Walchand College of Engineering, Sangli

(A Government Aided Autonomous Institute)

Course Contents (Syllabus) for

First Year M. Tech.
Electrical
(Power Systems Engineering)
Sem - I to II

AY 2020-21

BoS Minutes

MINUTES OF BOARD OF STUDIES
DEPARTMENT OF ELECTRICAL ENGINEERING
WALCHAND COLLEGE OF ENGINRRING, SANGLI

Meeting No.	: 24
Day/ Date/ Time	: Tuesday, 28th May 2019, 11.00 a.m.
	: H.O.D Cabin, Department of Electrical Engineering, WCE, Sangli.

MEMBERS PRESENT:

1. Dr.D.S.More, Chairman (H.O.D.)
2. Prof.Dr.P.M.Joshi (Member)
3. Dr.D.B.Kulkarni (Member)
4. Dr. S. S. Dambhare (Member)
5. Dr. V. N. Kalkhambkar (Member)
6. Prof.Dr.A.P.Vaidya (Member)
7. Mr.A.B.Patil (Member)
8. Mr.N.V.Patel (Member)
9. Mrs.S.L.Shaikh (Member)
10. Dr.R.P.Hasabe (Members)
11. Mrs.S.P.Diwan (Member)
12. Mr.S.S.Karvekar (Member)
13. Mr.V.P.Mohale (Member)
14. Dr.S.B.Joshi (Member)

Agenda Item No BOS – 24 -01:

Approval of Minutes of Last BOS Meeting.

Structure of B.Tech Electrical, M.Tech Power System Engineering and M.Tech Control System Engineering were approved. Also content of the course Basic Electrical Engineering was approved.

Agenda Item No BOS – 24 -02:

Approval of the resolution made in adhoc BOS and DAB.

Redefining of POs for M.Tech Power System Engineering and Control System Engineering were approved.

Agenda Item No BOS – 24 -03:

Approval of Revised POs for UG Electrical Engineering Programme.

It was suggested from external BOS members to reframe POs with simple words keeping the meaning same. In PSO's how WCE Electrical Engg programme is different from other institutes should get reflected was also suggested. With the modification as suggested by BOS members is carried out and POs of UG program are approved

Agenda Item No BOS – 24 -04:

Approval of New Syllabus of Second Year B.Tech Electrical Engineering Implemented from 2019-20 (First Year B.Tech Electrical from 2018-19).

It was asked by BOS members to include pre-requisite for all the courses and also to verify CO's of each course and if possible revisit it. BOS members advised to change the title of the experiments of all the courses so that the aim of the experiment becomes clear in the title itself. .

Agenda Item No BOS – 24 -05:

Approval for attainment of POs and PEOs for Academic Year 2017-18.

Attainment of POs and PEOs were explained to External BOS members in detail, with which they were satisfied. PO attainment of the 2017-18 is approved.

Agenda Item No BOS – 24 -06:

Any other point with the permission of the chairman.

Since there were no further issues, the meeting was concluded by giving vote of thanks to all committee members by the chairman.

Chairman

Dr.D.S.More
Department of Electrical Engineering
WCE, Sangli.

Dated: 28/05/2019

Copy To:

1. Director
2. Dean Academic
3. All Faculty Members, Department of Electrical Engineering

Table of Credits

Sr. No	Odd Sem Credits	Even Sem Credits	Total Credits
FY	**18**	**18**	**36**
SY	**13**	**16**	**29**
Total Credits	**31**	**34**	**65**

Summary of Changes Proposed

in the Curriculum for 2020-21

Sr. No.	Course Code	Course Name	Changes proposed	Purpose behind change or Expected Benefits

Credit System and Evaluation Scheme

First Year M. Tech Program in Power System Engineering Sem-I AY 2020-21

Sr.No.	Category	Course Code	Course Name	L	T	P	Hrs	Credits	ISE-1	MSE*	ISE-2	ESE
Professional Core (Theory)												
1	PC	4IC501	Research Methodology	2	0	0	2	2	10	30	10	50
2	PC	4PS501	Digital Protection of Power System	3	0	0	3	3	10	30	10	50
3	PC	4PS502	Application of Power Electronics to Power Systems	3	0	0	3	3	10	30	10	50
Professional Core (Lab)												
4	PC	4PS551	Digital Protection of Power System Lab	0	0	4	4	2	25	25	25	25
5	PC	4PS552	Application of Power Electronics to Power Systems Lab	0	0	4	4	2	25	25	25	25
Professional Elective (Theory)												
6	PE	4PS5**	Professional Elective 1	3	0	0	3	3	10	30	10	50
7	PE	4PS5**	Professional Elective 2	3	0	0	3	3	10	30	10	50
Mandatory Life Skill Courses												
8	MC	Refer list	Mandatory Life Skill Course	2	0	0	2	0	10	30	10	50
Value Added Professional Courses #												
9	VAPC	Refer list	Value Added Professional Courses	0	0	0	2	2	0	0	0	0
Value Added Life-Skill Courses #												
10	VALS	Refer list	Value Added Life Skill Courses	0	0	0	2	2	0	0	0	0
			Total	**16**	**0**	**8**	**24**	**18**				

Course List for F.Y. M. Tech. (Power System Engineering) Sem-I AY 2020-21

Sr.No.	Course Code	Course Name
Professional Elective 1		
1	4PS511	Power Apparatus Modeling
2	4PS512	DSP Application to Power System

Professional Elective 2		
1	4PS515	Neural Network and Fuzzy Application to Power System
2	4PS516	Grid Integration of Renewable Energy

First Year M. Tech Program in Power System Engineering Sem-II AY 2020-21

Sr.No.	Category	Course Code	Course Name	L	T	P	Hrs	Credits	ISE-1	MSE*	ISE-2	ESE
Professional Core (Theory)												
1	PC	4PS521	Power Quality in Distribution Systems	3	0	0	3	3	10	30	10	50
2	PC	4PS522	PLC and Embedded Systems	3	0	0	3	3	10	30	10	50
Professional Core (Lab)												
3	PC	4PS571	Power Quality in Distribution Systems Lab	0	0	4	4	2	25	25	25	25
4	PC	4PS572	PLC and Embedded Systems Lab	0	0	4	4	2	25	25	25	25
5	PC	4PS580	Industrial Project	0	0	4	4	2	25	25	25	25
Professional Elective (Theory)												
6	PE	4PS5**	Professional Elective 3	3	0	0	3	3	10	30	10	50
7	PE	4PS5**	Professional Elective 4	3	0	0	3	3	10	30	10	50
Mandatory Life Skill Courses												
8	MC	Refer list	Mandatory Life Skill Course	2	0	0	2	0	10	30	10	50
Value Added Professional Courses #												
9	VAPC	Refer list	Value Added Professional Courses	0	0	0	2	2	0	0	0	0
Value Added Life-Skill Courses #												
10	VALS	Refer list	Value Added Life Skill Courses	0	0	0	2	2	0	0	0	0
			Total	**14**	**0**	**12**	**26**	**18**				

Course List for F.Y. M.Tech. (Power System Engineering) Sem-II AY 2020-21

Sr.No.	Course Code	Course Name
Professional Elective 3		
1	4PS531	Power System Dynamics
2	4PS532	EHVAC
3	4PS533	Deregulated Power System

Professional Elective 4		
1	4PS535	Computer Aided Power System Analysis
2	4PS536	Smart Grid

ODD Semester

Professional Core (Theory) Courses

Title of the Course: Research Methodology **Course Code: 4IC501**	L	T	P	Cr
	2	--	--	2

Pre-Requisite Courses: None

Textbooks:

1. C. R. Kothari, Research Methodology, New Age international
2. Deepak Chopra and Neena Sondhi, Research Methodology : Concepts and cases, Vikas Publishing House, New Delhi
3. Ranjit Kumar, Research Methodology: A Step by Step Guide for Beginners, 2nd Edition

References:

1. E. Philip and Derek Pugh, How to get a Ph. D. – a handbook for students and their supervisors, open university press
2. Stuart Melville and Wayne Goddard, Research Methodology: An Introduction for Science & Engineering Students
3. G. Ramamurthy, Research Methodology, Dream Tech Press, New Delhi

