	Modern Control Systems	3	0	0	3	3	25	25	50	--	--	100	
6	20EE507P	Modern Control Systems – Lab.	0	0	2	2	1	--	--	--	50	50	100	
7	20EE508T	Smart Grid Technologies	3	0	0	3	3	25	25	50	--	--	100	
8	20EE508P	Smart Grid Technologies – Lab.	0	0	2	2	1	--	--	--	50	50	100	
9	20EE509T	Open Elective 2	3	0	0	3	3	25	25	50	--	--	100	
10	20EE5XXT	Core Elective 1	3	0	0	3	3	25	25	50	--	--	100	
11	20EE5XXP	Core Elective 1 – Lab.	0	0	2	2	1	--	--	--	50	50	100	
12	17CE527T	Successful Research and Development Program	2	0	0	2	0	--	--	--	--	--	0	
		Total	**20**	**0**	**10**	**30**	**23**	**150**	**150**	**300**	**250**	**250**	**1100**	
IA- Internal Assessment, MS-Mid Semester; ES – End Semester Exam														

<table>
<tr><td colspan="5">20EE505T</td><td colspan="6">GRID INTEGRATION OF RENEWABLE ENERGY SOURCES</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
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</table>

COURSE OBJECTIVES

1. To understand the fundamental concepts of Wind Energy and Solar Photovoltaic Energy systems.
2. To acquire knowledge of grid integration of Solar PV and Wind energy conversion system and its issues.
3. To analyse the dynamic behaviour of renewable energy sources while operating on grid integration
4. To know the basics about other renewable energy technologies and hybrid renewable power generation system.

UNIT 1 BASICS OF RENEWABLE ENERGY SOURCES **10 Hrs.**

Fundamentals of Wind Energy conversion System: Components of Wind Turbine Generating System and its Function, Betz Limit, Performance Co-efficient, Tip Speed Ratio, Active and Passive Stall and Pitch Control, Yaw control, Power-Speed & Power-Torque Characteristics, Maximum Power Point Tracking. **Fundamentals of Solar Photovoltaic Conversion System:** Operating Principle and Construction of PV Cell, Technologies-Amorphous, Monocrystalline, Polycrystalline, Equivalent Circuit of Cell/Module, Cells to Modules to Arrays, Standard Test Conditions (STC) of Photovoltaics for I-V & P-V Characteristics, Impacts of Temperature and Insolation on performance of PV module.

UNIT 2 GRID INTEGRATION OF SOLAR ENERGY CONVERSION SYSTEM **12 Hrs.**

PV Plant Design: Design considerations for standalone and grid connected PV plants. **Solar Photovoltaic (SPV) System:** PV plant layout, Single-inverter plant, Plant with one inverter for each string, Multi-inverter plant, Interfacing of the inverters, Types of photovoltaic system, Current–voltage curves for loads, Maximum Power Point Trackers, Grid connected PV systems, Interfacing with the Utility, DC and AC Rated Power, The ‘‘Peak-Hours’’ Approach to Estimating PV Performance, Capacity Factors for PV Grid-Connected Systems, Grid-Connected System Sizing, Grid-Connected PV System Economics, Concept of three phase grid integration with three phase to two phase conversion concept with park transformation.

UNIT 3 GRID INTEGRATION OF WIND ENERGY CONVERSION SYSTEM **12 Hrs.**

Wind Speed Statistics: Wind Energy Estimation, Discrete Wind Histogram, Wind Power Probability Density Functions, Weibull and Rayleigh Statistics, **Wind Turbine Generators**: Classification of Wind Turbines, Fixed speed induction generator based wind turbine generating system, Doubly Fed Induction Generator (DFIG)-based Wind Turbines, Fully Rated Converter-based (FRC) Wind Turbines, Comparison of Wind Energy Systems in Context with Type of Generator Used (Type A, B, C, D), The Integration of Wind Farms into the Power System, Reactive Power Compensation, HVAC Connections, HVDC Connections, Wind Turbine Control for System Contingencies, Contribution of Wind Generation to Frequency Regulation, Fault Ride-through (FRT) capabilities of wind generators Grid code and IEEE 1547 standard for distributed energy sources.

UNIT 4 FURUTRISTIC RENEWABLE ENERGY SOURCES & HYBRID RENEWABLE ENERGY SYSTEMS **05 Hrs.**

Tidal Power: Concept, Tidal Turbine, Types of Tidal Power Plant, **Biomass and Geothermal**: Definition and Overview; **Fuel cell:** Fuel cell basics, types of fuel cells, components of fuel cell and characteristics of different types of fuel cells, fuel cell equivalent circuit, **Hybrid renewable system:** Wind & solar PV hybrid system with battery backup power generating system, Wind, PV, battery and diesel generator power generating system, and other types of hybrid system.

Max Hrs: 39

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 – Understand the basic aspects of solar photovoltaic energy system and wind energy systems.
CO2 – Recognise and model different types of variable energy sources with more focus on solar and wind
CO3 – Analyse and model basic control strategies required for grid connection of renewable energy sources
CO4 – Compare behaviour of various types of wind energy generation system during grid integration
CO5 – Evaluate the performance characteristics of solar and wind energy systems
CO6 – Implement a complete system, including power sources, converters, control, storage and grid.

TEXT/REFERENCE BOOKS

1. Masters G., “Renewable and Efficient Electric Power Systems”, John Wiley & Sons, Inc., Publication, 2013.
2. Lara O, Jenkins N, Ekanayake J, “Wind Energy Generation Modelling & Control”, John Wiley & Sons, 2009.
3. Mathew S., Wind Energy-Fundamentals, Resource Analysis and Economics, Springer, 2006
4. Rao & Parulekar, Khanna Energy Technology - Publications, New Delhi, 2007.
5. Patel M R. “Design, Analysis, and Operation Wind and Solar Power Systems”, Taylor & Francis, 2nd Edition, 2005.
6. Sawhney G. S., “Non-conventional energy sources”, PHI Learning Pvt. Ltd.
7. Ackermann T., “Wind Power in Power Systems”, John Wiley & Sons Ltd., 2005
8. Bansal R.C., Bhatti T.S., “Small Signal Analysis of Isolated Hybrid Power Systems Reactive Power and Frequency Control Analysis”, Narosa Series in Power and Energy Systems, Narosa Publishing House, 2008.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A: Definitions/Short Questions (1-2 Marks) from Unit I, Short Notes (4-5 Marks) from Unit IV 25 Marks
Part B: Derivations/Long Questions (5-8 Marks) from Unit II and Unit III 75 Marks

20EE505P					GRID INTEGRATION OF RENEWABLE ENERGY SOURCES– LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
-	-	2	1	2	-	-	-	50	50	100

COURSE OBJECTIVES

1. To understand and familiarize with the use of various simulation tools used in renewable energy systems.
2. To analyse the performance of solar PV system and wind energy system connected with grid
3. To gain practical knowledge of the operation and control of solar PV and wind energy conversion system.
4. To develop the concept on role of energy storage system in renewable energy system.

