PROGRESSIVE EDUCATION SOCIETY'S

MODERN COLLEGE OF ENGINEERING

1186A, SHIVAJINAGAR, OFF J.M, PUNE-411005

(AFFILIATED TO SAVITRIBAI PHULE PUNE UNIVERSIT, PUNE)

DEPARTMENT OF ELECTRICAL ENGINEERING

E-CURRICULUM BOOKLET

(2015 Pattern)

FOR THE PROGRAMME

BE – ELECTRICAL ENGINEERING

(SEMISTER-I)

QUALITY POLICY OF THE INSTITUTE

We, PES Modern College of Engineering are committed to develop and foster cultured and promising professionals by imparting quality education in the field of Engineering and Management.

VISION OF THE INSTITUTION

To create a collaborative academic environment to foster professional excellence and ethical values

MISSION OF THE INSTITUTE

1. **To develop outstanding engineers & professionals with high ethical standards capable of creating and managing global enterprises.**
2. **To foster innovation and research by providing a stimulating learning environment.**
3. **To ensure equitable development of students of all ability levels and backgrounds.**
4. **To be responsive to changes in technology, socio-economic levels and environmental conditions.**
5. **To foster and maintain mutually beneficial partnerships with alumni and industry.**

QUALITY POLICY OF THE DEPARTMENT

Electrical Engineering department is committed to develop promising engineers with ethical and social responsibility through excellence in academics, research, skill development and consultancy.

VISION OF THE DEPARTMENT

To build technically competent Electrical Engineers with ethical and social responsibility.

MISSION OF THE DEPARTMENT

- **To develop abilities in students for acquiring knowledge and skills to flourish in dynamic technical environment.**
- **To nurture cultured professionals by providing facilities for their overall development.**
- **To motivate the students for research work and activities beneficial to society.**
- **To enhance strong bonding with various organization and alumni.**

Program Educational Objectives (PEOs)

Graduates will be able to:

PEO 1: Solve and analyze problems in Electrical Engineering using fundamental knowledge.

PEO 2: Adopt lifelong learning ability by acquiring various skills.

PEO 3: Practice ethically in their profession.

PEO 4: Achieve global competency through interactions with various industries, research and professional organizations.

PROGRAM OUTCOMES (POs)

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, research literature, and analyses complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: The problems that cannot be solved by straight forward application of knowledge, theories and technique applicable to the engineering discipline that may not have a unique solution. For example, a design problem can be solved in many ways and lead to multiple possible solutions that require consideration of appropriate constraints/requirements not explicitly given in the problem statement. (Like: cost, power requirement, durability, product life, etc.). Which need to be defined (modeled) within appropriate mathematical framework that often requires use of modern computational concepts and tools.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. Communication: Communicate: effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES:

PSO 1: Students will have skill set in Energy Audit, Design of Solar System, and Automation in PLC and SCADA Applications, Microcontroller and analysis for power quality in Power System.

PSO 2: Students will be capable of dealing with techno-commercial aspect in Electrical Engineering.

CORE VALUES

- Excellence in the field of Electrical Engineering.
- Social responsibility with integrity.
- Lifelong Learning.
- Unity in Diversity.

SHORT TERM GOALS

- To enhance alumni interaction.
- To develop innovation lab to enhance research and entrepreneurship by providing various facilities.

LONG TERM GOALS

- To promote consultancy activity for revenue generation by developing high-tech standard laboratory.
- To encourage the faculty for research work and up gradation of qualifications.
- To enhance teaching-learning process through ICT.
- To establish competitive entrance exam cell in department.

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Course Structure

Savitribai Phule Pune University
FACULTY OF ENGINEERING
B.E. Electrical Engineering (2015 Course)
(w.e.f. 2018-2019)

SEMESTER-I

Sr No	Subject Code	Subject Title	Teaching Scheme (Hrs/Week)			Examination Scheme (Marks)					Total Marks	Credit	
						PP		TW	PR	OR		TH / TUT	PR+OR
			Th	Pr	Tu	In Sem	End Sem						
1	403141	Power System Operation and Control	03	02	--	30	70	25	--	25	150	03	01
2	403142	PLC and SCADA Applications	04	02	--	30	70	25	50	--	175	04	01
3	403143	Elective I	03	02	--	30	70	25	--	--	125	03	01
4	403144	Elective II	03	--	--	30	70	--	--	--	100	03	--
5	403145	Control System II	03	02	--	30	70	25	--	25	150	03	01
6	403146	Project I	--	--	02	--	--	--	--	50	50	--	02
	403152	Audit Course V											
TOTAL			16	08	02	150	350	100	50	100	750	16	06

SEMESTER-II

Sr. No	Subject Code	Subject Title	Teaching Scheme (Hrs/Week)			Examination Scheme (Marks)					Total Marks	Credit	
						PP		TW	PR	OR		TH/ TUT	PR +OR
			Th	Pr	Tu	In Sem	End Sem						
1	403147	Switchgear and Protection	03	02	--	30	70	50	--	25	175	03	01
2	403148	Power Electronic Controlled Drives	04	02	--	30	70	25	50	--	175	04	01
3	403149	Elective III	03	02	--	30	70	25	--	25	150	03	01
4	403150	Elective IV	03	--	--	30	70	--	--	--	100	03	--
5	403151	Project II	--	--	06	--	--	50	--	100	150	06	--
	403153	Audit Course VI											
Total			13	06	06	120	280	150	50	150	750	19	03

Elective I (403143)
- A) Fundamentals of Microcontroller MSP430 and its Applications [Open Elective]
- B) Power Quality
- C) Renewable Energy Systems
- D) Digital Signal Processing

Elective II (403144)
- A) Restructuring and Deregulation
- B) Electromagnetic Fields
- C) EHV AC Transmission
- D) Electric and Hybrid Vehicles
- E) Special Purpose Machines

Elective III (403149)
- A) High Voltage Engineering
- B) HVDC and FACTS
- C) Digital Control System
- D) Intelligent Systems and Applications in Electrical Engineering
- E) Analog Electronics and Sensing Technology [Open Elective]

Elective IV (403150)
- A) Smart Grid
- B) Robotics and Automation
- C) Illumination Engineering
- D) VLSI Design [Open Elective]

Power system operation & control (403141)

Name of the Subject – Power system operation & control

Weekly Work Load(in Hrs)	Lecture	Tutorial	Practical
	03	-	02

Online/ In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	25	25	150	-

Syllabus:

Unit 01 : Power System Stability: (6hrs)
Introduction to stability, dynamics of synchronous machine, swing equation, power angle equation and curve, types of power system stability (concepts of steady state, transient, dynamic stability), equal area criterion, applications of equal area criterion (sudden change in mechanical input, effect of clearing time on stability, critical clearing angle, short circuit at one end of line, short circuit away from line ends and reclosure), solution of swing equation by point by point method, methods to improve steady state and transient stability, numerical based on equal area criteria.

Unit 02 : Reactive Power management: (6 hrs)
Necessity of reactive power control, reactive power generation by a synchronous machine, effect of excitation, loading capability curve of a generator, compensation in power system (series and shunt compensation using capacitors and reactors), Problems with Series Compensation, synchronous condenser.

Unit 03 : FACTs Technology: (6 hrs)
Problems of AC transmission system, evolution of FACTs technology, principle of operation, circuit diagram and applications of SVC, TCSC, STATCOM and UPFC.

Unit 04 : Automatic Generation and Control (AGC): (6 hrs)
Concept of AGC, complete block diagram representation of load-frequency control of an isolated power system, steady state and dynamic response, control area concept, two area load frequency control. Schematic and block diagram of alternator voltage regulator scheme
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Unit 05 : Economic Load Dispatch and Unit Commitment: (6 hrs)
A) Economic load dispatch:Introduction, revision of cost curve of thermal and hydropower plant, plant scheduling method, equal incremental cost method, method of Lagrange multiplier (neglecting transmission losses), Bmn coefficient, economic scheduling of thermal plant considering effect of transmission losses, penalty factor, numerical.
B) Unit commitment:
Concept of unit commitment, constraints on unit commitment –spinning reserve, thermal and hydro constraints, methods of unit commitment –priority list and dynamic programming

Unit 06 : Energy Control and Reliability of Power Systems: (6 hrs)

A) Energy Control:

Interchange of power between interconnected utilities, economy interchange evaluation, interchange evaluation with unit commitment, types ofinterchange,
capacity and diversity interchange, energy banking, emergency power interchange, inadvertent power exchange, power pools.

B)Reliability of Power Systems:

Definition of reliability of power system, Hierarchical levels for reliability study, Reliability evaluation of generation system, loss of load probability (LOLP), loss of load expectation (LOLE), Expected Energy Not Supplied (EENS), generation model, load model, risk model, composite system reliability evaluation, Distribution system reliability evaluation for radial and parallel sys
tem, customer oriented and energy based reliability indices.

Text Books:

1.Abhijit Chakrabarti, Sunita Halder, "Power System Analysis Operation and Control", Prentice Hall of India.
2.I. J. Nagrath, D. P. Kothari, "Modern Power System Analysis", 4thEdition,
Tata McGraw Hill Publishing Co. Ltd.,
3.P. S. R. Murthy, "Power System Operation & Control", Tata McGraw Hill Publishing Co. Ltd.
4.P. S. R. Murthy, "Operation & Control in Pow
er System", B. S. Publication
.

References :

1.Allen J. Wood, Bruce F. Wollenberg "Power Generation, Operation, and Control", Wiley India Edition.
2."Electrical Power System Handbook", IEEE Press.
3.Narain G. Hingorani, Laszlo Gyugyi, "Understanding FACTs" IEEE Press.
4.Olle I. Elgerd, "Electrical Energy System Theory", 2nd Edition, Tata McGraw Hill. Publishing Co. Ltd.
5.Prabha Kundur " Power system stability and control" Tata McGraw Hill.
6.R. Mohan Mathur, Rajiv K. Varma, "Thyristor based FACTs controller for Electrical transmission system", John Wiley & Sons Inc.

Reference Web Links/ Research Paper/ Referred Book other than Mention in Syllabus:

1.NPTEL link.
2.www.investopedia.com/terms/w/whitepaper.asp
3.www.ieeexplore.ieee.org/

Course Objectives

- To develop ability to analyze and use various methods to improve stability of power systems.
- To understand the need for generation and control of reactive power
- To impart knowledge about various advanced controllers such as FACTs controllerswith its evolution, principle of operation, circuit diagram and applications.
- To illustratethe automatic frequency and voltage control strategies for single and two area case and analyze the effects, knowing the necessity of generation control.
- To understand formulation of unit commitment and economic load dispatch tasks and solve it using optimization techniques
- To illustrate various ways of interchange of power between interconnected utilities and define reliability aspects at all stages of power system.

Course Outcomes

After successfully completing the course students will be able to:

- **Identify and analyze** the dynamics of power system and suggest means to improve stability of system.
- **Suggest** the appropriate method of reactive power generation and control
- **Analyze** the generation-load balance in real time operation and its effect on frequency and develop automatic control strategies with mathematical relations.
- **Formulate** objective functions for optimization tasks such as unit commitment and economic load dispatch and get solutionusing computational techniques.