Course Objectives:

1. Understand some basic concepts of research and its methodologies
2. Identify and formulate the research problems, state the hypothesis,
3. Organize and conduct and present research in a more appropriate manner
4. Prepare research artifacts to the college and papers to Conferences and Journals

Course Learning Outcomes:

CO	**After the completion of the course the student should be able to**	Bloom's Cognitive	
		level	Descriptor
CO1	**Classify** various methods to solve research problem.	3	Applying
CO2	**Construct** a research problem in respective engineering domain.	3	Applying
CO3	**Investigate** various data analysis techniques for a research problem.	4	Analyzing
CO4	**Author** the survey paper based on literature review for research problem.	6	Creating

CO-PO Mapping:

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

Assessments :

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to Research	**Hrs.**
What is research? Literature survey and review, types of research, the process of research.	**4**
Module 2: Research Procedures	**Hrs.**
Formulation of a research problem, Experimental design, Classification. Theoretical research, Formulating a problem, verification methods, modeling and simulations, ethical aspects, IPR issues, Copyrights and Patenting etc.	**4**
Module 3: Research Methods	**Hrs.**
Steps in conducting research, Research Problem identification, Probable solutions, verification of the proposed methodology, conclusions. Meaning, Need and Types of research design, Research Design Process, Measurement and scaling techniques, Data Collection – concept, types and methods, Processing and analysis of data, Design of Experiment	**5**
Module 4: Analysis Techniques	**Hrs.**
Quantitative Techniques Sampling fundamentals, Testing of hypothesis using various tests like Multivariate analysis, Use of standard statistical software, Data processing, Preliminary data analysis and interpretation, Uni-variate and bi-variate analysis of data, testing of hypotheses, techniques such as ANOVA, Chi square test etc., Nonparametric tests. Correlation and regression analysis	**5**
Module 5: Research Communications	**Hrs.**
Writing a conference paper, Journal Paper, Technical report, dissertation/thesis writing. Presentation techniques, Patents and other IPRs, software used for report writing such as WORD, Latex etc.	**4**
Module 6: Case Studies	**Hrs.**
Case studies related to the respective disciplines of Engineering.	**4**

Module wise Measurable Students Learning Outcomes:
After completion of the course students will be able to:
Module 1: Understand the process of research.

Module 2: Formulation of a research problem in respective study domains
Module 3: Learn the important steps in conducting research
Module 4: Applying data analytics for research validation.
Module 5: Learn methods for presenting the research results
Module 6: Applying RM in respective disciplines of Engineering.

Title of the Course: Digital Protection of Power System Course Code: 4PS501	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power system protection

Textbooks:

1. Badri Ram, D.N. Vishwakarma, *Power System Protection and Switchgear,* TMH, 2004.
2. Y.G. Paithankar, S.R. Bhide, *Fundamentals of Power System Protection,* PHI, 2003.

References:

1. L.P. Singh, *Digital Protection,* New Age, Second Edition, 2004.
2. A.G. Phadke, J.S. Thorp, *Computer Relaying for Power Systems*, Wiley India, II Edi., 2012

Course Objectives :

Modern power system protection systems are extensively using digital techniques for realizing various needs of protection. This course will strengthen the concepts in power system protection and develop the skills necessary to analyze, design and implement digital protective relays.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Interpret** the performance of devices like CT, PT and relays used in digital protection of Power Systems.	3	Applying
CO2	**Analyze** the use of digital systems for protection of different parts of power system.	4	Analyzing
CO3	**Estimate** and Justify settings of relays for protection of different parts of power system.	5	Evaluating
CO4	**Design** analog/digital protection scheme for simple electrical systems	6	Creating

CO-PO Mapping :

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Review of Relaying Schemes	**Hrs.**
Protection schemes for alternator, transformer, bus bar and induction motors. Transmission line protection using over current- time graded and current graded schemes, drawbacks of these schemes, differential & distance schemes, Electromagnetic CT and PT.	**6**
Module 2: Comparators	**Hrs.**
a. Dual Input Comparator: Amplitude comparator, phase comparator, duality between amplitude and phase comparators, cosine-type and sine-type phase comparators, coincidence type phase comparator. **b. Multi Input Comparator:** Amplitude comparator, phase comparator.	**4**
Module 3: Over Current Relays	**Hrs.**
Different time-current characteristics of over current relay, Microprocessor/microcontroller based over current relay, Directional over current relay and its implementation using microprocessor/microcontroller based scheme.	**8**
Module 4: Differential Relays	**Hrs.**
Circulating current differential protection, percentage differential protection of power transformers, effect of magnetizing inrush, effect of over voltage inrush, hardware and software used for digital protection of transformer.	**8**
Module 5: Distance Protection Relays	**Hrs.**
Microprocessor/microcontroller based impedance, reactance and admittance relays, and measurement of R and X. Quadrilateral characteristics. Digital protection scheme based upon fundamental frequency signals, hardware and software design.	**8**
Module 6: Recent Developments in Digital Protection	**Hrs.**
Digital Relaying techniques based on modern tools of digital signal processing like DFT, Haar Transform, WT etc.	**4**

Module wise Measurable Students Learning Outcomes :

After completion of the course students will be able to:

1. Interpret performance of components used in protection of electrical power systems
2. Examine comparator techniques used for protection.
3. Analyze electronic circuits and software programs for digital over current relays.
4. Use simulation software like Proteus to analyze the electronic circuits.
5. Estimate & justify relay settings for proper co-ordination.
6. Design microcontroller based over current/ differential/ distance relay.

Title of the Course: Application of Power Electronics to Power systems Course Code: 4PS502	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power System Engineering , Power Electronics

Textbooks:

1. R. Mohan Mathur, Rajiv. K. Varma, *Thyristor – Based Facts Controllers for Electrical Transmission Systems*, IEEE press and John Wiley & Sons Inc., 2002

References:

1. A.T.John, *Flexible AC Transmission System*, Institution of Electrical and Electronic Engineers (IEEE), 1999.
2. NarainG.Hingorani, Laszio. Gyugyl, *Understanding FACTS Concepts and Technology of Flexible AC Transmission System*, Standard Publishers, Delhi, 2001.

Course Objectives:

The advent of high power electronic devices has led to the development of FACTs Technology. The concept of FACTs envisages the use of power electronics to improve system operation by fast & reliable control. This course is intended to cover concepts of FACTs including the description, principle of working and analysis of various FACTs controllers, control of FACTs and system interactions.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Explain** necessity**,** operating principals and benefits of FACTs devices.	2	Understanding
CO2	**Choose** the suitable FACTs device/controller for particular application.	3	Applying
CO3	**Analyze** the characteristics of FACTs Controllers and effect of location of the controller on Power System.	4	Analyzing

CO-PO Mapping :

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

Page

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
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MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group

discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction	**Hrs.**
The concept of flexible AC transmission - reactive power control in electrical power transmission lines -uncompensated transmission line – series and shunt compensation. Overview of FACTS devices - Static Var Compensator (SVC) – Thyristor Switched Series capacitor (TCSC) – Unified Power Flow controller (UPFC) - Integrated Power Flow Controller (IPFC).	**6**
Module 2: Static VAR Compensator (SVC) and Applications	**Hrs.**
Voltage control by SVC – advantages of slope in dynamic characteristics – influence of SVC on system voltage. Applications - enhancement of transient stability – steady state power transfer – enhancement of power system damping – prevention of voltage instability.	**6**
Module 3: Thyristor Controlled Series Capacitor(TCSC) and Applications	**Hrs.**
Operation of the TCSC - different modes of operation – modeling of TCSC – variable reactance model – modeling for stability studies. Applications - improvement of the system stability limit – enhancement of system damping – voltage collapse prevention.	**6**
Module 4 : Emerging FACTS Controllers I	**Hrs.**
Static Synchronous Compensator (STATCOM) – operating principle – V-I characteristics	**6**
Module 5 : Emerging FACTS Controllers II	**Hrs.**
Unified Power Flow Controller (UPFC) – Principle of operation - modes of operation – applications – modeling of UPFC for power flow studies.	**6**
Module 6 : Co-Ordination of FACTS Controllers	**Hrs.**
FACTs Controller interactions – SVC–SVC interaction - co-ordination of multiple controllers using linear control techniques – Quantitative treatment of control	**6**

Module wise Measurable Students Learning Outcomes :

After completion of the course students will be able to:

1. Explain necessity and benefits of FACTs controllers.
2. Explain the concept and analyze the effect of application of SVC in power transmission system.
2. Application and analysis of TCSC in Power transmission System.
3. Analysis of STATCOM for various loading conditions.
4. Analysis of UPFC for various loading conditions.
5. Explain the co-ordination of FACTs devices.