List of Experiments:

1. To carry out simulation of PV module connected with buck converter fed to the DC load with maximum power point tracking algorithm.
2. To carry out simulation of PV module connected with boost converter fed to the DC load with maximum power point tracking algorithm.
3. To simulate the photovoltaic system connected with single phase grid.
4. To simulate the standalone PV system connected with DC and AC load.
5. To understand basic model of solar PV connected with three phase grid.
6. To demonstrate the partial shading of PV module via simulations.
7. To compare different maximum power point tracking algorithm for grid connected PV system.
8. To simulate the wind turbine model with constant speed and constant power mode.
9. To implement maximum power point tracking algorithm for grid connected PV system.
10. To simulation impact of fixed pitch and variable pitch on wind turbine connected with grid.
11. To develop a model for estimation wind energy with Weibull and Rayleigh statistics.
12. To model complete wind farm connected with three phase grid.
13. To compare the performance of various types of wind turbine generating system
14. To develop and simulate a complete integrated hybrid model having different renewable energy sources, power convertors and energy storage.

COURSE OUTCOMES

On completion of the course, student will be able to;

CO1 – Understand the modelling aspects of wind and solar PV energy conversion system.
CO2 – Examine the characteristics of renewable energy sources in different environmental conditions.
CO3 – Distinguish the different types of maximum power point tracking methods for solar PV energy system.
CO4 – Analyse, model and simulate basic control strategies of renewable energy sources with more focus on solar and wind required for grid connection and operation.
CO5 – Compare the performance of different types of wind turbine generating system.
CO6 – Model a complete system, including power sources, converters, control, storage and grid.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Continuous evaluation 50 marks
End semester examination and Viva-voce 50 marks

20EE506T					POWER SYSTEM DYNAMICS AND STABILITY					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To classify power system stability and introduce techniques for power system stability analysis
2. To impart knowledge on synchronous generator modelling connected to SMIB and Multi-Machine systems
3. To understand the dynamic behaviour of power system for various small and large disturbance

UNIT I: MODELLING OF SYNCHRONOUS MACHINES FOR POWER SYSTEM STABILITY ANALYSIS **10 HRS**

Physical and mathematical description of synchronous machine, derivation of stator and rotor inductances, dq0 transformation, voltage equation in dq0, electrical power output and torque, physical interpretation of dq0 transformations, per unit system representation for stator and rotor quantities, equivalent circuits for d- and q- axis, steady state analysis for synchronous machine, develop steady state equivalent circuit for SMIB system, computation of active and reactive power and electric torque, computation of initial conditions, synchronous machine representation for stability studies

UNIT II: MODELLING OF LOAD AND EXCITATION SYSTEM FOR POWER SYSTEM STABILITY ANALYSIS **08 HRS**

Static and dynamic load models, dynamic model of induction motor, steady state and dynamic load-voltage characteristics, steady-state dynamic characteristics, component based approach, sample load characteristics, need of excitation systems, elements and types of excitation systems, control and protective functions of excitation systems, mathematical model of component of excitation systems, modeling of complete excitation system and IEEE models for excitation systems

UNIT III SMALL SIGNAL, TRANSIENT AND VOLTAGE STABILITY ANALYSIS OF POWER SYSTEM **16 Hrs**

Fundamental concepts of stability of dynamic system, linearization, block diagram of state-space representation, eigen property of state matrix: eigen value and stability, mode shape, sensitivity and participation factors. **Small Signal Stability of SMIB system:** classical model representation, effect of field circuit dynamics & excitation system, need for power system stabilizer (PSS), application of PSS, swing equation, application of equal area criteria for transient stability analysis, time-domain solution of swing equations, multi-machine transient stability analysis. **Voltage Stability:** definitions, general transmission, generation, load and compensation device characteristic for VS, voltage collapse scenario, methods for voltage stability analysis. Methods for stability improvement

UNIT IV: SUB-SYNCHRONOUS RESONANCE IN POWER SYSTEM **06 HRS**

Turbine-generator torsional characteristic, torsional interactions with power system, sub-synchronous resonance, characteristics of series compensated transmission system, IG and TI effect, analytical methods and mitigation techniques for SSR

TOTAL HOURS **40 Hrs**

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Model synchronous machines for stability analysis
CO2 – Model excitation systems and loads for stability analysis
CO3 – Classify power system stability and apply develop linearized model of SMIB system to analyzed small-signal stability of power systems
CO4 – Analyze transient behavior of SMIB and multi-machine power system with application of large disturbances
CO5 – Develop static and dynamic methods for voltage stability analysis and propose measures to enhance voltage stability of power system
CO6 – Investigate sub-synchronous resonance (SSR) in power system and propose techniques for its mitigation

TEXT/REFERENCE BOOKS

1. Prabha Kundur ***"Power System Stability and Control"***, Tata McGraw Hill, 1994
2. K N Shubhanga, "***Power System Analysis: A Dynamic Perspective",*** Pearson Education, 2018
3. K R Padiyar, "***Power System Dynamics and Control",*** Anshan Ltd, 2004
4. Hadi Sadat, "***Power System Analysis***", Tata McGraw Hill, 2002.
5. J.D. Glover, M.S. Sharma and T.J. Overbye, "***Power System Analysis and Design***", 6th Edition, Cengage Learning
6. C W Taylor, ***"Power System Voltage Stability"***, McGraw-Hill, 1994.
7. NPTEL video lectures by Prof. A M Kulkarni on "***Power System Dynamics and Control"***

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Derivation/long questions of 5-8 Marks 60 Marks
Numerical of 5-8 Marks 40 Marks

20EE506P					POWER SYSTEM DYNAMICS AND STABILITY – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To introduce modelling of power system components for SMIB and Multi-machine stability analysis
2. To introduce static and dynamic stability problem of power system
3. To learn computer programming and use of power system simulation software to analyse power system stability problem

LIST OF SIMULATIONS

1. Introduction to power system stability problem and power system simulation tool
2. To solve differential equations in MATLAB
3. To compute inductances of synchronous machine in per unit
4. To evaluate initial operating conditions of synchronous machine for given load
5. To simulate excitation system for controlling voltage and reactive power
6. To analyse transient stability of power system using equal area criteria for different disturbances
7. To obtain time domain solution of swing equation for transient stability analysis
8. To simulate transient stability SMIB and multi-machine system in Power System Analysis Software
9. To analyse small signal stability with (1) classical generator (2) field circuit dynamics (3) effect of excitation system (AVR)
10. To improve small signal stability with use of power system stabilizer
11. To plot PV and QV curve for voltage stability analysis
12. To analyse voltage stability using continuation power flow
13. To simulate sub-synchronous resonance in power system

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Operate simulation software to analyze power systems stability and control
CO2 – Write programs for power system stability and control
CO3 – Analyze transient stability problem of power system to under large disturbances
CO4 – Perform small signal stability analysis of power system and propose solution to enhance dynamic performance of power system
CO5 – Apply static methods to investigate voltage stability problem and propose measure to improve voltage stability
CO6 – Simulate sub-synchronous resonance condition for power system

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE507T					MODERN CONTROL SYSTEM					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To teach students the concept of state, state space and state space models
2. To teach students about linearization of nonlinear systems
3. To introduce the concept of controllability and observability of a system
4. To introduce modern control design using state feedback, LQG and MPC controllers
5. To familiarize the concept of state estimation

UNIT 1: INTRODUCTION TO MODERN CONTROL THEORY **14 Hrs.**

Introduction to modern control theory, Advantages of modern control theory over conventional control, Concept of state, state variables and state space models, State and output equation, Modelling of physical systems using state space approach, Canonical realizations, Diagonalization, Conversion of state space to TF Model, Solution of state equation, Properties of state transition matrix, Controllability and observability of systems, Stability analysis in state space approach, Linearization of non-linear systems.