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Academic Activity Planner

Units	Unit Test1 (30marks)	Unit Test2 (20marks)	Assignment (Each 20marks)	OBT (20marks)	Unit Test (70marks)	Industrial Visit
I	✓					✓
II	✓					✓
III	✓					✓
IV					✓	✓
V					✓	✓
VI					✓	✓

Teaching Plan

Teaching plan as per University Syllabus

Sr.No.	Unit	Broad Topics to be Covered	Total Lecture Planned
1	I	Power System Stability	11
2	II	Reactive Power management	7
3	III	FACTs Technology	6
4	IV	Automatic Generation and Control (AGC)	7
5	V	Economic Load Dispatch and Unit Commitment	11
6	VI	Energy Control and Reliability of Power Systems:	10

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Unit wise Lecture Plan

Unit No.-I: Power System Stability

Pre-requisites: Concepts of Power system-I & II

Objectives :

- To understand Power system stability.
- To study the various solutions under steady state, transient conditions.

Outcomes :

- **Explain** the operation of interconnected power systems and their operation along with variation in load angle.
- **Analysis** of various solutions for transient stability**.**

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction to stability, dynamics of synchronous machine	T2, T1	Chalk & Talk
2	Swing equation, power angle equation and curve	T2, T1	Chalk & Talk
3	Types of power system stability (concepts of steady state, transient, dynamic stability)	T2, T1	Chalk & Talk
4	Equal area criterion	T2, T1	PPT
5	Applications of equal area criterion (sudden change in mechanical input)	T2, T1	PPT
6	Effect of clearing time on stability, critical clearing angle, short circuit at one end of line, short circuit	T2, T1	Chalk & Talk
7	Solution of swing equation by point by point method,	T2, T1	Chalk & Talk
8	Methods to improve steady state and transient stability	T2, T1	Chalk & Talk
9	Numerical based on equal area criteria	T2, T1,R5	Chalk & Talk
10	Numerical based on equal area criteria	T2, T1,R5	Chalk & Talk
11	Flip		Demonstration of Synchronous machine

Question Bank – Unit I

1. Define stability and explain dynamics of synchronous machine.
2. Derive swing equation expression.
3. Explain power angle equation and obtain power angle curve.
4. Explain types of power system stability (concepts of steady state, transient, dynamic stability)
5. Explain Equal area criterion.
6. Effect of sudden change in mechanical input for equal area criterion.
7. Explain effect of clearing time on stability, critical clearing angle.
8. Explain effect of short circuit at one end of line, short circuit.
9. Solution of swing equation by point by point method.
10. Methods to improve steady state and transient stability.

Unit No.-II: Reactive Power management

Pre-requisites:-
Basic concepts of Apparent, active and reactive power.

Objectives:-
To understand reactive power scenario in power system
To suggest solutions for reactive power management

Outcomes :- After successfully completing this unit students will be able:
To apply practical aspects of reactive power management

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Necessity of reactive power control,	R4,R5, T2	Chalk & Talk
2	Reactive power generation by a synchronous machine	R4,R5, T2	PPT
3	Effect of excitation	R4,R5, T2	PPT
4	Loading capability curve of a generator	R4,R5, T2	PPT
5	Compensation in power system (series and shunt compensation using capacitors and reactors)	R4,R5, T2	Chalk & Talk
6		R4,R5, T2	PPT
7	Problems with Series Compensation synchronous condenser	R4,R5, T2	PPT

Question Bank: Theory
Unit 2:

1. Explain the necessity of Necessity of reactive power control.
2. Explain necessity of reactive power control and also explain the effect of excitation.
3. What is loading capability curve of a generator? Explain.
4. How compensation in power system is carried out (series and shunt) & also mention problems associated with it.

Unit No.-III: FACTs Technology

Pre-requisites:-
Basic concepts of AC and DC transmission.

Objectives:-
To give overview of aspects of Flexible AC transmission.

Outcomes: - After successfully completing this unit students will be able to:
Understand various methods of transmission, advantages and practical implications of FACTs technology

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Problems of AC transmission system	**T1,T5,R1 IS : 4029 – Testing of 3 Phase Induction Motor.**	PPT
2	Evolution of FACTs technology	**T1**	PPT
3	Principle of operation,	**T1**	PPT
4	Circuit diagram & explanation	**T1,T5**	PPT
5	Applications of SVC, TCSC	**T1,T5**	PPT
6	STATCOM and UPFC	**T1,T5**	PPT

Question Bank: Theory
Unit No.-III

1. Describe the problems of Problems of AC transmission system
2. Write a note on evolution of FACTs technology.
3. Explain the FACTs methodology with a neat circuit diagram.
4. Describe the applications of SVC, TCSC, STATCOM and UPFC.

Unit No.-IV: Automatic Generation and Control (AGC):

Pre-requisites:-

- Basic concepts of generation of power and methods to control it.

Objectives:-

- To understand Automatic Generation and Control.

Outcomes:- After successfully completing this unit students will be able to:
Analyze requirements of automatic generation and can provide solutions for AGC

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Concept of AGC	R5,R4, T2	Chalk & Talk
2	Complete block diagram representation of load frequency control of an isolated power system	R5,R4, T2	Chalk & Talk
3	Steady state and dynamic response	R5,R4, T2	Chalk & Talk
4	Control area concept	R5,R4, T2	Chalk & Talk
5	Two area load frequency control.	R5,R4, T2	Chalk & Talk
6	Schematic and block diagram of alternator voltage regulator scheme	R5,R4, T2	PPT
7	Concept of AGC	R5,R4, T2	PPT

Question Bank: Theory
Unit No.-IV

1. Describe the concept of AGC.
2. Explain with complete block diagram representation of load frequency control of an isolated power system.
3. Write a note on Steady state and dynamic response.
4. What is control area concept? Explain two area load frequency control.
5. With a schematic diagram explain alternator voltage regulator scheme.

Unit No.-V: Economic load dispatch unit commitment

Pre-requisites:- Basics of load dispatch and market scenario

Objectives:-
To understand the basic concepts, of load dispatch and hence study economic load dispatch

Outcomes: - After successfully completing this unit students will be able to:
Obtain optimum solution for economic load dispatch and implement unit commitment.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Economic load dispatch: Introduction	T2, T3, R4	Chalk & Talk
2	Revision of cost curve of thermal and hydropower plant	T2, T3, R4	Chalk & Talk
3	Plant scheduling method, equal incremental cost method,	T2, T3, R4	Chalk & Talk
4	Method of Lagrange multiplier neglecting transmission losses	T2, T3, R4, R5	Chalk & Talk
5	B_{mn} coefficient, economic scheduling of thermal plant considering effect of transmission losses	T2, T3, R4, R5	PPT
6	Penalty factor, numerical	T2, R5	Chalk & Talk
7	Concept of unit commitment, constraints on unit commitment spinning reserve	T2, R5	PPT
8	Thermal and hydro constraints, methods of unit commitment priority list and dynamic programming	T2, R5	PPT

Question Bank: Theory
Unit No.-V

1. Explain the concept of economic load dispatch.
2. Write short notes on plant scheduling method, equal incremental cost method.
3. Explain the method of Lagrange multiplier neglecting transmission losses.
4. Define Bmn coefficient.
5. Explain the method of economic scheduling of thermal plant considering effect of transmission losses.
6. Describe penalty factor.
7. Describe the concept of unit commitment and hence explain constraints on unit commitment spinning reserve

Unit No.-VI: Energy Control and Reliability of Power Systems:

Pre-requisites: Basic concepts of energy and power distribution.

Objectives: -To enable candidate to study regarding reliability and consistence of power supply

Outcomes: - After successfully completing this unit, students will be able to:
Suggest the methods of practical applications for energy control and reliability for hassle free functioning of power system.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Interchange of power between interconnected utilities,	T2, T3, R4	PPT
2	Economy interchange evaluation, interchange evaluation with unit commitment, types of interchange	T2, T3, R4	PPT
3	Capacity and diversity interchange, energy banking,	T4, T3, R4	PPT
4	Emergency power interchange, inadvertent power exchange, power pools	T4, T3, R5	PPT
5	Definition of reliability of power system, Hierarchical levels for reliability study	T2, T3, R4	PPT
6	Reliability evaluation of generation system,	T2, T3, R4	PPT
7	Loss of load probability (LOLP) Loss of load expectation (LOLE)	T2, T3, R5	PPT
8	Expected Energy Not Supplied (EENS), generation model, load model	T2, T3, R5	PPT
9	Risk model, composite system reliability evaluation, Distribution system reliability evaluation for radial and parallel system	T2, T3, R5	PPT
10	Customer oriented and energy based reliability indices.	T2, T3, R5	PPT

Question Bank: Theory

1. Explain how interchange of power takes place between interconnected utilities.
2. Describe economy interchange evaluation. Also explain interchange evaluation with unit commitment &types of interchanges.
3. Define reliability of power system hence give hierarchical levels for reliability study.
4. Explain how reliability evaluation of generation system is carried out.
5. Define loss of load probability (LOLP), loss of load expectation (LOLE).
6. What is EENS, explain with respect to generation model and load model.
7. How is distribution system reliability evaluation for radial and parallel system carried out?
8. Describe customer oriented and energy based reliability indices.

Practical Assessment
List of Experiments

Sr.No.	Name of the Practical
1	To determine Steady state stability of medium transmission line (performance).
2	To plot swing curve by Point by Point method for transient stability analysis.
3	To apply equal area criteria for analysis stability under sudden rise in mechanical power input
4	To apply equal area criteria for stability analysis under fault condition.
5	To study reactive power compensation using any FACTS device.
6	To study Lagrange multiplier technique for economic load dispatch
7	To study load frequency control using approximate and exact model.
8	To study load frequency control with integral control.
9	To study the two area load frequency control.

PLC and SCADA Applications (403142)

Name of the Subject –PLC and SCADA Applications

Weekly Work Load(in Hrs)	**Lecture**	**Tutorial**	**Practical**
	04	**-**	**02**

Online/ In-sem	**Theory**	**Practical**	**Oral**	**Term-work**	**Total Marks**	**Credit**
30	**70**	**50**	**-**	**25**	**150**	

Syllabus:

Unit 01 : Introduction to PLC **(08 Hrs)** Role of automation in Industries, benefits of automation, Necessity of PLC, History and evolution of PLC, Definition as per NEEMA (National Electrical Engineering Manufacturers' Association), types – fixed/modular/dedicated, Overall PLC system, PLC Input and output modules (along with Interfaces), CPU, programmers and monitors, power supplies, selection criterion, advantages and disadvantages, specifications, comparison of various PLCs manufactured by Allen Bradley, Siemens, ABB, Mitsubishi, GE, Fanuc and Schneider.

Unit 02 : Interfacing of PLC with I/O devices **(08 Hrs)** Input ON/OFF switching devices, Input analog devices, Output ON/OFF devices, Output analog devices Sensors-temperature, pressure, flow, level Actuators-Electrical, pneumatic, hydraulic Encoders-Incremental, Absolute Transducers, Limit switches, proximity sensors Control Elements- Mechanical, Electrical, Fluid valves

Unit 03 : Programming of PLC **(09 Hrs)** Programming languages for PLC, Ladder diagram fundamentals, Rules for proper construction of ladder diagram Timer and counter- types along with timing diagrams, Reset instruction, latch instruction MCR (master control relay) and control zones Developing ladder logic for Sequencing of motors, ON OFF Tank level control, ON OFF temperature control, elevator, bottle filling plant, car parking, traffic light controller.

Unit 04 : Advance function and Applications of PLC **(08 Hrs)** Analog PLC operation and PLC analog signal processing, PID principles, Typical continuous process control curves, simple closed loop systems, closed loop system using Proportional, Integral and Derivative (PID), PID modules, PID tuning, tuning methods including "Adjust and observe" method Motors Controls: AC Motor starter, AC motor overload protection, DC motor controller, Variable speed (Variable Frequency) AC motor Drive. PLC Applications in developing systems- Tank level controller using analog signals, temperature controller using RTD, speed control of electric motor.