Professional Core (Lab) Courses

Title of the Course: Digital Protection of Power System Lab **Course Code: 4PS551**	L	T	P	Cr
	--	--	4	2

Pre-Requisite Courses: Digital Protection of Power Systems

Textbooks:

1. Badri Ram, D.N. Vishwakarma, *Power System Protection and Switchgear*, TMH, 2004.

References:

1. PRDC Relay user manuals
2. MiPower user manuals
3. A.G. Phadke, J.S. Thorp, *Computer Relaying for Power Systems*, Wiley India, II Edi., 2012

Course Objectives :

This laboratory course will develop analytical skills of the student and help to evaluate modern relaying practices. It will enable the student to develop protective relaying concepts as well as provide an opportunity for designing relaying hardware and software.

Course Learning Outcomes:

CO	**After the completion of the course the student will be able to**	Bloom's Cognitive	
		level	Descriptor
CO1	**Demonstrate** the operation of electromagnetic & digital relays.	3	Applying
CO2	**Test** digital relays to verify the operating characteristics.	4 & 5	Analyzing & Evaluating
CO3	**Design** hardware and compile programs for simple digital relays, as a group task.	6	Creating

CO-PO Mapping :

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

Assessments :

Lab Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	Based on	Conducted by	Conduction and Marks Submission	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course.

The experimental lab shall have typically 8-10 experiments.

Course Contents:

1) Perform experiment by assembling a set up to obtain Time-Current characteristics of Electromagnetic O/C and E/F relays.
2) Perform experiment by assembling a set up to verify Directional O/C relay operation.
3) Perform experiment for Plotting Time-current characteristics of DMT, IDMT, NI3, NI1.3, VI, EI etc. using Digital O/C relay.
4) Perform experiment and analyze performance of digital distance relay – quadrilateral characteristics.
5) Fabricate Hardware to realize and program a microprocessor/microcontroller based over current relay.
6) Fabricate Hardware to realize and program a microprocessor/microcontroller based differential relay.
7) Fabricate Hardware to realize and program microprocessor/microcontroller based distance relays.
8) Perform Relay co-ordination study using MiPower software for simple radial feeder system.
9) Demonstrate application of NRDE for development of digital relays.

Title of the Course: Application of Power Electronics to Power Systems Lab **Course Code: 4PS552**	L	T	P	Cr
	--	--	4	2

Pre-Requisite Courses: Power System Engineering , Power Electronics

Textbooks:

1. R. Mohan Mathur, Rajiv. K. Varma, *Thyristor – Based Facts Controllers for Electrical Transmission Systems*, IEEE press and John Wiley & Sons Inc., 2002

References:

1. A.T.John, *Flexible AC Transmission System*, Institution of Electrical and Electronic Engineers (IEEE), 1999.
2. Narain G.Hingorani, Laszio. Gyugyl, *Understanding FACTS Concepts and Technology of Flexible AC Transmission System*, Standard Publishers, Delhi, 2001.

Course Objectives:

The advent of high power electronic devices has led to the development of FACTs Technology. The concept of FACTs envisages the use of power electronics to improve system operation by fast & reliable control. This course is intended to cover concepts of FACTs including the description, principle of working and analysis of various FACTs controllers, control of FACTs and system interactions.

Course Learning Outcomes:

CO	**After the completion of the course the student will be able to**	Bloom's Cognitive	
		level	Descriptor
CO1	**Simulation of various** FACTs devices to understand principle and modelling.	2	Understanding
CO2	**Choose** the suitable FACTs device/controller for particular application.	3	Applying
CO3	**Analyze** the characteristics of FACTs Controllers and effect of location of the controller on Power System.	4	Analyzing

CO-PO Mapping :

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1			2			
CO2				2		
CO3					Page	2

Assessment:

Lab Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	Based on	Conducted by	Conduction and Marks Submission	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities,	Lab Course Faculty	During Week 10 to Week 14	25

	attendance, journal		Submission at the end of Week 14	
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.
Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

Course Content:

1. Simulation and modelling of application of SVC in power system.
2. Analysis of various types of SVCs.
3. Comparison of effectiveness of various types of SVCs.
4. Simulation of TCSC,
5. Simulation of TCSC characteristics.
6. Simulation of STATCOM.
7. Simulation of UPFC.
8. Analysis of STATCOM and UPFC for various loading conditions.

Computer Usage / Lab Tool: MATLAB SIMULINK.

Professional Elective (Theory) Courses

Title of the Course: Power Apparatus Modeling	L	T	P	Cr
Course Code: 4PS511	3	--	--	3

Pre-Requisite Courses: Power System Engineering, A.C. Machines, Power System Analysis and Stability

Textbooks:

1. P. Kundur, *Power System, Stability and Control*, Tata McGraw Hill, New Delhi, 1994.

References:

1. K.R.Padiyar, *Power System Dynamic, Stability & Control*, B.S. Publication, 2008.
2. Peter W.Sauer, M.A. Pai, *Power System Dynamics and Stability*, Person Education Asia, 1998.

Course Objectives :

1. To provide the students the ability to understand the problem of stability of single machine connected to infinite bur and multi machine system.
2. To give the students a sound mathematical approach towards modeling of various approach used in power system.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Construct** models of apparatus in power system.	3	Applying
CO2	**Analyze** models for stability of power systems.	4	Analyzing
CO3	**Recommend** solutions to the problem of power system stability and control.	5	Evaluating

CO-PO Mapping :

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to Power System Stability Problem	Hrs.
Classification of stability, resolution of stability problem by classical method, transient	**6**

stability of multi-machine system.	
Module 2: Modeling of Synchronous machine	**Hrs.**
Physical description, mathematical description of synchronous machine, dq0 transformation, per unit representation, equivalent circuits for direct and quadrature axis.	**6**
Module 3: Excitation System	**Hrs.**
Elements of excitation system, types of excitation system, necessity of stabilizing circuits IEEE excitation systems.	**6**
Module 4: Prime Movers and Energy supply Systems	**Hrs.**
Turbines and governing systems, modeling of steam turbines, steam turbine controls, steam turbine off-frequency capability.	**6**
Module 5: Dynamic modeling of hydro turbine and governors	**Hrs.**
Hydraulic turbine transfer function, governors for hydraulic turbines, detailed hydraulic system model, guidelines for modeling hydraulic turbines	**6**
Module 6: Load modeling for stability studies.	**Hrs.**
Basic load modeling concepts, static load models, dynamic load models, modeling of induction motor, per unit representation, representation in stability studies.	**6**

Module wise Measurable Students Learning Outcomes:

After completion of the course students will be able to:

1. Interpret power system stability phenomenon.
2. Estimate the characteristics of Synchronous machine and develop accurate model.
3. Choose required dynamic performance criteria for identification and specification of excitation systems.
4. Estimate the characteristics of prime mover and energy supply system.
5. Construct model of hydro turbine and governor.
6. Apply load modeling concepts, load composition, component characteristics, and acquisition of load model parameters and modeling of introduction motor.

Title of the Course: Digital Signal Processing Application to Power System **Course Code: 4PS512**	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Signals and Systems

Textbooks:

1. K P Soman, Ramachandran, Resmi, Insights into wavelets from theory to practice, Prentice Hall, New Delhi,
2. A.N. Akansu and R.A. Haddad, “Multiresolution signal Decomposition: Transforms, Subbands and Wavelets”, Academic Press, Oranld, Florida, 1992.
3. John G. Proakis, Dimitris G. Manolakis, “Digital Signal Processing”, Pearson Prentice Hall, 2007.