UNIT 2: DISCRETE TIME STATE SPACE MODELS **06 Hrs.**

Introduction to discrete time systems, Relationship between s-plane (continuous-time) and z-plane (discrete time), Bilinear transformation, Discrete state space models, Conversion of continuous to discrete state space model, state transfer matrix, solution of state difference equation, stability analysis of discrete systems, Reachability and constructability of discrete systems.

UNIT 3: MODERN CONTROL DESIGN **12 Hrs.**

Conventional control, Control system design using state feedback, Pole placement control, Integral pole placement control, Introduction to optimal control, Control system performance indices, Linear Quadratic Regulator (LQR), Riccati equation, Model Predictive Control (MPC), QP formulation, Objective functions, Receding horizon control, Constraints handling in MPC.

UNIT 4: STATE ESTIMATION **08 Hrs.**

Need of state estimation and filtering, State observers, The separation principle, Introduction to Kalman Filter, Prediction and Estimation steps, Non-linear filtering , Extended Kalman Filter(EKF), Case studies of state estimation in Electrical Engineering.

Max Hrs: 40

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 -Understand concepts of modern control theory and state space models.
CO2 - Analyse the controllability and observability of the system.
CO3 - Convert continuous to discrete time state space models.
CO4 - Design control systems using state feedback control.
CO5 - Understand the formulation of Linear Quadratic Regulator &Model Predictive Control.
CO6 - Understand the concept of state estimation and filtering.

TEXT/REFERENCE BOOKS

1. Katsuhiko Ogata, Modern Control Engineering, PHI Learning Pvt. Ltd., New Delhi, 2010.
2. Norman N. Nise, Control system engineering, Wiley International Edition, 2017.
3. K. Ogata, Discrete Time Control Systems, Pearson Education/PHI, 2nd Edition, 2003.
4. M. Gopal, Digital Control and State Variable Methods, Tata Mcgraw Hill, 3/e, 2008.
5. K. M. Moudgalya, Digital Control, Wiley-Interscience; 1/e, 2008
6. K. J. Astroms and B. Wittenmark, Computer Controlled Systems - Theory and Design, Prentice Hall, 3/e, 1997.
7. E. F. Camacho and A. C. Bordons, Model Predictive Control, 2/e, Springer, 2007

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: Four short questions of five marks each	20 Marks
Part B/Question: Five medium questions of eight marks each	40 Marks
Part C/Question: Four Large questions of Ten marks each	40 Marks

20EE507P					MODERN CONTROL SYSTEM – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To make the students acquainted with the use of computational software such as MATLAB and its simulations.
2. To learn the identification of continuous and discrete models of physical processes.
3. To develop the simulation skills for the design of a controller.
4. To verify the concepts of controllability and observability using simulations.
5. To conduct hands-on control experiments on standard experimental setups.

LIST OF EXPERIMENTS

1. Introduction to control system tool box and MATLAB commands to represent continuous and discretesystems.
2. Solution of state equation using MATLAB/Simulink.
3. Identification of continuous and discrete state space model of Single Board Heater System using step response data.
4. Linearization of a non-linear process using Taylor Series Expansion.
5. Simulation of discrete PID controller using MATLAB/Simulink.
6. Discrete PID control of Single Board Heater System: An experimental study
7. Simulation of discrete Pole Placement Control using MATLAB/Simulink.
8. Pole placement control of Inverted Pendulum: A simulation study.
9. Model Predictive Control of Single Board Heater System: A simulation study.
10. Model Predictive Control of Single Board Heater System: An experimental study.
11. To check controllability and observability of the system using state space models (verifying using MATLAB).
12. State Estimation of Quadruple Tank Process using Kalman Filter:A simulation study

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand the use of various MATLABcommands and functions used in modern control theory.
CO2 – Model the process using step response data.
CO3 – Perform hands-on experiments using PID controller.
CO4 – Perform hands-on experiments to control single board heater system using MPC.
CO5 – understand the implementation of Kalman Filter for state estimation.
CO6 – Understand the process of linearization of non-linear systems

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE508T					SMART GRID TECHNOLOGIES					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	-	-	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce students with the concept of smart and futuristic power grid.
2. To understand communication technologies that shall convert a power network into a smart grid.
3. To understand cyber security and interoperability of power networks.
4. To apply smart grid for smart energy management in power systems.

UNIT I: INTRODUCTION **08 Hrs.**

Evolution of power grid, Drivers of Smart Grid (SG), SG Definitions, Components and features, Trans-disciplinary nature, Attributes/goals of SG, Steps required to accelerate formation of a SG, Smart Generation, Transmission and distribution, Electricity Markets. Global Population Access to Electricity, Global Scenario of Smart Grids. Indian Power Sector: Overview, National Smart Grid Mission, SG roadmap of India

UNIT II:ADVANCED PROTECTION AND CONTROL FOR SMART GRIDS **11 Hrs.**

Smart Sensing and Measurement: Review of existing SCADA system, Advanced Metering Infrastructure, Synchro-Phasor Measurement Technology: PMUs, WAMS, Smart meter measurements. **Communication technologies:** Analogy between the Power Grid and Communication Network, Communication model for SG, Smart grid applications and corresponding communication network types, IEEE 802.15.4 communication protocols, 6LoWPAN, IEEE 802.11, SG protection. **Networked Control:** Communication for control in the power grid, wide-area networked control system, State estimation and power system stability analysis with high penetration of distributed generation.

UNIT III: INTEROPERABILITY AND CYBER SECURITY **08 Hrs.**

Interoperability and Cyber Security: Benefits and Challenges of Interoperability, Model for Interoperability in the Smart Grid Environment, Key standards. Threats Facing the Electric Power System, Cyber security risks and mitigation approach.

UNIT IV:SMARTENERGY MANAGEMENT **13 Hrs.**

Electricity market, deregulation and restructuring, Demand Side Management, Smart Buildings, Buildings-to-Grid concept, Vehicle-to-Grid concept, Transactive Energy Systems: Concept, Peer-to-peer (P2P) power sharing, architecture, case studyand P2P trading. Futuristic power grid: wireless power transmission, Nano generation, near-space power generation.

Total HOURS 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 - Understand concept and significance of smart grids.
CO2 - Understand the Global electricity scenario and latest developments of smart grids in the world.
CO3 - Understand the concepts of smart grid communications.
CO4 - Analyse the operation of smart grid operation and control of power systems.
CO5 - Estimate the state of smart grid power system with/without distributed generation and EVs.
CO6 - Analyse the energy management techniques of smart grid power system.

TEXT/REFERENCE BOOKS

1. Clark W. Gellings, "**The Smart Grid: Enabling Energy Efficiency and Demand Response**", CRCPress, 2009.
2. James A.Momoh,"**Smart grid: fundamentals of design and analysis**". Vol. 63. John Wiley & Sons, 2012.
3. Stephen F. Bush, **"Smart grid: Communication-enabled intelligence for the electric power grid**". John wiley & sons, 2014.
4. C. Garcia-Valle, R., & Lopes, J. A. P. (Eds.). "**Electric vehicle integration into modern power networks**". Springer Science & Business Media, 2012.
5. Borlase, S. (2^{nd} Ed.). "**Smart grids: Advanced technologies and solutions**". CRC Press, 2017.
6. Liu, C. C., McArthur, S., & Lee, S. J. "**Smart grid handbook**", 3 volume set. John Wiley & Sons, 2016.