Unit 05 : SCADA Systems **(08 Hrs)** Introduction, definitions and history of Supervisory Control and Data Acquisition, typical SCADA system Architecture, important definitions HMI, MTU, RTU, communication means, Desirable Properties of SCADA system, advantages, disadvantages and applications of SCADA. SCADA generations (First generation - Monolithic, Second generation - Distributed, Third generation – Networked Architecture), SCADA systems in operation and control of interconnected power system, Functions and features of SCADA systems, Automatic substation control, Energy management systems (EMS), System operating states, SCADA system in critical infrastructure: Petroleum Refining Process, Conventional electric power generation, Water Purification System, Chemical Plant.

Unit 06 : SCADA Protocols **(07 Hrs)** Open systems interconnection (OSI) Model, TCP/IP protocol, Modbus model, DNP3 protocol, IEC61850 layered architecture, Control and Information Protocol (CIP), Device Net, Control Net, Ether Net/IP, Flexible Function Block process (FFB), Process Field bus (Profibus).

Prerequisite: Logic gates operations, Boolean algebra, Relay logic

Text Books:

1. Gary Dunning, "Introduction to Programmable Logic Controllers", Thomson, 2nd Edition
2. John R. Hackworth, Frederick D., Hackworth Jr., "Programmable Logic Controllers Programming Methods and Applications", PHI Publishers
3. John W. Webb, Ronald A. Reis, "Programmable Logic Controllers: Principles and Application", PHI Learning, New Delhi, 5th Edition
4. Ronald L. Krutz, "Securing SCADA System", Wiley Publishing
5. Stuart A Boyer, "SCADA supervisory control and data acquisition", ISA, 4th Revised edition
6. Sunil S. Rao, "Switchgear and Protections", Khanna Publication
7. L.A. Bryan, E. A. Bryan, "Programmable Controllers Theory and Implementation" Industrial Text Company Publication, Second Edition

Reference books:

1. Batten G. L., "Programmable Controllers", McGraw Hill Inc., Second Edition
2. Bennett Stuart, "Real Time Computer Control", Prentice Hall, 1988
3. Doebelin E. O., "Measurement Systems", McGraw-Hill International Editions, Fourth Edition, 1990
4. Gordan Clark, Deem Reynders, "Practical Modern SCADA Protocols", ELSEVIER
5. Krishna Kant, "Computer Based Industrial Control", PHI
6. M. Chidambaram, "Computer Control of Process", Narosha Publishing
7. P. K. Srivstava, "Programmable Logic Controllers with Applications", BPB Publications
8. Poppovik, Bhatkar, "Distributed Computer Control for Industrial Automation", Dekkar Publications
9. S. K. Singh, "Computer Aided Process Control", PHI
10. Webb J. W, "Programmable Controllers", Merrill Publishing Company, 1988

Course Objective:

The course aims:- ·
To understand the generic architecture and constituent components of a Programmable Logic Controller.
To develop architecture of SCADA explaining each unit in detail. ·
To develop a software program using modern engineering tools and technique for PLC and SCADA. ·
To apply knowledge gained about PLCs and SCADA systems to real-life industrial applications.

Course Outcome:

Upon successful completion of this course, the students will be able to :-
1. Develop and explain the working of PLC with the help of a block diagram.
2. Classify input and output interfacing devices with PLC.
3. Develop architecture of SCADA and explain the importance of SCADA in critical infrastructure.
4. Execute, debug and test the programs developed for digital and analog operations.
5. Describe various SCADA protocols along with their architecture.
6. Observe development of various industrial applications using PLC and SCADA.

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Academic Activity Planner

Units	Unit Test1 (10marks)	Unit Test2 (20marks)	Workshop (20marks)	PPT (10marks)	IEEE paper (10marks)	Unit Test3 (70marks)	Mini ckt (10ma)	Model of I/O devices (10ma)
1	✓						✓	✓
2&3		✓	✓					
4			✓	✓				
5					✓			
6					✓			
1 to 6						✓		✓

Teaching Plan
Teaching plan as per University Syllabus

Sr. No.	Unit	Broad Topic to be covered	Books Referred	Total Lectures Planned
1	Unit 01 :	Introduction to PLC	T1 R2	(08 Hrs)
2	Unit 02 :	Interfacing of PLC with I/O devices	T1, T2, T6 R3, R4	(08 Hrs)
3	Unit 03 :	Programming of PLC	T1, T7 R5	(09 Hrs)
4	Unit 04 :	Advance function and Applications of PLC	T1, T2, T6 R2, R5	(08 Hrs)
5	Unit 05 :	SCADA Systems	T3, T4, T5 R1	(08 Hrs)
6	Unit 06 :	SCADA Protocols	T3 R1	(07 Hrs)

Unit wise Lecture Plan
Unit No.-I: Introduction to PLC

Pre-requisites:- Basic concepts of Microprocessor, Microcontroller PIC microcontroller and different solid state memories.

Objectives:-

- To understand role of Automation industries.
- To study overall PLC system along with Different types of PLC and selection criteria for PLC

Outcomes:

- Understand Overall PLC system along with its merits and demerits

Lect. No	Unit No.	Main Topic to be Covered	Sub Topics to be Covered	Mode of Delivery
1	I	Introduction to PLC	Discussion: Syllabus, CO, PO, Vision, Mission of College and Department. Role of automation in Industries, benefits of automation.	PPT
2			Role of automation in Industries, benefits of automation, Necessity of PLC,	Chalk and Talk
3			History and evolution of PLC, Definition as per NEEMA (National Electrical Engineering	PPT
4			Manufacturers' Association), types – fixed/modular/dedicated,	PPT, Chalk and Talk
5			Overall PLC system: PLC Input and output modules (along with Interfaces)	PPT, Chalk and Talk
6			Overall PLC System :CPU, programmers and monitors, power supplies,	PPT, Chalk and Talk, mini ckt making
7			Selection criterion, advantages and disadvantages,	Chalk and Talk , PPT
8			specifications, comparison of various PLCs manufactured by Allen Bradley, Siemens, ABB, Mitsubishi, GE, Fanuc and Schneider	PPT

Question Bank – Unit I

1. What is PLC? What are the basic components of a PLC? Draw and explain the block diagram of PLC.
2. State the classification of PLC based on size and type.
3. Explain the operation of a PLC system.
4. What are the advantages and disadvantages of PLC?
5. State the need of automaton in the Industry.
6. List the advantages of PLC over conventional Relay logic.
7. Describe the classification of input / output module.
8. What is Sinking and Sourcing operation with reference to PLC I/O module?
9. Explain the functions of each sections of PLC CPU.
10. Describe the various types of solid state memory used in a PLC.
11. Describe the classification of input/ output module.
12. Describe the operation of Input module
13. Describe operation of output module
14. Explain how AC- in /DC- out power supply functions.
15. State the use of PLC.
16. List the various types of PLC.
17. State the purpose of input output interface.
18. Explain the operation flow chart of an output module
19. State advantages and disadvantages of output module
20. Write a note on Programming monitor

Unit: 2: Interfacing of PLC with I/O devices

Pre-requisites:- Basic concepts of I/O devices (Analog and Digital)

Objectives:-

- Apply the concept of various Transducers.
- Interface Analog and digital input/output devices with PLC system.

Outcomes: - After successfully completing this unit students will be able to:

- Select particular PLC for specific applications along with the input output devices for any application.

Lect. No	Unit No.	Main Topic to be Covered	Sub Topics to be Covered	Mode of Delivery
	II	**Interfacing of PLC with I/O devices**	Input ON/OFF switching devices, Input analog devices,	Chalk and Talk, PPT
			Output ON/OFF devices, Output analog devices Sensors-temperature,	PPT, video
			Output analog devices :pressure, flow	PPT, video
			level Actuators-Electrical, pneumatic, hydraulic	PPT
			Encoders-Incremental, Absolute Transducers,	PPT
			Limit switches, proximity sensors	PPT
			Control Elements- Mechanical, Electrical	PPT
			Control Elements- Fluid valves	PPT

Question Bank – Unit 2

1. Explain any three temperature measurement Analog input devices
2. Describe basic input on/off switching system.
3. Describe operation of various types of input devices such as pushbutton, switches, selector switches and limit switches.
4. List the different advanced sensors and explain any one.
5. Discuss output devices such as relays, solenoids and hydraulic cylinders.
6. Explain the various magnetic Transducers
7. Describe the different types of Encoders.
8. Explain analog and digital input & output devices
9. Explain liquid level, flow, pressure type of sensors.

Unit No: 3: Programing of PLC

Pre-requisites:- Principles of Digital logic design Operation of Relay

Objectives:-

- Apply the concepts of digital logic to develop ladder diagram.
- Develop different logical functions like timer and counter using ladder diagram coding.
- To Study Advanced Instructions

Outcomes: - After successfully completing this unit students will be able:

- Demonstrate ladder diagram coding using mimic diagram.
- Explain Arithmetic and logical instructions with various examples.
- To develop different ladder Programs using Various Instructions, Timer, Counter combination applicable to Various Industrial Processes

Lect. No	Unit No.	Main Topic to be Covered	Sub Topics to be Covered	Mode of Delivery
	III	**Programing of PLC**	Programming languages for PLC, Ladder diagram fundamentals	Chalk and Talk, workshop
			Rules for proper construction of ladder diagram	Chalk and Talk
			Timer and counter- types along with timing diagrams.	Chalk and Talk, video animation, workshop
			Reset instruction, latch instruction MCR (master control relay) and control zones Developing ladder.	Chalk and Talk, workshop
			Logic for Sequencing of motors, ON OFF Tank level control.	Chalk and Talk, industrial example video
			Logic for Sequencing of ON OFF temperature control, elevator.	Chalk and Talk,
			logic for Sequencing of elevator, bottle filling plant, car parking, traffic light controller	Chalk and Talk,

Question Bank – Unit 3

1. Explain Ladder diagram of PLC with one suitable example.
2. What are the standard steps involved in developing a ladder?
3. Describe the difference between legal and illegal PLC Ladder programming layouts
4. List the important considerations of program scanning rate and its effects
5. Explain PLC Timers along with their Timing Diagrams.
6. Draw Symbol , Write Truth table, and equivalent logic diagram of Different Logic gates
7. Draw the Ladder diagram for three motor having the following conditions
8. Draw the Ladder diagram for two motor having the following conditions
9. Blinking indicator lights are used in industry. Design a circuit in which two lights are flashed alternatively every 15secs
10. Make a program to turn a lamp ON after a specific time and then to turn a fan ON a fixed time after turning the lamp ON. Draw a ladder diagram for this system.
11. Write a program to show a counter that will count up to 4000.Draw a ladder diagram for this system.
12. Explain any three logical instructions in details with examples.
13. Explain any three Mathematical instructions in details with examples.
14. Explain any three Comparison instructions in details with examples.
15. Explain Necessity and Significance of SCP instruction.

Unit No: 4 : Advance function and Applications of PLC

Pre-requisites:-

- Basic knowledge of different sensors used for measurement of non- electrical parameters.
- Different motor starters, variable frequency drive, overload protection of AC motor
- Principles of PID ,concept of open loop and closed loop system.

Objectives:-

- To Interface different sensors with PLC
- Measure and monitor different parameters of process using PLC.
- Describe simple codes based on closed loop applications.

Outcomes:- After successfully completing this unit students will be able to:

- Develop ladder logic for different applications like Tank level control, bottle filling plant etc.
- Design ladder diagram coding for monitoring and control of different parameters of process.