References:

1. C. Sidney Burrus, Ramesh A. Gopinath, Haitao Guo, *Introduction to Wavelets and Wavelet Transforms*, A Primer PH International Editions, 1998.
2. Raghuveer M. Rao, Ajit S. Bopardikar, *Wavelet Transforms – Introduction to Theory and Applications*, Addison Wesley Pearson Education Asia, 2000
3. IEEE Transaction Papers.

Course Objectives:

1. This course is intended to provide a mathematical introduction to the theory and applications of orthogonal wavelets and their use in analyzing functions and function spaces.
2. It includes a brief survey of Fourier series representation of functions, Fourier transform and the Fast Fourier Transform (FFT) before proceeding to the Haar wavelet system, multi resolution analysis, decomposition and reconstruction of functions, Daubechies wavelet construction, and other wavelet systems.
3. It aims at imparting skills to develop wavelet-based algorithms for applications in the area of Power Systems.

Course Learning Outcomes:

CO	**After the completion of the course the student will be able to**	Bloom’s Cognitive	
		level	Descriptor
CO1	**Explain** the basic concepts and terminology that are used in the Fourier Techniques, wavelets Transforms and Time frequency analysis.	2	Understanding
CO2	**Calculate** filter bank coefficients and **Apply** the concepts of CWT, STFT and DWT for signal analysis.	3	Applying
CO3	**Construct** perfect reconstruction wavelet filter banks for a particular application and **justify** why wavelets provide the right tool.	4,5	Analyzing Evaluating

CO-PO Mapping :

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Fundamentals of Linear Algebra:	**Hrs.**
Vector spaces, Bases, Orthogonality, Orth normality, Projection, Functions and function Spaces, Orthogonal functions, Orthonormal functions, Orthogonal basis functions.	**4**
Module 2: Signal Representation in Fourier Domain	**Hrs.**
Fourier series, Orthogonality, Orth normality and the method of finding the Fourier coefficients Complex Fourier series, Orthogonality of complex exponential bases, Mathematical preliminaries for continuous and discrete Fourier transform, limitations of Fourier domain signal processing, Review of Nyquist theorem., Review of Z transform, Application of Fourier family transforms in power systems.	**6**
Module 3: Discrete Wavelet Transform	**Hrs.**
Introduction to Wavelet Transform: The origins of wavelets, Wavelets and other wavelet like transforms, History of wavelet from Morlet to Daubechies via Mallat, Different communities and family of wavelets, Different families of wavelets within wavelet communities **Discrete wavelet transform:** Introduction, Haar Scaling Functions and Function Spaces, Translation and Scaling, Orthogonality of Translates, Function Space Vo, Finer Haar Scaling Functions, Nested Spaces Haar Wavelet Function, Scaled Haar Wavelet Functions, Orthogonality of φ(t) and ψ(t), Normalization of Haar Bases at Different Scales, Standardizing the Notations, Refinement Relation with Respect to Normalized Bases, Support of a Wavelet System, Triangle Scaling Function, Daubechies Wavelets.	**8**
Module 4: Discrete Wavelet Transform and Relation to Filter Banks	**Hrs.**
Signal decomposition (Analysis), Relation with filter banks, Frequency response, Signal reconstruction: Synthesis from coarse scale to fine scale, Up sampling and filtering, Perfect reconstruction filters, QMF conditions, Computing initial sj+1 coefficients, Concepts of Multi-Resolution Analysis (MRA) and Multi-rate signal processing, Applications of DWT in power systems.	**8**
Module 5: Short Time Fourier Transform(STFT) and Continuous Wavelet Transform (CWT)	**Hrs.**

Short Time Fourier Transform: Signal representation with continuous and discrete STFT, concept of time-frequency resolution, Resolution problem associated with STFT, Heisenberg's Uncertainty principle and time frequency tiling, Why wavelet transform? **Continuous Wavelet Transform:** Wavelet transform-A first level introduction, Continuous time-frequency representation of signals, Properties of wavelets used in continuous wavelet transform, Continuous versus discrete wavelet transform	**6**
Module 6: Designing Orthogonal Wavelet Systems-A Direct Approach	**Hrs.**
Refinement relation for orthogonal wavelet systems, Restrictions on filter coefficients, Condition-1: Unit area under scaling function, Condition-2: Orth normality of translates of scaling functions, Condition-3: Orth normality of scaling and wavelet functions, Condition-4: Approximation conditions (Smoothness conditions), Designing Daubechies orthogonal wavelet system coefficients, Constraints for Daubechies' 6 tap scaling function.	**8**

Module wise Measurable Students Learning Outcomes:

After completion of the course students will be able to:

1. Discuss fundamentals of Vector algebra.
2. Explain concepts of signal processing.
3. Construct two channel filter bank for perfect reconstruction.
4. Calculate time bandwidth product.
5. Explain and Apply concepts of CWT and STFT for signal analysis.
6. Design orthogonal wavelets.

Title of the Course: Neural Network and fuzzy Application to Power System Course Code: 4PS515	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power system

Textbooks:

1. S. N. Sivanandam, *Introduction to Neural Networks using MATLAB 6*, Tata McGraw hill education, 2006.
2. Hagan, Demuth, Mark Beale, *Neural Network Design*, Cengage Learing india Private Limited, 2011.

References:

1. Stamatios V. Kartalopoulos, *Understanding neural networks and fuzzy logic basic concepts and applications*, Prentice Hall of India (P) Ltd, New Delhi, 2000.
2. J.M. Zurada, *Introduction to artificial neural systems*, Jaico Publishers, 1992.
3. Timothy Ross, *Fuzzy Logic with Engineering Applications*, Tata Mc Graw Hill Publication, 1993
4. George J. Klir and Bo Yuan, *Fuzzy Sets and Fuzzy Logic*, PHI Learning Private Limited, 1995.
5. Research Papers.

Course Objectives :

1. To make the student conversant with basic knowledge of Neural Network**.**
2. To make the student conversant with design and programming knowledge for power system operation and control.
3. To make the student conversant with basic knowledge of fuzzy system and fuzzy applications.

Course Learning Outcomes:

CO	**After the completion of the course the student will be able to**	Bloom's Cognitive	
		level	Descriptor
CO1	**Explain** the basic knowledge of Neural Network.	2	Understanding
CO2	**Apply** the Neural network and fuzzy knowledge about different neural networks, their architecture and training algorithm to solve power system problems.	3	Applying
CO3	**Study** the different applications of neural networks and fuzzy logic.	4	Analyzing

CO-PO Mapping :

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to Neural Networks.	**Hrs.**
Introduction, Organization of the Brain, Biological Neuron, Biological and Artificial Neuron Models, Historical Developments, Neuron Model, McCulloch and Pitts models of neuron, ANN terminologies, weights, sigmoidal functions, Bias.	**6**
Module 2: Essentials of Neural Networks.	**Hrs.**
Types of Neuron Activation Function, Neural networks architectures , Linearly separable and linearly non separable systems and their examples, Learning Strategy (Supervised, Unsupervised, Reinforcement), Learning Rules, Hebbian learning rule, Perceptron learning rule etc.	**6**
Module 3: Feed Forward Neural Networks	**Hrs.**
Introduction, single layer Perceptron Models, architecture, Limitations of the Perceptron Model, Applications, Back Propagation Network, architecture, Multilayer Feed Forward Neural Networks. Use of ANN MATLAB tools for programing.	**6**
Module 4: Fuzzy Systems	**Hrs.**
Basic Fuzzy logic theory, history, operation of Fuzzy Logic, Fuzzy relation and extension principle, Fuzzy membership functions and linguistic variables, mamdani and sugens models. Use of MATLAB tools of fuzzy logic.	**6**
Module 5: Application of Neural Network and fuzzy to power system operation and control problems.	**Hrs.**
Use of MATLAB tools of ANN and fuzzy logic for power system applications. Case studies such as load fore-casting, optimal power flow, control applications in FACTS devices, etc.	**6**
Module 6: Application of Neural Network and fuzzy to recent power system protection problems.	**Hrs.**
Use of MATLAB tools of ANN and fuzzy logic for protection applications. Case studies such as fault analysis, fault detection, fault classification, fault location, etc. Page	**6**

Module wise Measurable Students Learning Outcomes :

After completion of the course students will be able to:

1. Use comparison between Biological and Artificial Neuron Models.
2. Summarize different learning strategy.
3. Explain different neural network models.
4. Apply different fuzzy logic tools.
5. Solve power system operation and control problems by using ANN and Fuzzy.
6. Study recent power system protection problems by using ANN and Fuzzy.