WEBLINKS

1. IEEE Smart Grid. https://smartgrid.ieee.org/.
2. National Smart Grid Mission.https://www.nsgm.gov.in/en/content/sg-technologies.
3. European Technology & Innovation Platforms. https://www.etip-snet.eu/about/etip-snet/.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Derivation/long questions of 5-8 Marks 70 Marks
Numerical of 5-8 Marks 30 Marks

<table>
<tr><th colspan="5">20EE508P</th><th colspan="6">SMART GRID TECHNOLOGIES – LAB.</th></tr>
<tr><th colspan="5">Teaching Scheme</th><th colspan="6">Examination Scheme</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">C</th><th rowspan="2">Hrs/Week</th><th colspan="3">Theory</th><th colspan="2">Practical</th><th rowspan="2">Total Marks</th></tr>
<tr><th>MS</th><th>ES</th><th>IA</th><th>LW</th><th>LE/Viva</th></tr>
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</table>

COURSE OBJECTIVES

1. To introduce software packages that can be used to develop Smart Grid simulation models.
2. To apply optimization techniques for renewable energy forecasting.
3. To develop smart energy meter model.

LIST OF SIMULATIONS

1. To understand usage of optimization techniques in MATLAB/Simulink.
2. To understand the use of Open DSS software.
3. To estimate wind power generation using probability density functions.
4. To estimate solar power generation using optimization technique.
5. To develop battery model and estimate its state of charge.
6. To optimally develop a solar PV based net-zero energy building model and calculate the energy savings.
7. To develop Home Automation system applying application profile of the ZigBee specification.
8. To generate and decode ZigBee Smart Energy frames for demand Response and Load Control (DRLC) cluster
9. To develop simulation model for IoT based smart energy meter.
10. To simulate IoT based smart energy meter using Arduino/Raspberry pi controller.
11. To develop battery model and estimate its state of charge.
12. To develop an integrated isolated multi energy system model for a cluster of residential buildings
13. To develop an electric vehicle model with drive train and battery.
14. To simulate vehicle-to-grid model and analyse voltage and frequency dynamics.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Demonstrate usage of artificial intelligence techniques for smart grid applications.
CO2 – Conduct forecasting studies for solar and wind energy systems.
CO3 – Develop a smart grid model integrated with renewable energy sources and loads.
CO4 – Apply Internet-of-Things for Smart Grid applications.
CO5 – Develop communication system model for smart grid applications.
CO6 – Develop electric vehicle model and analyze their behavior as cluster on the power grid.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE509T					GRID-INTERACTIVE BUILDING ENERGY SYSTEMS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	-	-	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. Students shall be exposed to the concept of net zero building energy systems.
2. To develop mathematical models for electricity consuming services of buildings.
3. To optimally control building energy usage in accordance to the grid dynamics.

UNIT I:INTRODUCTION **06Hrs**

Building energy consumption and GHG emissions, Smart cities mission, National smart grid mission, flexibility issues in power systems. Basic concepts of calculus of variations, Free end point problem, Optimum of functions with conditions.

UNIT II:BUILDING ENERGY SYSTEMS **15 Hrs**

Energy use intensity, End uses, Energy transfer processes in building space, Building energy modelling and simulation: Building envelope model-Thermal network model, Resistance-Capacitance (RC) network, transfer function method, single zone model of building space, Heating/cooling load calculation HVAC and Lighting systems, Principles for Net Zero Building Enclosures, Passive and Active Systems. Occupancy Comfort Analysis: Interactions between forms of comfort and building energy use, Thermal comfort, Visual comfort and daylighting, Indoor air-quality, acoustic comfort.

UNIT III: BUILDING ENERGY OPTIMAL CONTROL **10 Hrs.**

Review of Optimal Control: Linear regulator problem - Pontryagin's minimum principle. Dynamic programming - Principle of optimality and its application to optimal control problem, Building energy optimal control of HVAC systems.

UNIT IV:BUILDINGS-TO-GRID INTEGRATION **09 Hrs.**

Introduction to the concept, mathematical framework: State space RC-network modelling, Building cluster dynamics: e generator-to-node and building-to-node incidence matrices, Building cluster model, swing equation. Optimal power flow analysis, Optimal control problem: cost-function Formulation: cost of power from grid, deviations in the mechanical power setpoints of generators, penalty factor, defining Constraints, Analysing building set point temperature levels and HVAC loads

TOTAL HOURS 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 - Understand the concept of net zero energy building and modelling methods
CO2 - Understand energy transfer processes within and for a building space
CO3 - Apply optimization techniques to optimize the energy consumption in buildings
CO4 - Understand the building to grid integration framework
CO5 - Examine the energy systems responsible for energy usage in buildings
CO6 - Determine optimal measures to save energy in a building and power grid connection

TEXT/REFERENCE BOOKS

1. Athienitis, Andreas K., and William O'Brien, eds. "**Modelling, design, and optimization of net-zero energy buildings**". Berlin: Ernst & Sohn, 2015.
2. F.L. Lewis. **Optimal Control**. John Wiley & Sons Inc. New York, NY, 1986.
3. M. Gopal. **Modern Control Systems Theory**. New Age International. 2012.
4. Jadhav, Nilesh Y. "**Green and smart buildings: advanced technology options**". Springer, 2016.

RESEARCH PAPERS/OTHER REPORTS

1. Dong, B., Li, Z., Taha, A., & Gatsis, N. (2018). **Occupancy-based buildings-to-grid integration framework for smart and connected communities**. Applied Energy, 219, 123-137.
2. Taha, A. F., Gatsis, N., Dong, B., Pipri, A., & Li, Z. (2017). **Buildings-to-grid integration framework**. IEEE Transactions on Smart Grid, 10(2), 1237-1249.
3. Harish, V. S. K. V., & Kumar, A. (2016). **A review on modelling and simulation of building energy systems**. Renewable and sustainable energy reviews, 56, 1272-1292.
4. US DoE. Buildings-to-Grid Integration. https://www.energy.gov/eere/buildings/about-buildings-grid-integration

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Derivation/long questions of 5-8 Marks	70 Marks
Numerical of 5-8 Marks	30 Marks

PANDIT DEENDAYAL ENERGY UNIVERSITY, GANDHINAGAR

SCHOOL OF TECHNOLOGY

COURSE STRUCTURE FOR M. TECH. (POWER SYSTEM) IN ELECTRICAL ENGINEERING														
Semester III			**M. Tech. in Electrical Engineering**											
Sr. No.	**Course/Lab Code**	**Course/Lab Name**	**Teaching Scheme**					**Examination Scheme**						
			L	**T**	**P**	**Hrs**	**C**	**Theory**			**Practical**		**Total**	
								MS	**IA**	**ES**	**LW**	**LE/ Viva**	**Marks**	
1	20MT611	Seminar	--	--	--	--	5	--	40	60	--	--	100	
2	20MT612	Project	--	--	--	--	14		40	60	--	--	100	
3	20MT613	Industrial Training (During Summer Break)	--	--	--	--	0		--	--	--	--	--	
		Total	--	--	--	--	19						**200**	
IA- Internal Assessment, MS-Mid Semester; ES – End Semester Exam														

20MT611					SEMINAR					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
-	-	-	5	--	--	60	40	--	--	100

The student is required to identify an emerging topic in the field of power system and carry out an in-depth study, which can include literature survey, identification of developments and existing problems, analyzing the impact and operation of the technology, etc. During the mid and end semester evaluation, the student is required to submit a report detailing fundamental concepts, theory, significance and recent developments pertaining to the selected topic. Also, a seminar is to be delivered in front of the department committee to demonstrate the presentation skills and technical knowhow.