Lect. No	Unit No.	Main Topic to be Covered	Sub Topics to be Covered	Mode of Delivery
	IV	Advance function and Applications of PLC	Analog PLC operation and PLC analog signal processing.	Chalk and Talk
			PID principles, Typical continuous process control curves, simple closed loop systems, closed loop system using Proportional, Integral and Derivative (PID),	Chalk and Talk
			PID modules, PID tuning,	Chalk and Talk
			Tuning methods including "Adjust and observe" method	Chalk and Talk
			Motors Controls: AC Motor starter, AC motor overload protection, DC motor controller,	Chalk and Talk, Videos
			Variable speed (Variable Frequency) AC motor Drive..	Chalk and Talk, Videos
			PLC Applications in developing systems- Tank level controller using analog signals,	Chalk and Talk, Videos
			PLC Applications in developing systems temperature controller using RTD.	Chalk and Talk, Videos
			PLC Applications in developing systems of speed control of electric motor	Chalk and Talk, Videos

Question Bank – Unit 4

1. Explain the basic parts of a simple closed loop control systems
2. Explain problems with simple closed loop control systems
3. Explain closed loop control systems using PID
4. Describe the PLC output control motors and motor starters
5. Explain the various tuning methods used for PID.
6. Explain variable speed AC motor drive using PLC control
7. Describe PLC control of Tank level controller using analog signals
8. Describe how PLC is used designing temperature controller using RTD
9. Design the speed control of Electric motor using PLC
10. Why motor starter is needed to control large AC motors.
11. Write note on AC motor overload protection
12. Explain in detail different types of speed control of DC Motor
13. How VFD operates to control speed of DC Motor State the purpose of input output interface
14. Develop the ladder program for Sequencing of motors, Tank level control
15. Develop the ladder program for ON/OFF temperature control and car parking

Unit No.-V:
SCADA Systems

Pre-requisites:- Basics of process control, Concept of Automation

Objectives:-

- Define SCADA system and explain its architectures.
- Explain the automation of interconnected power system.
- How SCADA can be implemented in critical infrastructures

Outcomes:- After successfully completing this unit students will be able to:

- Describe process automation in Industries using PLC and SCADA.
- Define & Explain SCADA system and its architecture.

Lect. No	Unit No.	Main Topic to be Covered	Sub Topics to be Covered	Mode of Delivery
	v	**SCADA Systems**	Introduction, definitions and history of Supervisory Control and Data Acquisition,	PPT, Chalk and Talk
			Typical SCADA system Architecture, important definitions HMI, MTU, RTU,	PPT , Chalk and Talk
			Communication means, Desirable Properties of SCADA system, advantages, disadvantages and applications of SCADA.	PPT, Chalk and Talk
			SCADA generations (First generation - Monolithic, Second generation - Distributed, Third generation – Networked Architecture).	PPT, Chalk and Talk
			SCADA generations (Third generation)– Networked Architecture) and its comparison	PPT, Chalk and Talk
			SCADA systems in operation and control of interconnected power system,	PPT, Industrial visit ,Chalk and Talk
			Functions and features of SCADA systems,	PPT, Industrial visit, Chalk and Talk
			Automatic substation control, Energy management systems (EMS), System operating states,	PPT, Industrial visit, Chalk and Talk
			SCADA system in critical infrastructure: Petroleum Refining Process, Conventional electric power generation.	PPT and Talk
			SCADA system in critical infrastructure: Water Purification System, Chemical Plant	PPT and Talk

Question Bank – Unit 5

1. Explain with the help of block diagram SCADA system in detail. Give advantages and disadvantages of SCADA system.
2. Explain the various communication technologies used in SCADA system
3. Explain with a block diagram RTU and its use.
4. Compare SCADA,DCS and PLC based systems
5. Draw and explain various SCADA architectures with different advantages and disadvantages of each system.
6. Draw and explain SCADA Server.
7. Write note on SCADA system security issues.
8. Explain SCADA functions.
9. Explain desirable properties of SCADA system.
10. Write short note on Intelligent Electronic Devices (IED)
11. Explain in detail SCADA in substation automation.
12. Explain with block diagram use of SCADA in Energy Management system or interconnected power systems.
13. Explain with block diagram use of SCADA in oil and gas industries
14. Explain with block diagram use of SCADA in chemical plant.
15. Explain with block diagram use of SCADA in electrical power generation.
16. Explain with block diagram use of SCADA in Water Purification System.
17. Explain with block diagram use of SCADA in Petroleum Refining Process.
18. Compare PLC and SCADA systems in detail.

Unit No.-VI: SCADA Protocols

Pre-requisites:- Scada Architecture, Concept of protocol

Objectives: -

- To understand various protocols used in SCADA
- Compare different protocols used for SCADA system.
- Interface SCADA and PLC

Outcomes : - After successfully completing this unit, students will be able to

- Differentiate and compare different protocols used for SCADA system.
- Explain layered structure of SCADA protocols

Lect. No	Unit No.	Main Topic to be Covered	Sub Topics to be Covered	Mode of Delivery
1	VI	SCADA Protocols	Open systems interconnection (OSI) Model,	PPT, chalk and Talk
			Open systems interconnection (OSI) Model,	PPT, chalk and Talk
			TCP/IP protocol, Modbus model,	PPT, chalk and Talk
			DNP3 protocol, IEC61850 layered architecture,	PPT, chalk and Talk
			Control and Information Protocol (CIP), Device Net, Control Net,	PPT, chalk and Talk
			Ether Net/IP, Flexible Function Block process (FFB), Process Field bus (Profibus).	PPT, chalk and Talk

Question Bank – Unit 6

1) Explain seven layers of OSI Model and their functions.
2) Explain in details SCADA protocols.
3) Explain TCP/IP SCADA Protocols.
4) Explain Control and Information Protocol (CIP),
5) Explain Device Net Control Net and Flexible Function Block process (FFB)
6) Explain Flexible Function Block process (FFB)
7) Compare PLC and SCADA systems in detail
8) Draw and explain SCADA Server
9) Draw and explain IEC 61850 layered architecture
10) Write short note on the following
    a) Seven layers of OSI model and their functions.
    b) IEC 61850
    c) DNP3
    d) Control Net , Device Net, Ethernet/IP
    e) FFB
    f) Profibus
    g) Control and Information Protocol
11) Explain security implementation of SCADA protocols.

Practical Assessment

List of Experiments

1. Introduction to PLC
2. Interfacing of lamp & button with PLC for ON & OFF operation. Verify all logic gates.
3. Performed delayed operation of lamp by using push button.
4. UP/DOWN counter with RESET instruction.
5. Combination of counter & timer for lamp ON/OFF operation.
6. Set / Reset operation: one push button for ON & other push button for OFF operation.
7. PLC based temperature sensing using RTD.
8. PLC interfaced with SCADA & status read/command transfer operation.
9. Parameter reading of PLC in SCADA.
10. Alarm annunciation using SCADA.
11. Reporting & trending in SCADA system.
12. Temperature monitoring by using SCADA.

Industrial Visit: Compulsory visit to SCADA and PLC based automation industry.

Power Quality
(403143-B)

Name of the Subject –Power Quality

Weekly Work Load(in Hrs)	Lecture	Tutorial	Practical
	03	-	02

In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	-	25	125	

Syllabus:

Unit 01 : Basics of power quality (06 Hrs)
Introduction and importance of power quality, symptoms of poor power quality. Classification of power quality events, power quality definition as per IEEE 1159. Grounding of sensitive electronic equipments and guidelines of IEEE std 1100. Long duration RMS voltage variations, its sources, effects and solutions.

Unit 02 : Voltage Sag (06 Hrs)
Sources of voltage sags, classification of voltage sags, factors governing severity of voltage sag. Area of vulnerability, critical distance. Voltage sag characteristics. Classification of equipments based on its sensitivity to various characteristics of voltage sag. Effect of voltage sag on various equipments. Voltage tolerance curve, ITIC and SEMI F47 curve, investigation of sensitivity of equipments to voltage sags. Voltage sag mitigation techniques at equipment level, LT power entrance and medium voltage. Voltage sag indices. Study of important provisions in IEEE Std 1346.

Unit 03 : Transient Overvoltage and Flicker (06 Hrs)
Sources of transient over voltages, Impulsive and oscillatory transients. Magnification of capacitor switching transients, pre insertion reactors to control capacitor switching transients, ferroresonance, principle of over voltage protection. Devices for over voltage protection. Voltage flicker, its sources. Factors governing severity of flicker. Flicker measurement, Pst and Plt. Flicker mitigation solutions.

Unit 04 : Fundamentals of Harmonics (06 Hrs)
Waveform Distortion, Harmonics, Harmonic phase sequences. Classification of harmonics harmonic, Voltage Verses Current distortion, AC quantities under non-sinusoidal conditions, Voltage and current harmonic indices, Sources of harmonics, General and special Effects of Harmonics on Electrical Equipments, cables, switchgears, Meters and Communications.

Unit 05 : Harmonic Mitigation Techniques (06 Hrs)
System behaviour to harmonics, location of harmonic sources, Series and parallel resonance, Harmonic mitigation, passive tuned and detuned filters, design of tuned filters, Active Filter, Sizing and location of active filters, Advantages of active filters over passive filters, Hybrid filters.IEEE 519-2014 standard.

Unit 06 : Power Quality Monitoring (06 Hrs)

Objectives of Power quality monitoring. Types of power quality monitoring, Power quality monitoring equipments, Power quality analyser specification requirement as per EN50160 Standard. Selection of power quality equipments for cost effective power quality monitoring, selection of voltage and current transducers. Power quality indices. IEEE 1159 standard and important provision related with power quality monitoring. Computer Tools for analysis of power quality.

Text Books:

[T1] R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication.
[T2] M. H. J. Bollen, "Understanding Power Quality Problems, Voltage Sag and Interruptions", New York: IEEE Press, 2000, Series on Power Engineering.
[T3] C.Sankaran "Power quality", CRC Press
[T4] Arrillaga, M. R. Watson, S. Chan, "Power System Quality Assessment", John Wiley and Sons.
Reference Books:
[R1] Enriques Acha, Manuel Madrigal, "Power System Harmonics: Computer Modeling and Analysis", John Wiley and Sons Ltd.
[R2] Ewald F. Fuchs, Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines" Elsevier Publication.
[R3] G. J. Heydt, "Electric Power Quality", Stars in Circle Publications
[R4] EN50160and IEEE 1100, 1346,519 and 1159 standards
[R5] Arrillaga, M. R. Watson, "Power System Harmonics", John Wiley and Sons

Reference Web Links/ Research Paper/ Referred Book other than Mention in Syllabus:

1. ***Power Quality*** in Electrical Systems by Alexander Kusco
2. **ieeexplore**.**ieee**.org/ Conferences on power quality

Course Objectives

The course aims to:- ·

- Develop ability to identify various power quality issues, its sources and effects on various equipments. ·
- Monitor, analyze and characterize various power quality problems ·
- Study and selection of cost effective power quality mitigation solutions. ·
- Study and use of power quality standards

Course Outcomes

After successfully completing the course students will be able to:

CO1. Understand/Identify importance of various power quality issues.

CO2. List and explain various causes and effects of power quality problems.

CO3. Analyze power quality parameters and carry out power quality analysis.

CO4. Select cost effective mitigation technique for various power quality problems.

CO5. Use IEEE 519-2014 power quality standard for harmonic compliance

CO6. Carry out power quality monitoring.