Title of the Course: Grid Integration of Renewable Energy Course Code: 4PS516	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power Electronics, Renewable Energy

Textbooks:

1. Amirnaser Yazdani, Reza Iravani - Voltage-sourced converters in power systems_ modeling, control, and applications (2010, IEEE Press_John Wiley)
2. Remus Teodorescu, Marco Liserre, Pedro Rodriguez - Grid Converters for Photovoltaic and Wind Power Systems (2011, John Wiley & Sons, Ltd.)

References:

1. [Iet Energy Engineering] Antonio Moreno-Munoz - Large Scale Grid Integration of Renewable Energy Sources (2017, The Institution of Engineering and Technology)
2. Math J. Bollen, Fainan Hassan 'Integration of Distributed Generation in the Power System', IEEE Press, 2011.

Course Objectives :

1. Course will make the students conversant with configurations of renewable energy grid integration.
2. To provide the advance knowledge about voltage-sourced converters & their control.
3. To make the students aware of research avenues in the field of renewable grid integration along with DC micro-grid concepts.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Summarize** two level voltage source converter in various reference frame.	2	Understanding
CO2	**Apply** various voltage source converters and their control.	3	Applying
CO3	**Analyze** grid synchronization techniques and DC micro-gird.	4	Analyzing

CO-PO Mapping :

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

Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally

last three modules) covered after MSE.

Course Contents:

Module 1: Overview of Renewable Energy	**Hrs.**
Status & trends of renewable energy sources, solar fundamentals, electrical characteristics of PV, stand-alone grid connected PV configurations, wind energy assessment, fixed & variable speed turbines with reduced & full capacity converters.	**7**
Module 2: Two level, three phase voltage-sourced converter	**Hrs.**
Introduction. Two level voltage sourced-converter: structure, principle of operation & power loss. Average model of two level VSC, model in αβ-frame, model & control in *dq* frame.	**6**
Module 3: Three level, three phase, Neutral Point Clamped voltage-sourced converter	**Hrs.**
Introduction, Three level half bridge NPC, PWM sche e for three level half bridge NPC, switched model & average model for three level half bridge NPC, three level NPC: circuit structure, principle of operation. Three level NPC with impressed dc side voltage.	**6**
Module 4: Grid Imposed frequency VSC system: control in αβ-frame & *dq*-frame.	**Hrs.**
Introduction, structure of grid imposed frequency VSC system, real & reactive-power controller, Dynamic model & current mode control for real-/reactive power controller in αβ-frame & *dq* frame, Phase locked Loop.	**6**
Module 5: Grid Synchronization	**Hrs.**
Grid synchronization techniques for single-phase systems, grid synchronization using the Fourier analysis, grid synchronization using A phase-locked loop, PLL Based on a T/4 transport delay, PLL based on the Hilbert transform.	**6**
Module 6: DC Micro-grid	**Hrs.**
Introduction, DC micro-grid system overview, Operation and control of DC micro-grids, DC micro-grid system protection, Application of DC micro-grids to future smart grids.	**5**

Module wise Measurable Students Learning Outcomes :

1. Grasp fundamentals of renewable energy.
2. Interpret two level VSC model & control in αβ-frame & *dq* frame.
3. Employ model, operation of three level, three phase neutral point clamped VSC.
4. Employ grid imposed frequency VSC with real-/reactive power controller.
5. Examine different synchronization techniques.
6. Inspect concept of DC micro-grid, its control, protection & application.

Mandatory Life Skill Courses

Value Added Professional Courses $

Value Added Life-Skill Courses $

Professional Core (Theory) Courses

Title of the Course: Power Quality in Distribution Systems Course Code: 4PS521	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power Systems, Power Electronics

Textbooks:

1. Dr. Mahesh Kumar, IIT Chennai, *Power Quality in Distribution Systems*.
2. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, *Power Quality Problems and Mitigation Techniques*, Wiley, 2015.

References:

1. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, H. Wayne Beaty, *Electrical Power Systems Quality*, Mc-Graw Hill, Edition II, 1996.
2. Angelo Baggini, *Handbook on Power Quality*, John Wiley & Sons, New Jersey, USA, 2008

Course Objectives :

This course is intended to provide basic knowledge of causes, consequences and solutions of power quality problems that affect the operation of computerized processes and electronic systems.

It also aims to provide a theoretical background to correctly approach the problem of reactive, harmonic and unbalance compensation, in the context of the applicable power theory.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**State and Explain** the basic concepts of Power Quality disturbances, reactive power compensation, voltage regulation, power definitions and other figures of merit under distorted, operation and modelling of series and shunt compensators.	1,2	Remembering and Understanding
CO2	**Apply** the theory and algorithms to realize reference current generation, reactive power compensation, voltage regulation and harmonic compensation.	3	Applying
C03	**Analyze** theories of load compensation, reference generation, figures of merits and power definitions, Standards applicable to Power Quality.	4	Analyzing

CO-PO Mapping:

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to Power quality	**Hrs.**
Power Quality: Introduction, State of the Art on Power Quality, Classification of Power Quality Problems, Causes of Power Quality Problems, Effects of Power Quality Problems on Users, Classification of Mitigation Techniques for Power Quality Problems. **Power Quality Standards and Monitoring:** Introduction, State of the Art on Power Quality Standards and Monitoring, Power Quality Terminologies, Power Quality Definitions, Power Quality Standards, Power Quality Monitoring, Numerical Examples.	**6**
Module 2: Power Definitions in Single Phase and Three phase Circuits	**Hrs.**
Definitions of various powers, power factor and other figures of merit under balanced, unbalanced and non-sinusoidal conditions applicable to single phase circuits. Definitions of various powers, power factor and other figures of merit under balanced, unbalanced and non-sinusoidal conditions. IEEE 1459 power definitions applicable to three phase circuits	**6**
Module 3: Theories of Load compensation	**Hrs.**
Introduction, State of the Art on Passive Shunt and Series Compensators, Classification of Passive Shunt and Series Compensators, Principle of Operation of Passive Shunt and Series Compensators, Analysis and Design of Passive Shunt Compensators, Modelling, Simulation, and Performance of Passive Shunt and Series Compensators, Numerical Examples.	**6**
Module 4: Active Shunt Compensation	**Hrs.**
Introduction, State of the Art on DSTATCOMs, Classification of DSTATCOMs, Principle of Operation and Control of DSTATCOMs, Analysis and Design of DSTATCOMs, Modelling, Simulation, and Performance of DSTATCOMs, Numerical Examples.	**6**
Module 5: Active Series Compensation	**Hrs.**
Introduction, State of the Art on Active Series Compensators, Classification of Active Series Compensators, Principle of Operation and Control of Active Series Compensators, Analysis and Design of Active Series Compensators, Modelling, Simulation, and Performance of Active Series Compensators, Numerical Examples. Page	**6**
Module 6: Unified Power Quality Compensators	**Hrs.**
Introduction, State of the Art on Unified Power Quality Compensators, Classification of Unified Power Quality Compensators, Principle of Operation and Control of Unified Power Quality Compensators, Analysis and Design of Unified Power Quality Compensators, Modelling, Simulation, and Performance of UPQCs, Numerical Examples.	**6**

Module wise Measurable Students Learning Outcomes:

After completion of the course students will be able to:

1. Explain Power quality problems, indices and effects.
2. Calculate various power components under balanced and unbalanced and sinusoidal and non-sinusoidal conditions in single phase circuits and three phase circuits.
3. Investigate theories of load compensation.
4. Explain the design operation and modeling of unified power quality compensators

5. Apply real time mitigation methods to power quality problems using series and shunt devices.
6. Analyze the effect of compensators on the power system.