20MT612					PROJECT					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
-	-	-	14	--	--	60	40	--	--	100

The student is required to identify and analyse independently problems in the field of power systems. The project will include preliminary work in the area of interest and will be a base for the Project & Dissertation in the semester IV.
The student is required to submit detailed report. It should consist of objectives of study, scope of work, literature review and preliminary work done pertaining to the project undertaken and will defend his/her work carried out.

PANDIT DEENDAYAL ENERGY UNIVERSITY, GANDHINAGAR

SCHOOL OF TECHNOLOGY

COURSE STRUCTURE FOR M. TECH. (POWER SYSTEM) IN ELECTRICAL ENGINEERING														
Semester IV			M. Tech. in Electrical Engineering											
Sr. No.	Course/Lab Code	Course/Lab Name	Teaching Scheme					Examination Scheme						
			L	T	P	Hrs	C	Theory			Practical		Total	
								MS	IA	ES	LW	LE/ Viva	Marks	
1	20MT621	Seminar	--	--	--		5	--	40	60	--	--	100	
2	20MT622	Project & Dissertation	--	--	--		24	--	40	60	--	--	100	
		Total	--	--	--	--	29						**200**	

IA- Internal Assessment, MS-Mid Semester; ES – End Semester Exam

20MT621					SEMINAR					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
-	-	-	3	6	--	60	40	--	--	100

As done in earlier semester, the student needs to recognize an emerging topic in the field of power system and carry out an in-depth study and analysis. The mid and end semester evaluation of Seminar will be carried out, wherein the student will present in format of the evaluation committee the selected topic, its significance, state of technology, recent trends and analysis of the technical concepts. Also, a report is to be submitted to the evaluation committee.

20MT622					PROJECT & DISSERTATION					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
-	-	-	24	--	--	60	40	--	--	100

Project & Dissertationis a continuation of the work done by the student during Semester III. The student is required to submit the thesis as a partial fulfilment of the M. Tech. degree. The project report should include the work of Project of semester III, which is completed before. In addition, the project report should consist of the detailed study of the project undertaken, concluding remarks and future scope of work, if any. At the end of the semester, the candidate will defend his/her work carried out before the examiners at the time of final evaluation.

<table>
<tr><td colspan="5">20EE510T</td><td colspan="6">SUBSTATION ENGINEERING AND AUTOMATION</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
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<tr><td>3</td><td>0</td><td>-</td><td>3</td><td>3</td><td>25</td><td>50</td><td>25</td><td>--</td><td>--</td><td>100</td></tr>
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COURSE OBJECTIVES

1. To understand the basics of substations and the process of design
2. To get a fair knowledge about the construction and design of air and gas insulated substations.
3. Design criteria for substation grounding and human safety, Protection of substations.
4. Determine the approaches/process for integration, automation and communication protocols of substations.

UNIT 1 BASICS OF SUBSTATIONS AND DESIGN PROCESS **08 Hrs.**

Introduction, Background, classification, need determination, budgeting, Traditional and innovative substation design, selection and location of site for a substation, design, construction and commissioning process, Key diagrams of typical substations.

UNIT 2 AIR AND GAS-INSULATED SUBSTATION **10 Hrs.**

Air Insulated Substations: Bus/switching configurations, various types of bus arrangements, components and equipments, high voltage switching equipments: disconnect and load break switches, grounding switches, selection and ratings of various equipments for a particular substation.
Gas-Insulated Substations: Introduction, sulphur hexafluoride Insulating gas, construction and design of GIS, service life, Advantages and economics of GIS.

UNIT 3 GROUNDING AND PROTECTION OF SUBSTATIONS **10 Hrs.**

Reasons for substation grounding, Accidental ground circuits, permissible body current limits, tolerable voltages, design criteria, soil resistivity, grid resistance, grid current, selection of electrodes and conductors for grounding system, Oil Containment and substation fire protection.

UNIT 4 SUBSTATION INTEGRATION, AUTOMATION AND COMMUNICATIONS **12 Hrs.**

Substation integration and automation system functional architecture, new versus existing substations, equipment condition, technical issues for integration and automation, Protocol fundamentals and considerations, choosing the right protocol, communication protocol application areas.
Supervisory control and data acquisition (SCADA): Introduction, SCADA Historical perspective, functional requirements, SCADA communication requirements, components, SCADA communication protocols, structure of a SCADA communications protocol. Security for substation communications, Electromagnetic Environment.

Total Hours 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 - Understand the basics and classification of substations
CO2 – Apply the electrical concepts in location selection and design of substation
CO3 – Evaluate the equipments and their ratings for a particular substation
CO4 – Design of air and Gas Insulated substations
CO5 – Design criteria for substation grounding and human safety
CO6 – Determine the approaches/process for integration, automation and communication protocols of substations.

TEXT/REFERENCE BOOKS

1. J. D. McDonald (Ed)., Electric Power Substations Engineering, CRC Press
2. P. S. Satnam and P. V. Gupta, Substation Design and Equipment, Dhanpat Rai and Sons
3. M. S. Naidu, Gas Insulated Substations, I. K. International Publishing House Pvt. Ltd., New Delhi
4. David Bailey, Edwin Wright, Practical SCADA for Industry, Elsevier

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A: 12 Questions of 3 marks each from the 4 Units 36 Marks
Part B: 2 Questions from each unit, each carrying 8 marks 64 Marks

20EE510P					SUBSTATION ENGINEERING AND AUTOMATION – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To understand the different type of substations and the process of design
2. To get a fair knowledge about the construction and design of air and gas insulated substations.
3. Design criteria for substation grounding and human safety in the substations.
4. To understand approaches/process for integration, automation and communication protocols of substations.

LIST OF EXPERIMENTS

1. Selection and location of site and design process of a substation.
2. Designing of a busbar system for a particular substation
3. Design of Distribution Substations
4. Design of Transmission Substations
5. Selection and ratings of equipments used in the Air-insulated substations.
6. Design the layout of Gas Insulated Substations.
7. Develop the layout of 66/11kV Sub-transmission substation.
8. Develop the layout of 400kV Transmission substation.
9. To design the control panel for low voltage switchgear
10. To understand the functions and requirements of SCADA system for remote monitoring and control
11. Approaches/process for substation integration, automation and communications
12. To measure the earth resistance of distribution substation by using Wenner method.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand the selection and location of site and design process of a substation.
CO2 – Design the distribution substations and evaluate the equipments and their ratings for a particular substation
CO3 – Develop the layout of Sub-transmission and transmission substations
CO4 – Design criteria for substation grounding and human safety
CO5 – Design the layout of Gas Insulated Substations
CO6 – Determine the approaches/process for integration, automation and communication protocols of substations

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**
Continuous Assessment 50 Marks
Viva-Voce Examination on Design Problems/Experiments 50 Marks

20EE514T					DIGITAL SIGNAL PROCESSING AND EMBEDDED SYSTEMS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce discrete time system.
2. To understand different transformation techniques & algorithms to simplify those techniques.
3. To design & implement digital filters with different structure.
4. To study the applications of digital signal processing in power systems and power electronics.