- **Academic Activity Planner**

Units	Unit Test1 (20marks)	Unit Test2 (20marks)	Unit Test 3 MCQ (20marks)	Assignment (Each 20marks)	OBT (20marks)	Unit Test3 (50marks)
1	MCQ Test		MCQ Test	Assignment No 1	Open Book Test	Unit Test 3
2		MCQ Test				
3				Assignment No 2		
4						
5				Assignment No 3		
6						

PROGRESSIVE EDUCATION SOCIETY'S

MODERN COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

Teaching Plan

Teaching plan as per University Syllabus

Sr.No.	Unit	Broad Topics to be Covered	Total Lecture Planned
1	I	Basics of power quality and standards	06
2	II	Voltage sag	06
3	III	Transient Over Voltages and Flickers	06
4	IV	Fundamentals of Harmonics	06
5	V	Measuring and control of harmonics	06
6	VI	Measuring and solving power quality problems	06

Unit wise Lecture Plan
Unit No.-I: Basics of power quality and standards.

Pre-requisites:-

1. Student should have a knowledge about power system structure.
2. Student should know about faults in power system.

Objectives:-

1. To develop ability to identify various power quality issues
2. To Understand relevant IEEE standards

Outcomes :

CO1. Understand/Identify importance of various power quality issues.
CO2. List and explain various causes and effects of power quality problems.

Lecture No.	Details of the Topic to be covered	References	Mode of delivery
1	**Basics of power quality and standards,** Introduction and importance of power quality, symptoms of poor power quality.	T1,T2, T3 R3, R4	**Chalk and talk**
2	Various power quality issues such as transients, short duration voltage variations,	T1,T2, T3 R3, R4	**PPT**
3	long duration voltage variations, voltage imbalance, voltage fluctuations,	T1,T2, T3 R3, R4	**PPT**
4	voltage flicker and waveform distortion.	T1,T2, T3 R3, R4	**PPT**
5	Relevant power quality standards such as IEEE 1159-2009, Grounding and power quality issues.	T1,T2, T3 R3, R4	**PPT**
6	Long duration RMS voltage variations, its sources, effects and solutions.	T1,T2, T3 R3, R4	**PPT**

Unit No.-II: Voltage sag

Pre-requisites:-

- Student should know about detail analysis of faults.
- Student should know about charateristics of sag.

Objectives:-

- To learn and characterize sag
- To identify different mitigation techniques of sag.

Outcomes:-After successfully completing this unit students will be able:

- CO2. List and explain various causes and effects of power quality problems.
- CO3. Analyze power quality parameters and carry out power quality analysis.
- CO4. Select cost effective mitigation technique for various power quality problems.

Lecture No.	Details of the Topic to be covered	References	Mode of delivery
1	Sources of voltage sags, classification of voltage sags, factors governing severity of voltage sag.	**T1,T2,T3 R2,R3, R4**	**PPT**
2	Sources of voltage sags, classification of voltage sags, factors governing severity of voltage sag. Area of vulnerability, critical distance.	**T1,T2,T3 R2,R3, R4**	**PPT**
3	Voltage sag characteristics. Classification of equipments based on its sensitivity to various characteristics of voltage sag.	**T1,T2,T3 R2,R3, R4**	**PPT**
4	Effect of voltage sag on various equipments. Voltage tolerance curve, ITIC and SEMI F47 curve,	**T1,T2,T3 R2,R3, R4**	**PPT**
5	investigation of sensitivity of equipments to voltage sags. Voltage sag mitigation techniques at equipment level, LT power entrance and medium voltage.	**T1,T2,T3 R2,R3, R4**	**PPT**
6	Voltage sag indices. Study of important provisions in IEEE Std 1346.	**T1,T2,T3 R2,R3, R4**	**PPT**

Question Bank: Theory
Unit 2:

1. Why voltage sag is important power quality event compared to other events? Explain economic impact of voltage sag.

2. Explain influence of fault location and fault level on voltage sags and concept of area of vulnerability.

3. Explain voltage sag characteristics such as magnitude, phase angle jump, point on wave initiation and point on wave recovery.

4. List various sag mitigation techniques and explain any one.

5. Explain steps in assessment of voltage sag. How voltage sag is measured?

Unit No.-III: Overvoltage transients and Flicker

Pre-requisites:-

- Student should know about various operations of power system.
- Student should know about charateristics of transients.

Objectives:-

- To learn and characterize transients and flicker.
- To learn varios mitigation and overprotection techniqes.

Outcomes:-After successfully completing this unit students will be able to:

- CO2. List and explain various causes and effects of power quality problems.
- CO4. Select cost effective mitigation technique for various power quality problems.
- CO3. Analyze power quality parameters and carry out power quality analysis.

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Lecture No.	Details of the Topic to be covered	References	Mode of delivery
1	Sources of transient over voltages, Impulsive and oscillatory transients.	T1,T2,T3 R2,R3	PPT
2	Magnification of capacitor switching transients, pre insertion reactors to control capacitor switching transients, ferroresonance,	T1,T2,T3 R2,R3	Chalk and talk
3	principle of over voltage protection. Devices for over voltage protection.	T1,T2,T3 R2,R3	PPT
4	Voltage flicker, its sources	T1,T2,T3 R2,R3	Chalk and talk
5	. Factors governing severity of flicker. Flicker measurement, Pst and Plt.	T1,T2,T3 R2,R3	PPT
6	mitigation techniques.	T1,T2,T3 R2,R3	Chalk and talk

Question Bank: Theory
Unit No.-III

1. Explain transient introduced by capacitor and load switching.
2. What are the various causes of voltage flicker? What are it impacts on power system equipment?
3. Explain various voltage flicker parameters obtained from flicker measurements.
4. Explain basic principles of over-voltage protection. Enlist various devices used for overvoltage protection.
5. Explain computer tools used for transient's analysis.

Unit No.-IV: Fundamental Of Harmonics

Pre-requisites:-

- Student should know about nature of various loads.
- Student should know about charateristics of harmonics.

Objectives:-

- To learn various effects of harmonic.
- To learn various indices and sources of harmonics.

Outcomes:-After successfully completing this unit students will be able to:

CO2. List and explain various causes and effects of power quality problems.
CO3. Analyze power quality parameters and carry out power quality analysis.
CO4. Select cost effective mitigation technique for various power quality problems.

Lecture No.	Details of the Topic to be covered	References	Mode of delivery
1	Waveform Distortion, Harmonics, Harmonic phase sequences.	T1,T3,T4 R1,R4, R5	**Chalk and talk**
2	Classification of harmonics harmonic, Voltage Verses Current distortion, AC quantities under non-sinusoidal conditions,	T1,T3,T4 R1,R4, R5	**Chalk and talk**
3	Voltage and current harmonic indices, Sources of harmonics,	T1,T3,T4 R1,R4, R5	**Chalk and talk**
4	General and special Effects of Harmonics on Electrical Equipments,	T1,T3,T4 R1,R4, R5	**Chalk and talk**
5	cables, switchgears,	T1,T3,T4 R1,R4, R5	**Chalk and talk**
6	Meters and Communications.	T1,T3,T4 R1,R4, R5	**Chalk and talk**

Question Bank: Theory
Unit No.-IV

1. Explain series and parallel harmonics resonances. What are its consequences?

2. Also explain various power quality indices used for assessment of harmonics.

3. In context to harmonic attenuation explain- i) Effect of system response
ii) Series and parallel resonance

4. Explain following terms in context to non sinusoidal supply conditions-
i) True power factor ii) Distortion power factor iii) Total harmonic distortion

5. Write a note on triplen harmonics.

Unit No.-V: Harmonic Mitigation Techniques

Pre-requisites:-

- Student should know about various effects of harmonic.
- Student should know about sources of harmonics.

Objectives:-

- To learn various tools for harmonic analysis.
- To design filters for mitigation of harmonics.

Outcomes:-After successfully completing this unit students will be able to:

CO3. Analyze power quality parameters and carry out power quality analysis.
CO4. Select cost effective mitigation technique for various power quality problems.
CO5. Use IEEE 519-2014 power quality standard for harmonic compliance
CO6. Carry out power quality monitoring

Lecture No.	Details of the Topic to be covered	References	Mode of delivery
1	System behaviour to harmonics, location of harmonic sources,	T1,T3,T4 R1,R4, R5	**PPT**
2	Series and parallel resonance,	T1,T3,T4 R1,R4, R5	**Chalk and talk**
3	Harmonic mitigation, passive tuned and detuned filters, design of tuned filters,	T1,T3,T4 R1,R4, R5	**PPT**
4	Active Filter, Sizing and location of active filters,	T1,T3,T4 R1,R4, R5	**PPT**
5	Advantages of active filters over passive filters, Hybrid filters.	T1,T3,T4 R1,R4, R5	**Chalk and talk**
6	IEEE 519-2014 standard.	T1,T3,T4 R1,R4, R5	**Chalk and talk**

Question Bank: Theory
Unit No.-V

1. Explain the concept of point of common coupling.
2. What is a tuned filter? Explain design of tuned harmonic passive filter for mitigation of harmonics.
3. Explain effect of harmonics on rotating devices, capacitors and power measurement devices.
4. Explain various harmonic mitigation methods.
5. What are the harmonic filtering? Discuss various detuned filters.

Unit No.-VI: Power Quality Monitoring

Pre-requisites:-

- Student should know various power quality issues.
- Student should know effects and sources of power quality issues.

Objectives: -

- To illustrate various PQ monitoring instruments .
- To illustrate various PQ monitoring techniques.

Outcomes:-After successfully completing this unit, students will be able to:

CO3. Analyze power quality parameters and carry out power quality analysis.
CO6. Carry out power quality monitoring

Lecture No.	Details of the Topic to be covered	References	Mode of delivery
1	Objectives of Power quality monitoring. Types of power quality monitoring,	T1,T3 R1,R4	**PPT**
2	Power quality monitoring equipments, Power quality analyser specification requirement as per EN50160 Standard. Selection of power quality equipments for cost effective power quality monitoring,	T1,T3 R1,R4	**PPT**
3	selection of voltage and current transducers. Power quality indices.	T1,T3 R1,R4	**PPT**
4	IEEE 1159 standard and important provision related with power quality monitoring.	T1,T3 R1,R4	**PPT**
5	Computer Tools for analysis of power quality.	T1,T3 R1,R4	**PPT**
6	Case Studies	T1,T3 R1,R4	**PPT**

Question Bank: Theory

Theory Paper

1. Explain the role of intelligent systems in power quality monitoring.

2. In context to power quality monitoring explain following
i) Initial site selection for power quality monitoring
ii) Requirement of power quality monitors and duration of monitoring

1. What is a need of power quality monitoring. What is a reactive and proactive approch?

2. Explain procedure for selection of monitoring equipments and use of various equipments required for PQ monitoring.

3. Explain selection procedure of transducers for power quality monitoring.

List of Experiments

Sr.No.	Name of the Practical
1	Study of power quality analyzer and measurement of voltage, current, power and power factor using it.
2	Measurement of harmonic distortion of various Equipments such as UPS /AC/DC drive
3	Harmonic compliance of institute as per IEEE 519-2014 standard and sizing of active filter.
4	Power quality audit of institute or department
5	Harmonic analysis of transformer for various conditions (no load, inrush, full load etc.)
6	Analysis of performance of induction motor/transformer operated with sinusoidal supply and under distorted supply conditions supplied by 3 phase inverter
7	Measurement of voltage sag magnitude and duration by using digital storage oscilloscope/ power quality analyzer
8	Harmonic load flow analysis by using professional software such as ETAP, PSCAD, ATP etc
9	Simulation studies of harmonic generation sources such as VFD, SVC, STATCOM and FACTS devices and harmonic measurement (THD) by using professional software like MATLAB

Renewable Energy Systems
(403143-C)

Name of the Subject – Renewable Energy Systems

Weekly Work Load(in Hrs)	Lecture	Tutorial	Practical
	03	-	02

Online/ In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	-	25	125	

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Syllabus:

Unit I : Solar Thermal : 9Hrs

Solar radiation at the earth's surface, Solar constant, Spectral distribution, Extraterrestrial Radiation, Solar Terrestrial Radiation, Solar radiation geometry, Computation of cosθ for any location having any orientation, Empirical equations for predicting the availability of solar radiation: Monthly average daily and hourly global and diffuse radiation, Beam and Diffuse radiation under cloudless skies, Solar radiation on tilted surfaces : a)Beam radiation, b)Diffuse radiation, c)Reflected radiation, d)Flux on tilted surface. Instruments for measuring solar radiation, Devices for thermal collection and storage, Thermal applications, designing and Performance analysis of liquid flat plate collector for given heat removal factor and loss coefficient. Introduction to concentrating solar power (CSP) plants using technologies like a) Parabolic troughs b) Linear Fresnel reflector, c) Parabolic Dish, etc.