Title of the Course: PLC and Embedded Systems Course Code: 4PS522	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Instrumentation Techniques, Electrical Measurements, Microcontroller and Applications

Textbooks:

1. John W. Webb, Ronald A. Reis, *Programmable logic controllers, principles & applications,* PHI publication, Eastern Economic Edition, 1994.

References:

1. John R. Hackworth and Peterson, *PLC controllers programming methods and applications*, PHI, 2004.
2. Gary dunning, *Introduction to PLC*, Thomson learning, Edition III, 2006.
3. William H. Bolton, *Programmable logic controllers*, Newnes , Edition VI, 2006.

Course Objectives :

1. The course intends to exploit the PLC and Embedded Control for industrial automation.
2. The course aims at developing programs using ladder logic for industrial automation.
3. It intends to analyze the performance of automation systems employing PLC and Embedded Control.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Interpret** features of PLC and Embedded Control Systems used for Industrial Automation.	3	Applying
CO2	**Use** ladder logic programming technique for various PLC applications.	3	Applying
CO3	**Evaluate** the performance of PLC network configurations, PLC functions used for different application	5	Evaluating

CO-PO Mapping :

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2			
CO2			2			
CO3				2		

Assessments :

Teacher Assessment:

Page

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to PLC	**Hrs.**
Introduction, Advantages, Disadvantages, Parts of PLC, PLC Input module, PLC Output Module, PLC Architecture, PLC Operation, PLC as a computer, PLC memory and interfacing, Power Supply for PLC	**6**
Module 2: PLC programming	**Hrs.**
Ladder Logic Symbols, Latching and Unlatching of PLC, Programming on/ off inputs to produce on/off outputs, relation of digital gate logic to contact / coil logic, creating ladder diagrams from process control description.	**6**
Module 3: PLC Timer and Counter Functions	**Hrs.**
PLC timer functions, Types of PLC timers, Programming of Non-retentive timers for various applications, Programming of ON timers, OFF timers, PLC counter functions, Programming of UP, DOWN counters, Case studies related to Industrial Automations	**6**
Module 4: PLC Arithmetic, Comparison and Branch functions	**Hrs.**
PLC Arithmetic functions, PLC comparison functions, Conversion functions, Master control relay functions, PLC jump functions, Jump with return and Jump with No return functions, Programs related to Arithmetic, Comparison and Branch functions	**6**
Module 5: Advanced PLC functions	**Hrs.**
Data move system, data handling functions, Digital bit functions and applications, sequencer functions Analog PLC operations, PID control of continuous process, PID modules & tuning, typical PID functions	**6**
Module 6: PLC Networking	**Hrs.**
Networking of PLCs, Levels of Industrial Control, Types of Networking, Network Communications, Cell control by PLC Networks, Factors to consider in selecting a PLC	**6**

Module wise Measurable Students Learning Outcomes :

After the completion of the course the student should be able to:

1. Interpret the basic features, advantages & disadvantages of PLC.
2. Implement programs in PLC by using programming tools like ladder diagrams.
3. Use PLC timer and counter functions to develop ladder logic programs.
4. Implement various applications of PLC using PLC arithmetic, comparison and branch functions.
5. Employ and evaluate PLC for analog operations and design PID control using PLC
6. Interpret the PLC network configuration and select the PLC to meet given constraints.

Professional Core (Lab) Courses

Title of the Course: Power Quality in Distribution Systems Lab **Course Code: 4PS571**	L	T	P	Cr
	--	--	4	2

Pre-Requisite Courses: Power Systems, Power Electronics

Textbooks:

1. Dr. Mahesh Kumar, IIT Chennai, *Power Quality in Distribution Systems*.
2. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, *Power Quality Problems and Mitigation Techniques*, Wiley, 2015.

References:

1. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, H. Wayne Beaty, *Electrical Power Systems Quality*, Mc-Graw Hill, Edition II, 1996.
2. Angelo Baggini, *Handbook on Power Quality*, John Wiley & Sons, New Jersey, USA, 2008

Course Objectives :

This course is intended to educate the students with the practical aspects of Power Quality issues. It also develops the critical thinking in solving power quality problems with contemporary Power Quality Theories and thereby hone the research skills.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Calculate** power components and other figures of merit under distorted conditions.	3	Applying
CO2	**Analyze** Power Quality Problems and provide suitable remedy.	4	Analyzing
C03	**Evaluate** theories of load compensation, reference generation using suitable simulation tool.	5	Evaluating

CO-PO Mapping :

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

Assessment:

Lab Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Page

Assessment	Based on	Conducted by	Conduction and Marks Submission	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

Course Contents:

1. Analysis of Power Quality Disturbances. (Harmonics, inrush/sag, Transients etc.)
2. Calculation of Power Component definitions in single phase circuits: linear and distorted current condition.
3. Calculation of Power Component definitions in single phase circuits: Non Sinusoidal supply and Non- linear load.
4. Evaluation of theories for power factor correction and load balancing.
5. Evaluation of Theories for harmonic compensation.(part 1: four theories)
6. Evaluation of Theories for harmonic compensation.(part 2: four theories)
7. Evaluation of theories for series compensation.
8. Modelling of unified power quality conditioner.

Computer Usage / Lab Tool: MATLAB SIMULINK

Title of the Course: PLC and Embedded Systems Lab	L	T	P	Cr
Course Code: 4PS 572	--	--	4	2

Pre-Requisite Courses: Instrumentation Techniques, Electrical Measurements, Microcontroller and Applications

Textbooks:

1. John W. Webb, Ronald A. Reis, *Programmable logic controllers, principles & applications,* PHI publication, Eastern Economic Edition, 1994.

References:

1. John R. Hackworth and Peterson, *PLC controllers programming methods and applications*, PHI, 2004.
2. Gary dunning, *Introduction to PLC*, Thomson learning, Edition III, 2006.
3. William H. Bolton, *Programmable logic controllers,* Newnes, Edition VI, 2006.

Course Objectives :

1. The lab course is aimed to develop programming skills using PLC for Industrial Automation
2. The course intends to introduce the use of PLC for solving real world problems.
3. It will enable students to use PLC for control applications in electrical engineering

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Execute** experiments based on PLC and SCADA systems.	3	Applying
CO2	**Construct** basic control systems using PLC and SCADA.	4	Analyzing
CO3	**Design** ladder logic programs for various PLC applications.	6	Creating

CO-PO Mapping :

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2			
CO2				2		
CO3				2		

Assessments :

Lab Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	Based on	Conducted by	Conduction and Marks Submission	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course. The experimental lab shall have typically 8-10 experiments.

Course Contents:

1. Use different components of Relay and PLC logic.
2. Implement ladder diagram for ON/OFF and latching functions.
3. Design of PLC program for motor reversal control.
4. Illustrate stair case lighting using PLC programming.
5. Implement PLC program for building automation.
6. Design of PLC program for various arithmetical functions.
7. Devise the PLC program for traffic control system.
8. Design of ON/ OFF control mechanism using PLC timer functions.
9. Design of basic applications employing PLC counter functions.
10. Design of basic applications employing PLC analog inputs.