UNIT 1: DISCRETE-TIME SIGNALS AND SYSTEMS **10 Hrs.**

Overview of Digital Signal Processing, Applications of Digital Signal Processing. Discrete-time Signals and its properties, Discrete Systems and its properties, Convolution, Difference Equations, The Discrete-time Fourier Transform (DTFT), The Properties of the DTFT, The Frequency Domain Representation of LTI Systems, Sampling and Reconstruction of Analog Signals

UNIT 2: THE Z- TRANSFORM &THE DISCRETE FOURIER TRANSFORM **10 Hrs.**

Z-Transform: Bilateral z-Transform, Important Properties of the z-Transform, Inversion of the z-Transform, System Representation in the z-Domain, Solutions of the Difference Equations. **Discrete Fourier Transform:** The Discrete Fourier Series, Sampling and Reconstruction in the z-Domain, The Discrete Fourier Transform, Properties of the Discrete Fourier Transform, Linear Convolution Using the DFT, The Fast Fourier Transform.

UNIT 3: IMPLEMENTATION OF DISCRETE-TIME FILTERS **10 Hrs.**

Basic Elements, IIR Filter Structures, FIR Filter Structures, Lattice Filter Structures, Overview of Finite-Precision Numerical Effects, Representation of Numbers, The Process of Quantization and Error Characterizations, Quantization of Filter Coefficients

FIR Filter Design: Properties of Linear-phase FIR Filters, Window Design Techniques, Frequency Sampling Design Techniques, Optimal, Equi-ripple Design Technique. **IIR Filter Design**: Characteristics of Prototype Analog Filters, Analog-to-Digital Filter Transformations, Lowpass Filter Design, Frequency-band Transformations

UNIT 4: DSP ON ARM PROCESSORS **10 Hrs.**

Introduction to STM32, Basic DSP notions, Data types, Floating point, Fixed point, Fixed-point vs. floating-point, Cortex® DSP instructions, Saturation instructions, MAC instructions, SIMD instructions, CMSIS Library, FFT demonstration, FFT performance, FIR filter demonstration, FIR filter design specification, FIR performance, Pulse Width Modulation Control (Synchronous and Asynchronous Modulation), Applications of DSP to power system/power electronics.

Max Hrs: 40

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Implement basic concepts of signals & systems for power system and power electronics applications.
CO2 - Determine the use of Fourier transform & Z transform in power systems and power electronics.
CO3 - Classify & Design digital filter using different techniques.
CO4 - Develop the knowledge about hardware component of digital signal processor.
CO5 - Make use of different algorithms & techniques to process discrete signal and their application in power electronics.
CO6 - Prioritize different transformation methods to process signal.

TEXT/REFERENCE BOOKS

1. John G. Proakis, Dimitris Manolakis, “Digital Signal Processing - Principles, Algorithms and Applications”, Pearson
2. Alan V. Openheim, “Discrete Time Signal Processing”, Pearson Education India
3. Sanjit K. Mitra, “Digital Signal Processing”, Mc-graw Hill
4. Richard G. Lyons, “Understanding Digital Signal Processing”, Prentice Hall

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Derivation/Long Questions 65 Marks

20EE514P					DIGITAL SIGNAL PROCESSING AND EMBEDDED SYSTEMS – LAB.					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To improvise the use of different software tools.
2. To implement DSP Algorithms on MATLAB.
3. To understand Cortex-M4, M7 DSP optimization strategies
4. To improve the software handling skills of students.

List of Experiments/Simulations:

1 To generate discrete sequence using software tool
2 To perform Operation on Sequence using software tool.
3 To represent basic signals (Unit step, unit impulse, ramp, exponential, sine and cosine).
4 To develop program for discrete convolution
5 To develop program for discrete correlation.
6 To understand stability test.
7 To perform Z Transform and Inverse Z-Transform and to find Poles, Zeros and gain from a given Z-Transform using software tool.
8 To understand sampling theorem
9 To design analog filter (low pass, band pass, band stop, high pass filter).
10 To design digital IIR filter.
11 To design FIR filter using windows technique.
12 To write a program to compare direct realization values of IIR filter
13 Understand Cortex-M4, M7 DSP optimization strategies
14 Perform convolution using the ARM CMSIS-DSP Library
15 Perform Fast Fourier Transform (FFT) using the CMSIS-DSP Library
16 Develop Windowed-Sinc filters on ARM Processors
17 Demonstrate a PWM (Pulse Width Modulation)
18 Control the PWM Output with the ADC and a Potentiometer

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Learn software tool to operate signal.
CO2 - Write the MATLAB and C++ codes for processing signals for different applications.
CO3 - Design digital filters using different techniques.
CO4 - Build passive Low-pass and High-pass filters
CO5- Develop and test DSP algorithm on ARM Processor
CO6- Perform spectral analysis on signals on ARM Processors

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE511T					DISTRIBUTION SYSTEM:MODELLING AND ANALYSIS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	-	-	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To apply mathematical techniques for modelling of electrical power distribution system.
2. To develop distribution line models and compute three phase impedance and admittance matrices.
3. To conduct power flow analysis for the distribution system/line models.

UNIT I:INTRODUCTION **06Hrs**

Distribution Systems, Nature of loads: Customer load, Transformer loading, feeder load. Load pattern, Duration curve, load factor, demand factor, Utilization factor, load diversity. Transformer load management. Load Survey. Case study

UNIT II:COMPUTATION OF THE PHASE IMPEDANCE AND PHASE ADMITTANCE MATRICES **12 Hrs**

Series Impedance of Overhead and Underground Lines: Transposed Three-Phase Lines, Untransposed Distribution Lines, Impedance Matrix for Overhead Lines, Sequence Impedances. Carson's equation analysis for Series Impedance of Underground Lines: Concentric Neutral Cable, Tape Shielded Cables Parallel Underground Distribution Lines.

Shunt Admittance of Overhead and Underground Lines: general voltage drop equation for overhead lines, development of shunt admittance matrix for parallel overhead lines, Capacitance calculation between the phase conductor and ground, Analysis for Tape-Shielded Cable Underground Lines, development of three-phase Sequence Admittance matrix, and development of Shunt Admittance matrix for Parallel Underground Lines.

UNIT III: DISTRIBUTION SYSTEM LINE MODELS AND FEEDER ANALYSIS **15 Hrs.**

Three-phase line segment model, degree of unbalance metric, Determination of generalized line constant matrices, modified line segment model with the shunt admittance neglected: three-wire delta connection, three-phase line with grounded neutral. Development of Approximate Line Segment Model by applying the reverse impedance transformation. equivalent Pi circuits for two parallel three-phase lines, Voltage regulation standards, voltage regulator models: Single-Phase and Three-phase, Load models: Wye and Delta connected loads, Capacitor banks and Induction motor model.