Unit II: Solar Photovoltaic: 8 Hrs

Introduction to family of solar film technology, Single c-Si, Poly c-Si PV Cell, Module and Array, Array Design (factors influencing the electrical design of the solar array) : a) Sun Intensity, b)Sun Angle, c) Shadow Effect, d) Temperature Effect, e) Effect of Climate, f) Electrical Load Matching, g) Sun Tracking, Peak Power Point Operation, Electrical characteristics of Silicon PV Cells and Modules, PV System Components, Efficiency of PV system, MPPT of solar system, PV system designing, PV powered water pumping.

Unit III: Wind Energy System: 9Hrs

Power Contained in Wind, Thermodynamics of Wind Energy, Efficiency Limit for Wind Energy Conversion, Maximum Energy obtained for a Thrust-operated converter (Efficiency limit), Design of Wind Turbine Rotor, Power-Speed Characteristics, Torque-Speed Characteristics, Wind Turbine Control Systems: a) Pitch Angle Control, b) Stall Control, c) Power Electronics Control, d) Yaw Control, Control Strategy, Wind Speed Statistics, Statistical Wind Speed Distributions, Site and Turbine Selection, Extraction of wind energy and wind turbine power. Introduction to Offshore Wind Energy System and its comparison with Wind Energy System

Unit IV : Biomass Energy Systems: 8 Hrs

Biomass Classification, Biomass Resources and their Energy Potential, Biomass Conversion Technologies: Anaerobic Digestion, Ethanol Fermentation, Biomass Gasification: Gasifiers, Fluidized Bed Gasifier, Biogas Technologies and their factor affecting Biogas Production,Biogas Plants: Floating and Fixed Dome type, designing of biogas plant Power Generation from Municipal Solid Waste (MSW), Land Fill Gas, Liquid Waste.

Unit V : Fuel Cell & Storage system: **7 Hrs**

a) Fuel Cells: Operating principles of Fuel Cell, Fuel and Oxidant Consumption, Fuel Cell System Characteristics, Introduction to Fuel Cell Technology and its type, application and limits.

b) Storage systems: Hydrogen storage: Hydrogen production, relevant properties, Hydrogen as an Engine Fuel, methods of Hydrogen storage.

Batteries: Introduction to Batteries, Elements of Electro Chemical Cell, Battery classification, Battery Parameters, Factors affecting battery performance.

Introduction to other storage technologies: pump storage, SMES, compressed air storage feeders, voltage levels, energy losses in feeders.

Unit VI : Integration and Economics of Renewable Energy System: 9Hrs.

Integration of RES with grid, standards. Grid codes

Economics of RES: Simple, Initial rate of return, time value, Net present value, Internal rate of return, Life cycle costing, Effect of fuel Escalation, Annualized and levelized cost of energy.

Text Books:

1. S.P. Sukhatme, "Solar Energy", Tata McGraw Hill
2. Mukund R. Patel, "Wind and Power Solar System", CRC Press
3. Tony Burton, Nick Jenkins, David Sharpe, "Wind Energy Hand Book-Second Edition", John Wiley & Sons, Ltd., Publication
4. Godfrey Boyle, "Renewable Energy", Third edition, Oxford University Press
5. Gilbert M. Masters, "Renewable and Efficient Electrical Power Systems", Wiley - IEEE Press, August 2004
6. Chetan Singh Solanki, "Solar Photovoltaics-Fundamentals, Technologies and Applications", PHI Second Edition.
7. H. P. Garg, J. Prakash, "Solar Energy-Fundamentals and Applications", Tata McGraw hill Publishing Co. ltd., First Revised Edition.

Reference books:

1. D.P.Kothari, K.C.Singal, Rakesh Rajan, "Renewable Energy Sources and Emerging Technologies", PHI Second Edition
2. Paul Gipe, "Wind Energy Comes of Age", John Wiley & Sons Inc.
3. Donald L. Klass, "Biomass for Renewable Energy, Fuels, and Chemicals, Elsevier, Academic Press
4. S. Rao, Dr. B. B. Parulekar, "Energy Technology – Non Conventional, Renewable and Conventional", Khanna Publication.
5. Tapan Bhattacharya, "Terrestrial Solar Photovoltaics", Narosa Publishing House.
6. Thomas Ackermann, "Wind Power in Power Systems", Wiley Publications.
7. B T.Nijaguna, "Biogas Technology", New Age International Publishers.

Reference Web Links/ Research Paper/ Referred Book other than Mention in Syllabus:

- www.e-booksdirectory.com
- onlinevideolecture.com/ebooks/?subject=Renewable%20Energy&level=4
- 3.www.solarenergy.org/.../solar-electric-handbook-photovoltaic-fundamentals-and-*appl*...

Course Objectives

- To develop fundamental understanding about Solar Thermal and Solar Photovoltaic systems.
- To provide knowledge about development of Wind Power plant and various operational as well as performance parameter/characteristics.
- To explain the contribution of Biomass Energy System in power generation.
- To teach different Storage systems, Integration and Economics of Renewable Energy System.

Course Outcomes

- Student will be able to describe various renewable energy sources such as Solar Photovoltaic, Biomass, Wind, Fuel cell and Solar thermal.
- Students will be able to explain different renewable energy sources as an alternate for conventional power sources in any application.
- Students will be able to identify and locate the use of renewable energy sources as per the requirement of the location.
- Students will be able to analyze, assess and design renewable energy sources such as solar and wind sources.
- Students will be able to compare the various storage sources for electrical energy.
- Students will be able to recognize the standards of renewable energy sources along with economic analysis and apply for evaluation of economic analysis.

Learning Outcome

Students will be able to

- Write theory of sources like solar, wind and also experiments of same.
- Analyze operating conditions like stand alone and grid connected of renewable sources,
- Reproduce different Storage Systems, concept of Integration and Economics of Renewable Energy System

PROGRESSIVE EDUCATION SOCIETY'S

MODERN COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

Academic Activity Planner

Units	Unit Test1 (10marks)	Unit Test2 (20marks)	MCQ (20marks)	Assignment (10 marks)	OBT (20marks)	Unit Test3(70marks)
I						
II						
III						
IV						
V						
VI						

Teaching Plan
Teaching plan as per University Syllabus

Sr.No.	Unit	Broad Topics to be Covered	Total Lecture Planned
1	I	Solar Thermal	06
2	II	Solar Photovoltaic	06
3	III	Wind Energy System	06
4	IV	Biomass Energy System	06
5	V	Fuel cell and Storage Systems	06
6	VI	Integration and Economics of Renewable Energy System	06

Unit wise Lecture Plan
Unit No.-I: Solar Thermal

Pre-requisites:-

- Basic concepts and fundamentals of Solar Thermal systems.

Objectives:-

- To develop fundamental understanding about Solar Thermal systems.

Outcomes:

- Student can describe various renewable energy sources such as Solar thermal systems.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Solar radiation at the earth's surface, Solar constant, Spectral distribution, Extraterrestrial Radiation	T1, T7,R4	Chalk and Talk & PPT
2	Solar Terrestrial Radiation, Solar radiation geometry	T1, T7,R4	Chalk and Talk
3	Computation of cosθ for any location having any orientation, Empirical equations for predicting the availability of solar radiation	T1, T7,R4	Chalk and Talk
4	Monthly average daily and hourly global and diffuse radiation, Beam and Diffuse radiation under cloudless skies,	T1, T7,R4	Chalk and Talk
5	Solar radiation on tilted surfaces : a)Beam radiation, b)Diffuse radiation, c)Reflected radiation, d)Flux on tilted surface.	T1, T7,R4	Chalk and Talk
6	Instruments for measuring solar radiation, Devices for thermal collection and storage	T1, T7,R4	Chalk and Talk
7	Thermal applications, designing and Performance analysis of liquid flat plate collector for given heat removal factor and loss coefficient.	T1, T7,R4	Chalk and Talk
8	Introduction to concentrating solar power (CSP) plants using technologies like a) Parabolic troughs b) Linear Fresnel reflector, c) Paraboloid Dish, etc.	T1, T7,R4	Chalk and Talk
9	Rubrics		

Question Bank: Theory
Unit: I

1) Explain the instruments used for measurement of solar radiation.
2) What are the different types of solar radiation?
3) Write empirical formulae for the monthly radiations. Write all the terms in them.
4) Define- a)declination angle b)azimuth angle c)slope d) latitude e) hour angle
5) Compare the difference in performance at different intensities.
6) Compare the difference in performance at different intensities under shadow effect.

Unit No.-II: Solar Photovoltaic

Pre-requisites:-

- Basic concepts and fundamentals of Solar Photovoltaic systems.

Objectives:-

- To provide knowledge about development of Photovoltaic systems and various operational as well as performance parameter/characteristics.

Outcomes:-

- Students can explain different renewable energy sources as an alternate for conventional power sources in any application.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction to family of solar film technology, Single c-Si, Poly c-Si and Modules	T2, T6, R4	Chalk and Talk
2	Module and Array, Array Design (factors influencing the electrical design of the solar array)	T2, T6, R4	Chalk and Talk
3	a) Sun Intensity, b)Sun Angle, c) Shadow Effect, d) Temperature Effect, e) Effect of Climate	T2, T6, R4	Chalk and Talk
4	f) Electrical Load Matching, g) Sun Tracking, Peak Power Point Operation	T2, T6, R4	Chalk and Talk
5	PV Cell Electrical characteristics of Silicon PV Cells	T2, T6, R4	Chalk and Talk
6	PV System Components, Efficiency of PV system, MPPT of solar system	T2, T6, R4	Chalk and Talk
7	PV system designing, PV powered water pumping.	T2, T6, R4	Chalk and Talk
8	Rubrics		

Question Bank: Theory
Unit 2:

1) Write a short note on factors affecting the electrical design of the solar array- 1) sun intensity 2) sun angle 3) temperature effect 4) electrical load matching
2) What is MPPT?
3) What is the difference between mono-crystalline Si PV module and multi-crystalline Si PV module?
4) What the difference in appearance of a crystalline silicon PV module and thin film PV module?
5) What is the difference in performance of a crystal Si PV module and a thin film PV module?
6) Show how PV modules are connected to supply 2 kW load. Draw a representative diagram.
7) Enlist the components used in a standalone PV system.
8) Define- a) short circuit current b) open circuit current c) Maximum power of PV module d) Fill factor e) module efficiency.

Unit No.-III: Wind Energy Systems

Pre-requisites:-

- Basic concepts of Wind Energy Conversion, design and various characteristics.