Computer Usage / Lab Tool: RSMicrologix, RSLinx, RSEmulator, PLC Trainerkit

Professional Elective (Theory) Courses

Title of the Course: Power System Dynamics Course Code: 4PS531	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power Apparatus Modeling and Simulation

Textbooks:

1. P. Kundur, *Power System, Stability and Control*, Tata McGraw Hill, New Delhi, 1994.

References:

1. K. R. Padiyar, *Power System Dynamic, Stability & Control*, B.S. Publication, 2008.

Course Objectives :

1. To introduce the concept of small signal and transient stability analysis of power systems.
2. To provide solutions to SSR problem and voltage stability problem.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Distinguish** various categories of system stability.	2	Understanding
CO2	**Analyze** models, use analytical tools to decide upon the stability of various types.	4	Analyzing
CO3	**Recommend** various methods to improve various type of stabilities of power system.	5	Evaluating

CO-PO Mapping :

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to small signal stability of power system	**Hrs.**
Small Signal Stability analysis of single machine connected to infinite bus. Step by step model development of single machine connected to infinite bus	**6**
Module 2:Improvement of small signal stability	**Hrs.**

Power system stabilizer, Simulation of Power System Dynamic response using power system stabilizer in the small signal stability model of single machine connected to infinite bus.	**6**
Module 3:Large scale power systems	**Hrs.**
Dynamic equalization of large scale system systems. Step by step reduction of large scale model to a smaller model for analysis purpose.	**8**
Module 4:Transient stability analysis	**Hrs.**
Introduction to Direct method of transient stability analysis by roller ball analogy. Development of model using energy concept, and analysis of model for transient stability.	**6**
Module 5:Sub synchronous resonance	**Hrs.**
Introduction to Sub-Synchronous oscillation & sub- synchronous resonance. Effect of series compensation of transmission line. Induction generator effect, stability of hydro turbines.	**6**
Module 6:Voltage stability	**Hrs.**
Reactive power compensation and Voltage stability. Development of model of power system for voltage stability. Sensitivity analysis and QV modal analysis for voltage stability. Methods of improving stability.	**6**

Module wise Measurable Students Learning Outcomes:

After completion of the course students will be able to:

1. Describe a model of SMIB and solve it analytically.
2. Investigate power system stabilizer and simulate the dynamic response of power system.
3. Estimate equivalent small dimension model of the given large scale system.
4. Assess stability of the system by energy based method.
5. Describe the characteristics and modeling of T.G shaft system and discuses problem related and sub synchronous torsional oscillation for design consideration of power system.
6. Assess the voltage instability problem by dynamic and static models.

Computer Usage / Lab Tool: MATLAB, ETAP, Mi POWER etc.

Title of the Course: EHVAC Course Code: 4PS532	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power system

Textbook:

1. Rakosh Das Begamudre, "EHVAC Transmission Engineering", Wiley Eastern Limited, 3rd Edition 2008.

References:

1. Twian Gonen, "EHVAC and HVDC Transmission System Engineering – Analysis and Design John Wiley and Sons 1988.
2. EHV –AC and HVDC Transmission Engineering &Practice : S.V. Rao
3. Twian Gonen, "Electric Power Transmission System Engineering-Analysis and Design", John Wiley and Sons 1988.

Course Objectives :

1. Student will understand parameters of EHVAC line
2. Student will develop a skill to design and analyze EHVAC line
3. Student will develop a skill to understand power frequency over voltages developed in EHVAC line
4. Student will develop a skill to understand insulation coordination based on lightening

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Outline** parameters of EHVAC line and develop skills to design and analyze EHVAC line.	2	Understanding
CO2	**Examine** power frequency over voltages developed in EHVAC line.	3	Applying
CO3	**Explain** insulation coordination based on lightening.	4	Analyzing

CO-PO Mapping :

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

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test / quize/ seminar etc.: 10 Marks to be submitted before MSE marks. It is open to students.

MSE: Assessment based on 50% of course content (Normally on module 1-3)

ESE: Assessment based on 100% of course content with 70-80% weightage for course content (Normally last three module) covered after MSE.

Course Contents:

Module 1: Introduction, Calculation of Line and Ground Parameters, Voltage Gradients of Conductor and Corona Effects	**Hrs.**
a. Introduction: Engineering aspects and growth of EHVAC transmission line trends and preliminaries, power transferability, transient stability limit and surge impedance loading. **b. Calculation of Line and Ground Parameters:** Resistance, power loss, temperature rise, properties of bundled conductors, inductances, and capacitances, calculation of sequence inductance and capacitance line parameters of modes of propagations, resistance and inductance of ground return. **c. Voltage Gradients of Conductor:** Charge potential relations for multi-conductor lines, surface voltage gradients on conductors, distribution of voltage gradient on sub conductors of bundle. **d. Corona Effects:** I^2R and corona loss, corona loss formulae, charge voltage diagram with corona. Attenuation of traveling waves due to corona loss Audible noise; corona pulses; their generation and properties, limits for radio interface fields.	**8**
Module 2: Theory of Traveling Waves and Standing Waves	**Hrs.**
Waves at power frequency, differential equations and solutions for general case, standing waves and natural frequencies , open ended line; double exponential response, response to sinusoidal excitation, line energization with trapped charge voltage, reflection and refraction of traveling waves.	**6**
Module 3: Lightning and Lightning Protection	**Hrs.**
Lightning strokes to lines, their mechanism, general principals of lightning protection problem, tower footing resistance, lightning arresters and protective characteristics, different arresters and their characteristics.	**6**
Module 4: Over Voltage in EHV Systems Covered by Switching Operations	**Hrs.**
Over voltages their types, recovery voltage and circuit breaker, Ferro resonance over voltages calculation of switching surges single phase equivalents.	**6**
Module 5: Power Frequency Voltage Control and Over Voltages	**Hrs.**
Generalized constants, charging current, power circle diagram and its use, voltage control shunt and series compensation, sub synchronous resonance in series capacitor compensated lines and static reactive compensating systems.	**5**
Module 6: Insulation Coordination	**Hrs.**
Insulation coordination, Insulation levels, voltage withstand levels of protected equipment's and insulation coordination based on lightning, Design of EHVAC lines.	**5**

Module wise Measurable Students Learning Outcomes

1. Student will be able to understand the need and advantages of EHVAC Transmission, they will be able to calculate line and ground parameters, they will understand voltage gradients of the conductor and the phenomenon of corona.
2. Student will be able to understand the concepts of travelling waves and standing waves as well as their mathematical representations.
3. Student will be able to understand the phenomenon of lightening and associated protection.

4. Student will be able to understand different causes of over voltages.
5. Student will be able to understand the power circle diagram and SSR phenomenon.
6. Student will be able to understand the importance of insulation coordination.

Title of the Course: Deregulated Power System Course Code: 4PS 533	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power System Engineering

Textbooks:

1. Loi Lei Lai, *Power System Restructuring and Deregulation: Trading, Performance and Information Technology*, John Wiley & Sons Ltd., UK, 2001.
2. M. Shahidhpour, M. Alomoush, *Restructured Electrical power systems: Operating, Trading and Volatility*, Marcel Dekker Inc., New York, 2001.
3. H. Lee, Willis, W. G. Scott, *Distributed Power Generation: Planning and Evaluation*, Marcel Dekker Inc., New York, 2000.

References:

1. Lorrin Philipson, H. Lee Willis, *Understanding Electric Utilities and Deregulation*, Marcel Dekker Inc., New York, 1998.
2. K. Bhattacharya, M.H.J. Bollen, J. E. Daalder, *Operation of Restructured Power Systems*, Kulwer Academic Publishers, Massachausetts, USA, 2001.
3. M. Shahidhpour, H. Yamin, Z. Li, *Market of Operations in Electric Power Systems: Forecasting Scheduling, and Risk Management*, John Wiley & Sons Ltd., New York, 2002.