Distribution Feeder Analysis: Ladder Iterative for power-flow analysis, Unbalanced Three-Phase Distribution Feeder analysis. Short-Circuit Studies: Unbalanced feeder short-circuit analysis model, Thevenin Equivalent Circuit model, Computation of short-circuit currents.

UNIT IV: Distribution System Automation **06 Hrs.**

Benefits and challenges of automation, Communication system for distribution automation: Data communication systems, Wireless sensor networks, Energy efficiency in electrical distribution & Monitoring, Integration of Distributed Energy Resources.

TOTAL HOURS 39 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 - Gather Knowledge of power distribution system
CO2 - Identify quantitatively different loads on an electrical distribution system
CO3 - Compute series Impedance matrix for Overhead and Underground distribution Lines
CO4 - Compute shunt admittance matrix for Overhead and Underground distribution Lines
CO5 - Develop distribution system line models
CO6 - Analyse the distribution system line models

TEXT/REFERENCE BOOKS

1. Kersting, W. H. (2012). **Distribution system modelling and analysis**. CRC press.
2. Das, B. (2016). **Power distribution automation**. The Institution of Engineering and Technology.
3. Pabla, A. S. (2012). **Electric power distribution**. Tata McGraw-Hill Education.
4. Short, T. A. (2014). **Electric power distribution handbook**. CRC press.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Derivation/long questions of 5-8 Marks	70 Marks
Numerical of 5-8 Marks	30 Marks

20EE511P					DISTRIBUTION SYSTEM: MODELLING AND ANALYSIS – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To introduce software packages that can be used to model and analyse an electrical power distribution system.
2. To develop IEEE-test feeder network models.
3. To conduct transient analysis and model placement of a distribution generator.

LIST OF SIMULATIONS

1. To introduce software packages and toolboxes used for Distribution System modelling.
2. To simulate a simple 2-bus system with one generator, single line/parallel line and a static load using ETAP.
3. To simulate a simple 2-bus system with one generator, single line/parallel line and a dynamic load using ETAP.
4. To develop IEEE 4-Bus Test Feeder model representing transformers of different configurations, full three phase lines, and unbalanced loads.
5. To develop IEEE 13-Bus Test Feeder model (4.16kV) with a single voltage regulator at the substation, overhead and underground lines, shunt capacitors, an in-line transformer, and unbalanced loading.
6. To develop IEEE 34-Bus Test Feeder model (24.9kV) characterized by long and lightly loaded, two in-line regulators, an in-line transformer for short 4.16 kV section, unbalanced loading, and shunt capacitors.
7. To develop IEEE 37-Bus Test Feeder model (4.8kV) characterized by delta configured, all line segments are underground, substation voltage regulation is two single-phase open-delta regulators, spot loads, and very unbalanced.
8. To develop IEEE 123 node Test Feeder model (4.16kV) characterized by overhead and underground lines, unbalanced loading with constant current, impedance, and power, four voltage regulators, shunt capacitor banks, and multiple switches.
9. To compute three-phase impedance matrix for an underground/overhead distribution system.
10. To compute three-phase admittance matrix for an underground/overhead distribution system.
11. To develop approximate Line Segment Model by applying the reverse impedance transformation.
12. To develop step-voltage regulators models: (a) wye-connected (b) closed-delta(c) open-delta and compute voltage gain, A_v, current gain, A_i and Impedance, Z_R matrices.
13. To conduct transient analysis by simulating single L-G fault for a LV distribution system model and compute short-circuit current.
14. To conduct power-flow analysis for a distribution feeder using Ladder-iterative technique.
15. To conduct power-flow analysis by employing a distributed generator/capacitor bank on a bus and analyse voltage profiles.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Develop simple power network model using simulation software.
CO2 – Develop IEEE test feeder network models.
CO3 – Analyse voltage and current profiles along with power factor studies for distribution system.
CO4 – Compute impedance and admittance matrices for underground distribution system.
CO5 – Compute impedance and admittance matrices for overhead distribution system.
CO6 – Conduct power-flow studies for an electrical power distribution system.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE512T					FACTS AND HVDC SYSTEMS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To overcome limitation of AC power control through FACTS devices
2. To introduce CSC and VSC based HVDC power transmission systems
3. To acquire knowledge for modelling of FACTS and HVDC devices for power flow

UNIT I: FLEXIBLE AC TRANSMISSION SYSTEMS **12 HRS**

Load and system compensation, active and reactive power transfer across long line, loadability of line, symmetrical line analysis and case study with passive shunt and series compensation, need of FACTS devices, classification and application of FACTS devices, operation of TCR and TCR, static and dynamic characteristic of SVC, importance of slope in V-I characteristic and influence on system voltage control by SVC, Need of variable series compensation, basic operation of TCSC and operating modes, variation of TCSC reactance with firing angle, closed loop control of TCSC, SVC application for enhancement power transfer capability, synchronizing and damping torques, STATCOM V-I characteristic and steady state operation, SSSC and UPFC for performance improvement of power systems

UNIT II: MODELLING OF FACTS DEVICES FOR POWER FLOW ANALYSIS **14 HRS**

SVC: Shunt variable Susceptance model, integrated transformer firing angle control, nodal voltage control and coordination with reactive compensation devices **TCSC:** Variable series impedance model, firing angle control model, **STATCOM:**Power flow constraints, multi-function control, voltage control model **SSSC:** Equivalent circuit and power flow constraints, P-Q-V control, power flow model and initialization **UPFC:** Operation, power flow constraints, control modes, power flow model and initialization

UNIT III CSC- BASED HVDC POWER TRANSMISSION **10 Hrs**

Comparison between AC and DC power transmission, classification of HVDC links, components of HVDC system **Control:** Basic means and basis for selection of control, ideal and actual control characteristics, combined rectifier and inverter characteristic, alternative inverter converter mode, control implementation of HVDC, converter firing control systems

UNIT IV: VSC- BASED HVDC POWER TRANSMISSION **06 HRS**

Power transfer, current relationship, AC current minimization, structure of VSC link, VSC-HVDC cable technology, VSC DC system control, different control level, DC link control coordination, control capability, assistance during grid restoration

TOTAL HOURS 40 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Identify limitation of AC power control and improve power system performance through compensation
CO2 - Understand operation of different thyristor-controlled FACTS devices to improve performance of power system
CO3 - Understand operation of different voltage source converter-based FACTS devices to improve performance of power system
CO4 - Model FACTS device for power flow analysis to evaluate steady-state performance of power system
CO5 - Analyse and control the operation of CSC-based HVDC systems
CO6 - Analyse and control the operation of VSC-based HVDC systems

TEXT/REFERENCE BOOKS

1. Prabha Kundur ***"Power System Stability and Control"***, Tata McGraw Hill, 1994
2. Hingorani, N. G., Gyugyi, L ***"Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems"***, Wiley-IEEE Press, Dec 1999.
3. R Mohan Mathur and R H Varma, ***"Thyristor Based FACTS Controllers for Electrical Transmission Systems",***IEEE Press, Wiley-INTERSCIENCE, 2002
4. E. Acha *et al.*, ***"FACTS: Modelling and Simulation in Power Networks",*** Wiley Publication, 2004
5. Sood, Vijay K., "***HVDC and FACTS controllers: Applications of Static Converters in Power Systems",*** Springer Science & Business Media, 2006
6. J. Arrillaga, T H Liu and N R Watson, ***"Flexible Power Transmission: The HVDC Options"***, John Wiley & Sons, 2007