Objectives:-

- To provide knowledge about development of Wind Power plant and various operational as well as performance parameter/characteristics.

Outcomes:-

- Students can analyses, assess and design renewable energy sources such as solar and wind sources.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Power Contained in Wind, Thermodynamics of Wind Energy	T2, R4	Chalk and Talk
2	Efficiency Limit for Wind Energy Conversion, Maximum Energy obtained for a Thrust-operated converter (Efficiency limit)	T2, R4	Chalk and Talk
3	Design of Wind Turbine Rotor, Power-Speed Characteristics	T2, R4	Chalk and Talk
4	Torque-Speed Characteristics	T2, R4	Chalk and Talk
5	Wind Turbine Control Systems: a) Pitch Angle Control, b) Stall Control, c) Power Electronics Control, d) Yaw Control	T2, R4	Chalk and Talk
6	Control Strategy, Wind Speed Statistics Wind Speed Distribution	T2, R4	Chalk and Talk
7	Site and Turbine Selection, Extraction of wind energy and wind turbine power	T2, R4	Chalk and Talk
8	Introduction to Offshore Wind Energy System and its comparison with Wind Energy System,	T2, R4	Chalk and Talk
9	Rubrics		

Question Bank: Theory

1) Compare the horizontal and vertical axis wind turbine.
2) Write the advantages and disadvantages of wind energy system.
3) What are the different controls in wind generator.
4) Define- Yaw control and pitch control

Unit No.-IV: Biomass Energy Systems

Pre-requisites:-

- Various classification of biomass, potential, conversion techniques.

Objectives:-

- To explain the contribution of Biomass Energy System in power generation

Outcomes:-

- Students can compare the various storage sources for electrical energy

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Biomass Classification, Biomass	R3, R4	Chalk and Talk
2	Resources and their Energy Potential	R3, R4	Chalk and Talk
3	Biomass Conversion Technologies: Anaerobic Digestion, Ethanol Fermentation,	R3, R4	Chalk and Talk
4	Biomass Gasification: Gasifiers, Fluidized Bed Gasifier,	R3, R4	Chalk and Talk
5	Biogas Technologies and their factor affecting Biogas Production,	R3, R4	Chalk and Talk
6	Biogas Plants: Floating and Fixed Dome type, designing of biogas plant	R3, R4	Chalk and Talk
7	Power Generation from Municipal Solid Waste (MSW), Land Fill Gas, Liquid Waste.	R3, R4	Chalk and Talk
8	Rubrics		

Question Bank: Theory

1) What is biomass gasification?
2) What are the different gasifies? Write the advantages and disadvantages of different gasifiers.
3) What are the components of biomass plants?
4) List the factors affecting the biomass plant.

Unit No.-V: Fuel Cell & Storage system

Pre-requisites:-

- Introduction of Fuel cell, characterisctics, storage system, details of batteries.

Objectives:-

- To teach different Storage systems, Integration and Economics of Renewable Energy System

Outcomes:-

- Students can compare the various storage sources for electrical energy.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Fuel Cells: Operating principles of Fuel Cell	R4	Chalk and Talk
2	Fuel and Oxidant Consumption, Fuel Cell System Characteristics	R4	Chalk and Talk
3	Introduction to Fuel Cell Technology and its type, application and limits.	R4	Chalk and Talk
4	Storage systems: Hydrogen storage: Hydrogen production, relevant properties, Hydrogen as an Engine Fuel, methods of Hydrogen storage.	R4	Chalk and Talk
5	Batteries: Introduction to Batteries, Elements of Electro Chemical Cell, Battery classification, Battery Parameters, Factors affecting battery performance.	R4	Chalk and Talk
6	Introduction to other storage technologies: pump storage, SMES, compressed air storage	R4	Chalk and Talk
7	Ruberics		

Question Bank: Theory

1) Explain the working of fuel cell.
2) What are the different types of fuel cells? Explain each one in detail with necessary diagram.
3) How to maintain lead acid battery?
4) Write down the different methods of charging the battery.

Unit No.-VI: Integration and Economics of Renewable Energy System

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Pre-requisites:-

- Basic Concepts of standards of renewable energy sources along with economic analysis

Objectives: -

- To teach different Storage systems, Integration and Economics of Renewable Energy System.

Outcomes:-

- Students can recognize the standards of renewable energy sources along with economic analysis and apply for evaluation of economic analysis.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Integration of RES with grid, standards.	R4	Chalk and Talk
2	Grid codes	R4	Chalk and Talk
3	Economics of RES: Simple, Initial rate of return	R4	Chalk and Talk
4	Time value, Net present value	R4	Chalk and Talk
5	Internal rate of return	R4	Chalk and Talk
6	Life cycle costing	R4	Chalk and Talk
7	Effect of fuel Escalation	R4	Chalk and Talk
8	Annualized and levelized cost of energy	R4	Chalk and Talk
9	Rubrics		

Question Bank: Theory

1) Explain-
   a) Initial rate of return, b) time value,c) Net present value, d) Internal rate of return, e) Life cycle costing ,f) Escalation,g) Annualized cost of energy h) levelized cost of energy.

2) List the factors required for synchronization of renewable source and Grid.

Practical Assessment
List of Experiments

Minimum 8 experiments from following list

1. **To identify and measure the parameters of a Solar PV Module with Series and/or Parallel combination.**
2. **To plot I-V and P-V characteristics with series and parallel combination of Solar PV Modules for different Insolation and temperature effects.**
3. **To evaluate effect of Shading and Tilt Angle on I-V and PV characteristics of Solar Module.**
4. **To estimate effect of sun tracking on energy generation by Solar PV Module.**
5. **To estimate efficiency of standalone Solar PV Module.**
6. **To evaluate performance of Solar flat plate collector.**
7. **To plot characteristics of lead-acid battery for various source and load condition.**
8. **To analyze effect of blade angles on performance of wind turbine.**
9. **To evaluate performance of horizontal axis wind turbine.**
10. **To evaluate performance evolution of vertical axis wind turbine.**
11. **To study synchronization of wind electric generator.**
12. **Wind generation analysis using Matlab for variable wind speeds.**
13. **To evaluate efficiency of DFIG System (Hardware setup only).**

Restructuring and Deregulation (403144-A)

Name of the Subject –Restructuring and Deregulation

Weekly Work Load(in Hrs)	Lecture	Tutorial	Practical
	03	-	-

Online/ In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	-	-	100	

Syllabus:

Unit 01: Power Sector Reforms in India (6 hrs)

Need of Regulation. Institutional structure before reforms and after reforms. Roles of various key entities like Ministry of Power, CEA, Planning Commission, CERC and SERC in India. Electricity Act 2003 and 2010 and its implications for Restructuring and Deregulation. National Energy policy. Critical issues and challenges before the Indian power sector.

Unit 02: Power Sector Regulation (6 hrs)

Regulatory process in India, Principles of Tariff setting, Phases of Tariff determination, types and methods of Regulation, cost plus, performance-based regulation, price cap, revenue cap, rate of return regulation, benchmarking or yardstick regulation. Considerations of socio economic aspects in regulation.

Unit 03: Power Sector Economics (6 hrs)

Introduction to various concepts such as capital cost, debt and equity, depreciation, fixed and variable costs, working capital. Typical cost components of utilities such as return in equity, depreciation, interest and finance charges, O and M expenses etc. Key Indices for assessment of utility performances (Generation, transmission and distribution). Financial tools to compare investment options.

Unit 04: Power Sector Restructuring Models and Introduction to energy Markets (6 hrs)

Introduction, models based on energy trading or structural models – monopoly, single buyer, wholesale competition, retail competition. Models based on contractual arrangements – pool model, bilateral dispatch, pool and bilateral trades, multilateral trades. ISO models. Introduction to Energy Exchange, Day ahead market (DAM) and Term ahead market (TAM) procedure adopted in Energy exchanges and trading of Renewable Energy Credits and Carbon Credits.

Unit 05: Electricity Markets (6 hrs)

Rules that govern electricity markets, peculiarity of electricity as a commodity. Various electricity markets such as spot markets, forward contracts and forward markets, future contracts and future markets, day ahead market, reserve market, ancillary services market, market for differences, Options contracts. Market operation- settlement process, Market Clearing Price (MCP), Market efficiency, Market power.

Unit 06: Transmission Pricing & Transmission Congestion Issues (6 hrs)

Cost components of transmission system, Cost allocation of Transmission system, Transmission pricing methods, physical transmission rights, Open Access, Role of Load Dispatch centers (SLDC, RLDC and NLDC). Congestion in power network, reasons for congestion, congestion management.

Text Books:

[T-1] Know Your Power: A citizen Primer on the electricity Sector, Prayas Energy Group, Pune
[T-2] Daniel S. Kirschen, Goran Strbac, "Power System Economics" John Wiely and Sons Publication Ltd. August 2006.
[T-3] Mohammad Shahidehpour, Muwaffaq Alomoush, "Restructured Electrical Power Systems: Operation Trading and Volatility" CRC Press, 06-Jun-2001

Reference books:

[R-1] Steven Stoft, "Power System Economics: Designing Markets for Electricity", John Wiley and Sons, 2002
[R-2] Sally Hunt, "Making Competition Work in Electricity", 2002, John Wiley Inc
[R-3] Geoffrey Rothwell, Tomas Gomez, "Electricity Economics Regulation and Deregulation" A John Wiley and Sons Publication 2003
[R-4] Mohammad Shahidehpour, Hatim Yamin, Zuyi Li, "Market operations in Electric Power System" A John Wiley and Sons Publication.
[R-5] Deregulation in Power Industry – A course under continuing Education Program, Department of Electrical Engineering , IIT , Bombay

Reference Web Links/ Research Paper/ Referred Book other than Mention in Syllabus:

1. NPTEL Website: http://nptel.ac.in/courses/108101005/2
2. http://www.cercind.gov.in/Function.htm
3. www.cercind.gov.in/serc.html
4. http://www.power.gov.ng/index.php/about-us/our-functions
5. http://www.cea.nic.in/functions.html
6. http://planningcommission.nic.in/reports/genrep/arep9920/ar9920role.htm

Unit	Text Books	Reference Books
1	T-1	Websites 1-6
2	T-1	R-3
3	T-1	R-1
4	T-2	R-5
5	T-2	R-5, R-2, R-4
6	T-3	R-1

Course Objectives

The course aims:-

- To educate students about the process and operation of restructuring of power system.
- To familiarize students about the various power system restructuring models.
- To teach students pricing of electricity.
- To give knowledge of fundamental concept of congestion, its management and transmission pricing.

Course Outcomes

Upon successful completion of this course, the students will be able to: -

1. Enlist the functions of various key entities in India and explain the implications of various policies and acts on restructuring and deregulation.
2. Describe the regulatory process in India along with various methods of regulations.
3. List the components involved in tariff determination.
4. Explain different power sector restructuring models
5. Explain different types of electricity markets.
6. State different transmission pricing methods and discuss congestion management

- **Academic Activity Planner**

Units	Unit Test1 (10 marks)	Unit Test2 (20 marks)	Assignment	Unit Test3 (70marks)
I	√	√	√	√
II				
III				
IV				
V				
VI				

Teaching Plan

Teaching plan as per University Syllabus

Sr.No.	Unit	Broad Topics to be Covered	Total Lecture Planned
1	I	Power Sector Reforms in India	06
2	II	Power Sector Regulation	06
3	III	Power Sector Economics	06
4	IV	Power Sector Restructuring Models and Introduction to energy Markets	06
5	V	Electricity Markets	06
6	VI	Transmission Pricing and Transmission Congestion issues	06

PROGRESSIVE EDUCATION SOCIETY'S

MODERN COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

Unit wise Lecture Plan

Unit No.-I: Power Sector Reforms in India

Pre-requisites:-Basic knowledge of Generation, Transmission and Distribution System

Objectives :-

- To understandthe process of restructuring of Indian power system
- To understand the concept of Indian Electricity Acts.