Course Objectives :

1. To deliver the knowledge of basic concepts and terminologies used in restructuring and deregulation.
2. To explain the difference between integrated and restructured power system.
3. To impart knowledge of various trading models, market architecture and market power.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Recognize** recent changes occurring in the structure of power supply utilities and electric supply market.	1	Remembering
CO2	**Explain** the problems associated with deregulation.	2	Understanding
CO3	**Solve** some problem associated with deregulate power system.	3	Applying

CO-PO Mapping :

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2					Page
CO2		3				
CO3			3			

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30

ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to Basic Concepts	**Hrs.**
Basic concept and definitions, privatization, restructuring, transmission open access, wheeling, deregulation, components of deregulated system, advantages of competitive system.	**6**
Module 2: Power System Restructuring	**Hrs.**
An overview of the restructured power system, Difference between integrated power system and restructured power system. Explanation with suitable practical examples.	**6**
Module 3: Deregulation of Power Sector	**Hrs.**
Separation of ownership and operation, Deregulated models, pool model, pool and bilateral trade model, multilateral trade model.	**6**
Module 4: Competitive Electricity Market	**Hrs.**
Independent System Operator activities in pool market, Wholesale electricity market characteristics, central auction, single auction power pool, double auction power pool, market clearing and pricing, Market power and its Mitigation Techniques, Bilateral trading, Ancillary services.	**6**
Module 5: Transmission Pricing	**Hrs.**
Marginal pricing of electricity, nodal pricing, zonal pricing, embedded cost, Postage stamp method, Contract path method, Boundary flow method, MW-mile method, MVA – mile method, Comparison of different methods.	**6**
Module 6: Congestion Management	**Hrs.**
Congestion management in normal operation, explanation with suitable example, Total Transfer Capability (TTC), Available Transfer Capability (ATC).	**6**

Module wise Measurable Students Learning Outcomes :

After completion of the course students will be able to:

1. State the components and advantages of competitive system.
2. Paraphrase integrated and restructured power system.
3. Summarize various trading models and use them as per requirements.
4. Explain problems related to market operations.
5. Apply different methods of pricing as per the system model.
6. Solve congestion management problems in normal condition.

Title of the Course: Computer Aided Power System Analysis Course Code: 4PS535	L	T	P	Cr
	3	--	--	3

Pre-Requisite Courses: Power system

Textbooks:

1. Pual M. Anderson, *Analysis of faulted system*, The Iowa state university press/ AMES, 1973.
2. K. Uma Rao, *Computer Techniques and Models in Power systems*, I. K. International Publishing house Pvt. Ltd. New Delhi, 2007.

References:

1. I. J. Nagrath, D. P. Kothari, *Power System Engineering*, Tata Mc-Graw Hill Publishing Co., 1994.
2. Hadi Sadat, *Power system analysis*, 1st edition, Tata Mc-Graw Hill publishing company ltd., 2002.
3. George L. Kusic, *Computer Aided Power System Analysis*, PHI, 2003.
4. Research Papers.

Course Objectives :

1. This course make the students conversant with different power system analysis methods.
2. This course is intended to provide basic knowledge of formation of Ybus methods. .
3. It also aimed to provide different power system computer analysis methods using computer.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Explain** various methods of analyzing shunt and series faults.	2	Understanding
CO2	**Apply** the Network Topology knowledge for power system analysis.	3	Applying
CO3	**Study** Power flow analysis and economic dispatch of generation.	4	Analyzing

CO-PO Mapping :

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

Assessment:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Page Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Analytical Simplifications.	Hrs.
Three Component method, Two-Component method, sequence network connections for different faults, Analysis of unsymmetrical shunt and series faults using three-component (symmetrical component method) and two-Component method.	6
Module 2: Network Topology.	**Hrs.**
Introduction, Elementary graph theory, Connected graph, tree, co-tree, basic cutsets, basic loops, Incidence matrices, Element-node, Bus incidence, Tree-branch path, Basic cutset, augmented cut-set, Basic loop and Augmented loop, Primitive network, Impedance form and Admittance form.	6
Module 3: Network Matrices.	**Hrs.**
Introduction, formation of Y_{bus} by method of Inspection, method of Singular Transformation, Step by Step building algorithm for formation of Y_{bus}. Formation of Bus Impedance Matrix, Modification of Zbus for addition of a branch, addition of link, removal of an element.	6
Module 4: Network Fault and Contingency Calculations.	**Hrs.**
Fault calculations using Zbus, fault calculations using the Ybus table of factors, Contingency analysis for Power systems. Using the Ybus table of factors for contingencies. Analysis of Unsymmetrical faults using Bus Impedance Matrix.	6
Module 5: Power flow analysis	**Hrs.**
Formulation of the problem and power flow equations. Application of numerical techniques to solve load flow problems using bus admittance matrix and bus impedance matrix in the bus – frame of reference such as Gauss, Gauss – Seidel, Newton – Raphson methods, Decoupled load flow methods etc.	6
Module 6: Optimal Dispatch of generation	**Hrs.**
Performance Curves, economic dispatch of generation without and with transmission-line losses, Iterative technique, approximate penalty factor, Derivation of transmission loss formula, Calculation of loss- coefficient using Ybus and sparse matrix techniques.	6

Module wise Measurable Students Learning Outcomes:

After completion of the course students will be able to:

1. Explain different analysis methods of shunt and series faults.
2. Study Impedance and Admittance form of Primitive network.
3. Compare different methods of Ybus formation.
4. Solve different methods of fault analyze using the admittance and impedance matrices.
5. Compare different methods of load flow analysis.
6. Study different planning methods for economic dispatch of generation.

Title of the Course: Smart Grid	L	T	P	Cr
Course Code: 4PS536	3	--	--	3

Pre-Requisite Courses: Power System, Power Electronics

Textbooks:

1. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "*Smart Grid: Technology and Applications*", Wiley
2. G. M. Masters, *Renewable and Efficient Electric Power Systems*, John Wiley & Sons Inc., 2004.

References:

1. Gilbert N. Sorebo, Michael C. Echols, *Smart grid security: An end to end view of security in new Electrical grid*, CRC press, Taylor &Fancis group, 2011.
2. S. P. Chowdhary, P. Crosley and S. Chowdhary, *Micro-grids and active distribution networks, The institution of engineering and technology*, London, 2009.
3. J. S. Thorp, A.G. Phadke, *Synchronized Phasor Measurement and Their Applications* Springer 2008.

Course Objectives :

1. To provide the advance knowledge in the field of smart – grid technology
2. To make the students aware of research avenues in the field of smart grid technology
3. To develop the skills of simulation and analysis of smart grid systems.

Course Learning Outcomes:

CO	After the completion of the course the student will be able to	Bloom's Cognitive	
		level	Descriptor
CO1	**Explain** various concepts associated with smart grid.	2	Understanding
CO2	**Apply** smart grid concept to power system monitoring, communication and protection.	3	Applying
CO3	**Analyze** tools for smart grid's performance, stability and computational analysis.	4	Analyzing

CO-PO Mapping :

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

Assessment:

Page

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weightage respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment, oral, seminar, test (surprise/declared/quiz), and group discussion. [One assessment tool per ISE. The assessment tool used for ISE 1 shall not be used for ISE 2]
MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with70-80% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Smart grid architecture	**Hrs.**
Introduction, smart grid verses today's grid, computational intelligence, power system enhancement, smart grid market drivers, architecture of smart grid, and function of smart grid components.	**6**
Module 2: Smart grid technologies	**Hrs.**
Introduction to Smart Meters, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV) & more, Substation Automation, Feeder Automation, Geographic Information System (GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection	**6**
Module 3: Transmission aspects	**Hrs.**
Wide area Monitoring Systems (WAMS), PMU and PDCs, PMU placement, linear state estimation, System security under smart grid environment, Concept of Resilient & Self-Healing Grid, adaptive relaying using PMUs	**6**
Module 4: Communication aspects	**Hrs.**
Elements of communication and networking: architectures, standards and adaptation of power line communication (PLCC), zigbee, GSM, and more; machine to machine communication models for the smart grid; Home area networks (HAN) and neighborhood area networks (NAN); reliability, redundancy and security aspects.	**6**
Module 5: Performance analysis tool for smart grid design	**Hrs.**
Load flow in smart grid, load flow methods, congestion management flow effect, load flow for smart grid design, dynamic stochastic optimal power flow (DSOPF), DSOPF application to smart grid. Static security assessment and contingencies study for the smart grid.	**6**
Module 6: Stability analysis tools and computational tools for smart grid	**Hrs.**
Voltage stability assessment and its techniques, angle stability assessment and state estimation, optimization techniques, classical optimization methods, Heuristic optimization, evolutionary computational Techniques, Hybrid optimization techniques and application to smart grid.	**6**

Module wise Measurable Students Learning Outcomes :

After completion of the course students will be able to:

1. Explain the smart grid architecture.
2. Explain different smart grid technologies
3. Application to power system monitoring, state estimation& protection
4. Application of various communication & networking element for smart grid.
5. Design and performance analysis of smart grid using computational tools.
6. Analyze stability of smart grid using computational tools.

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