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Derivation/long questions of 5-8 Marks 70 Marks

Numerical of 5-8 Marks 30 Marks

20EE512P					FACTS AND HVDC SYSTEMS - LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES

1. To understand simulation studies and mathematical models of HVDC and FACTS system.
2. To vary the control and design inputs and analyse operation for HVDC and FACTS system
3. To gather knowledge about the computation tools and simulation software that can be used for transmission system

LIST OF SIMULATIONS AND EXPERIMENTS

1. To find the parameters of short, medium and long transmission line.
2. To plot voltage profile of uncompensated transmission line for different loading conditions
3. To plot voltage profile of transmission line for different loading conditions with shunt and series compensation
4. To perform series and shunt compensation of transmission line for different operating conditions
5. To develop a 6-pulse bridge circuit model and analyse its operation with commutation overlap less than 60^0feeding an inductive load.
6. To develop simulation model of FC-TCR based SVC to regulate (1) bus voltage (2) exchange of reactive power
7. To develop power flow programs with SVC and validate in simulation software
8. To develop power flow programs with TCSC and validate in simulation software
9. To develop power flow programs with STATCOM and validate in simulation software
10. To simulate HVDC line in 3-bus system and see its effect on power transfer on other transmission line
11. To simulate 12-pulse thyristor converters used on HVDC transmission systems
12. Case Study: Develop VSC based HVDC Transmission System

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Operate simulation software to analyze performance of power transmission systems
CO2 – Analyze the performance of transmission line without and with compensation
CO3 – Develop converter models for FACTS and HVDC devices
CO4 – Model FACTS devices for power flow analysis
CO5 – Develop HVDC system and observe its impact on power transfer
CO6 – Design, operate and control HVDC system

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**
Continuous Assessment 50 Marks
Simulation Based Examination and Viva 50 Marks

20EE513T					POWER QUALITY AND CUSTOM POWER DEVICES					
Teaching Scheme					**Examination Scheme**					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To review the power quality issues, their source and its impact on different loads
2. To analyse different power quality parameters, their significance and its determination
3. To explore the custom power devices and their roles in power quality enhancement

UNIT I: POWER QUALITY **08 Hrs**

Definition, Significance, Power Quality Issues and their Impacts on Power Factor, Loads and Distribution System, National and International Power Quality Standards, Significance of Power Quality in Smart City Mission.

UNIT II: HARMONICS AND ELECTRICAL TRANSIENTS **08 Hrs**

Harmonics: Linear and Nonlinear Loads, Sinusoidal, Non-Sinusoidal Sources and Unbalanced Supply Voltages, Voltage and Current Harmonics, Inter Harmonics, Sub-Harmonics, Sources and Impact of Harmonics, Power Quality Analysis with Harmonics, **Electrical Transients:** Sources of Transient Over Voltages, Atmospheric and Switching Transients,Transients due to Electric Loads and Switching..

UNIT III: INSTANTANEOUS REACTIVE POWER THEORY **12 Hrs**

Fourier Series, p-q Theory, Clarke Transformation, p-q theory for unbalanced and distorted supply, Series and Shunt Compensation, p-q Theory for Shunt Current Compensation and Series Voltage Compensation

UNIT IV: CUSTOM POWER DEVICES **12 Hrs**

Design and Analysis of Passive Filters, Problems with Passive Filtering, Classification of Custom Power Devices, Active Filters, Shunt Active Filters, Series Active Filters, Hybrid Filters, Power Electronic Converters in Active Filtering, STATCOM, Unified Power Quality Conditioners..

TOTAL HOURS **40 Hrs**

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Reviewthe different power quality issues and their impacts on the electrical equipments and distribution
CO2 – Analyze different power quality parameters, their significance and the national and international power quality standards
CO3 – Analyse the sources and effects of current and voltage harmonics and electrical transients
CO4 – Comprehend the p-q theory and its applications in power quality enhancement
CO5 – Design and analysis of passive filtering and comprehend its limitations
CO6 – Examine the power structure and functionality of different custom power devices

TEXT/REFERENCE BOOKS

1. H. Akagi, Edson Hirokazu Watanabe, and Mauricio Aredes, ***"Instantaneous Power Theory and Applications to Power Conditioning,"*** IEEE Press Series on Power Engineering.
2. Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, **"Power Quality Problems and Mitigation Techniques,"** John Wiley and Sons Ltd, 2015.
3. Arinthom Ghosh, Gerard Ledwich, and Kluwer "***Power Quality Enhancement Using Custom Power Devices***," Academic Publishers
4. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, and H. Wayne Deaty, "***Electrical Power Systems Quality***," McGraw-Hill.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: 4 Questions, one from each unit, each carrying 20 marks 80 Marks
Part B/Question: 2 Questions, one each from unit III and Unit IV, carrying 10 marks 20 Marks

20EE513P					POWER QUALITY AND CUSTOM POWER DEVICES – LAB.					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	2	1	2	--	--	--	50	50	100

COURSE OBJECTIVES
1. To impart the practical knowledge about power quality issues and their impacts on different loads.
2. To understand the terminologies related to power quality analysis and their measurement.
3. To analyse the passive and active filters through experimental and simulation studies.

LIST OF SIMULATIONS AND EXPERIMENTS

1. To simulate and study the impact of voltage sag and swell in a distribution system on different loads.
2. To simulate and study the impact of voltage interruption, voltage flicker and voltage unbalance on different loads
3. To simulate and study the impact of voltage notching and power frequency voltage variation on different loads.
4. To simulate and determine the impact of unbalance and distorted supply on the operation of 3-phase induction motor.
5. To determine the power factor, displacement factor, harmonic factor and distortion factor when feeding a 3-phase induction motor.
6. To determine the power factor, displacement factor, harmonic factor and distortion factor when feeding a 3-phase induction motor.
7. To determine the power factor, displacement factor, harmonic factor and distortion factor when feeding a 3-phase rectifier.
8. Power quality analysis at the input of 6-pulse uncontrolled rectifier with power quality analyzer.
9. Power quality analysis at the input of 6-pulse controlled rectifier with power quality analyzer.
10. Power quality analysis at the input of ac voltage controller and cycloconverter with power quality analyzer.
11. To simulate and analyse instantaneous reactive power theory.
12. Power quality analysis at the input of 6-pulse uncontrolled rectifier with dSPACE.
13. To analyse the operation of a custom power device through simulation studies.
14. To analyse the operation of a custom power device through experimental studies.
15. To write a code to design the passive filters.
16. To simulate and analyse the impact of passive filters on power quality.

COURSE OUTCOMES
On completion of the course, student will be able to
CO1 – Understand the significance of power quality in modern power system
CO2 – Determine the different power quality parameters for the given system through simulation studies
CO3 – Experimentally determine power quality parameters for the given system
CO4 – Analyse the power quality at the input of different power converters
CO5 – Validate the performance of custom power devices through experimental and/or simulation studies
CO6 – Design passive filters and study its impact on power quality

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100
Continuous evaluation 50 marks
End semester examination and Viva-voce 50 marks