Outcomes :

- Identify various operation of restructured power system
- Analyse the Electricity Act

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction	Know Your Power: A citizen Primer on the electricity Sector, Prayas Energy Group, Pune	Chalk and talk
2	Need of Regulation. Institutional structure before reforms and after reforms.		Chalk and talk
3	Institutional structure before reforms and after reforms.		Chalk and talk
4	Roles of various key entities like Ministry of Power, CEA, Planning Commission, CERC and SERC in India.		Chalk and talk and PPT
5	Electricity Act 2003 and 2010 and its implications for Restructuring and Deregulation.		Chalk and talk and PPT
6	National Energy policy. Critical issues and challenges before the Indian power sector.		Chalk and talk and PPT
7	Rubrics		

Question Bank: Theory

Q.1 What are the various challenges before Indian Power Sector
Q.2 Explain in Detail the function of CEA
Q.3 Why the reformation taken place in electrical power system
Q.4 Explain in Detail the function of PFC
Q.5 Explain the structure and working of Indian Energy Exchange
Q.6 Explain in Detail the function of National Electricity Policy
Q.7 Explain the objective of Electricity Act 2003. Also explain the guidelines under this act.
Q.8 Explain in Detail: REC.
Q.9 Explain in Detail: National Electricity Policy.
Q.10 Explain in Detail: Ministry of Power
Q.11 Explain the institutional structures of Indian Power Sector before and after structure.
Q.12 Explain the Rate of Return Regulation.
Q.13 Explain the Performance based Regulation.
Q.14 Explain the necessity of transmission planning with reference to market structure.
Q.15 Describe the concept of power exchange.

Unit No.-II: Power Sector Regulation

Pre-requisites :-Basic knowledge of tariff and regulation of Power System

Objectives :-

- To gain knowledge of fundamental concept of Regulatory commission in India
- To understand the Regulation in case Indian Power Sector.

Outcomes:-After successfully completing this unit students will be able to:

- Analyze Regulatory process in India
- Obtain detail knowledge of types and methods of regulation

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction	Know Your Power: A citizen Primer on the electricity Sector, Prayas Energy Group, Pune	Chalk and talk and PPT
2	Regulatory process in India, Principles of Tariff setting,		Chalk and talk and PPT
3	Phases of Tariff determination, types and methods of Regulation,		Chalk and talk and PPT
4	cost plus, performance-based regulation, price cap, revenue cap, rate of return regulation,		Chalk and talk and PPT
5	benchmarking or yardstick regulation		Chalk and talk and PPT
6	Considerations of socio economic aspects in regulation.		Chalk and talk and PPT
7	Rubrics		

Question Bank: Theory

Q.1 Explain role of regulation and evolution of regulatory commissions in India.
Q.2 What are the regulation externalities.
Q.3 With respect to the regulatory process in India explain:
- a) Composition of R.C.
- b) Authority.
- c) Decision Making Process.

Q.4 Give the structure of regulatory process in India.
Q.5 Explain the role of State Electricity Regulatory Commission and Central Electricity Regulatory Commission.
Q.6 Explain the importance of 'public' participation in regulatory process.
Q.7 What do you mean by
- a) Subsidy & cross – subsidy
- b) O and M expenses.

Q.8 What is role of regulation?
Q.9 Write short note on
- a) CERC
- b) Regulatory Process in India

Q.10 Explain following methods of regulations :
- a) Rate of return regulation.
- b) Performance based regulation.
- c) Incentive regulation.
- d) Benchmarking or Yardstick regulation.

Q.11 Explain different non-price issue.

Unit No.-III: Power Sector Economics

Pre-requisites:-Basic knowledge of Tariff.

Objectives:-

- To understand the pricing of electricity.
- To analyse the components of utilities.

Outcomes:-After successfully completing this unit students will be able:

- Find out Tariff in different utilities.
- Understand the economics of power sector regards Generation, transmission, distribution and utilization.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction	Know Your Power: A citizen Primer on the electricity Sector, Prayas Energy Group, Pune	Chalk and talk and PPT
2	Introduction to various concepts such as capital cost, debt and equity, depreciation, fixed and variable costs, working capital.		Chalk and talk and PPT
3	Typical cost components of utilities such as return in equity, depreciation,		Chalk and talk and PPT
4	interest and finance charges, O and M expenses etc.		Chalk and talk and PPT
5	Key Indices for assessment of utility performances (Generation, transmission and distribution).		Chalk and talk and PPT
6	Financial tools to compare investment options.		Chalk and talk and PPT
7	Rubrics		

Question Bank: Theory

Q.1 Explain following economic terms of power sector.
- a) Fixed cost and variable cost.
- b) Capital cost.
- c) Depreciation.
- d) Interest and finance charges.
- e) Profitability indices.

Q.2 Describe the desirable characteristics of tariff of electricity.
Q.3 Explain different performance indices for generation, transmission and distribution.
Q.4 Explain any two method to assess the financial feasibility of any project.
Q.5 Explain following basic concepts of power sector economics:
- a) Life cycle cost.
- b) Net present Value.
- c) Variable cost.

Q.6 Explain average, marginal and avoided cost.
Q.7 Write short notes
- a) Capital Cost
- b) Debt and Equity
- c) Depreciation

Q.8 Explain the tariff-Setting principle.
Q.9 Explain different methods to assess the financial feasability of any project.
Q.10 Explain following economic methods to compare investment options with examples.
- a) Payback period.
- b) Internal rate of return.
- c) Net present value.

Unit No.-IV: Power Sector Restructuring Models and Introduction to energy Markets

Pre-requisites:-Basic Knowledge of Power System

Objectives:-

- To understand the power system structure
- To understand the International experience with electricity reform

Outcomes:-After successfully completing this unit students will be able to:

- To analyze Energy Crisis in power sector.
- Analyze the international market.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction	Daniel S. Kirschen, Goran Strbac, "Power System Economics" John Wiely and Sons Publication Ltd. August 2006.	Chalk and talk and PPT
2	Models based on energy trading or structural models – monopoly, single buyer, wholesale competition, retail competition.		Chalk and talk and PPT
3	Models based on contractual arrangements – pool model, bilateral dispatch, pool and bilateral trades, multilateral trades.		Chalk and talk and PPT
4	ISO models.		Chalk and talk and PPT
5	Introduction to Energy Exchange, Day ahead market (DAM) and Term ahead market (TAM)		Chalk and talk and PPT
6	Procedure adopted in Energy exchanges and trading of Renewable Energy Credits and Carbon Credits		Chalk and talk and PPT
7	Rubrics		

Question Bank: Theory

Q.1 Write short note on following models based on industry structure and contractual arrangements :
- a) Wholesale Competition.
- b) Retail Competition.
- c) Pool and bilateral trade.
- d) Multi-lateral trade.

Q.2 Compare between 'competition for the market' and 'competition in the market'.
Q.3 Explain the important changes occurred in Indian power sector after electricity reform.
Q.4 Explain electricity reforms in Nordic pool & uk.
Q.5 Explain various ownership models.
Q.6 Explain electricity reforms in Latin America and China.
Q.7 Write a short note on the following trading models based on industrial structure.
- a) Pool and bilateral trades.
- b) Multi lateral trades.

Q.8 Explain in brief following structural models
- a) Monopoly.
- b) Single Buyer.
- c) Wholesale competition
- d) Retail competition

Q.9 Explain various ISO (Independent System Operator) models.
Q.10 Explain the California Energy Crisis after the electricity reforms.
Q.11 Explain the following models in details :
- a) Pool model.
- b) Bilateral trades.

Unit No.-V: Electricity Markets

Pre-requisites:-Basic knowledge of Electricity Market

Objectives:-

- To understand the deregulated electricity market system
- To understand the electricity market process.

Outcomes:-After successfully completing this unit students will be able to:

- Analyze the various electricity market
- Analyze the rules govern electricity market

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction	Daniel S. Kirschen, Goran Strbac, "Power System Economics" John Wiely and Sons Publication Ltd. August 2006.	Chalk and talk and PPT
2	Rules that govern electricity markets, peculiarity of electricity as a commodity.		Chalk and talk and PPT
3	Various electricity markets such as spot markets, forward contracts and forward markets,		Chalk and talk and PPT
4	Future contracts and future markets, day ahead market, reserve market, ancillary services market, market for differences,		Chalk and talk and PPT
5	Options contracts. Market operation- settlement process,		Chalk and talk and PPT
6	Market Clearing Price (MCP), Market efficiency, Market power		Chalk and talk and PPT
7	Rubrics		

Question Bank: Theory

Q.1Explain the concept of trading of power. Write short note on following trading models :
- a) Integrated trading model.
- b) Wheeling trading model.
- c) Decentralized trading model.

Q.2Explain retail competition. Also explain the retail access framework.
Q.3Explain the impact of reform on regulation and externalities.
Q.4Specify pecularities of electricity as a commodity. Explain rules that govern the electricity markets.
Q.5Compare integrated trading model and decentralized trading model.
Q.6Write a short note of following models of trading.
- a) Integrated
- b) Wheeling
- c) Decentralized

Q.7What are the impact of market reform on regulation and externalities.
Q.8Explain in detail Retail competition.
Q.9Specify pecularities of electricity as a commodity. Explain rules that govern the electricity markets.

Unit No.-VI: Transmission Pricing & Transmission Congestion Issues

Pre-requisites:-Basic knowledge of transmission system

Objectives: -

- To understand the locational marginal pricing and transmission rights.
- To understand the concept of congection management

Outcomes:-After successfully completing this unit, students will be able to:

- To get the knowledge of transmission pricing methods.
- To analyze the tariff concept rgards transmission system in India

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction	Kankar Bhattacharya, Math Bollen, Jaap E. Daalder, "Operation of Restructured Power Systems" Springer US, 2012.	Chalk and talk and PPT
2	Cost components of transmission system,		Chalk and talk and PPT
3	Cost allocation of Transmission system,		Chalk and talk and PPT
4	Transmission pricing methods, physical transmission rights, Open Access,		Chalk and talk and PPT
5	Role of Load Dispatch centers (SLDC, RLDC and NLDC).		Chalk and talk and PPT
6	Congestion in power network, reasons for congestion, congestion management.		Chalk and talk and PPT
7	Rubrics		

Question Bank: Theory

Q.1 Explain the concept of open access. Also explain the concept of transmission rights and transmission pricing.
Q.2 State the key features of Indian Grid code. Also explain transmission congestion issues.
Q.3 Explain three parts of Availability Based Tariff. Also explain how with implementation of ABT, the grid operation is improved in Indian power sector.
Q.4 Explain the working of Independent System Operator (ISO) and Load Dispatch Center (LDC).
Q.5 Explain and compare TRANSCO & ISO.
Q.6 Explain in detail congestion issue and management.
Q.7 Explain various methods of transmission pricing.
Q.8 Explain Power Exchanges in India. Also explain the concept of market clearing price.
Q.9 State and explain various methods of transmission pricing.
Q.10 Explain how with the implementation of Availability based tariff the grid operation is improved in Indian power sector.
Q.11 Explain the key features of Indian Grid Code and also explain transmission congestion issues.
Q.12 Explain the necessity of transmission planning with reference to market structure.
Q.13 Write brief notes on :
i) Ancillary Services.
ii) Role of Load Dispatch Centers in Electricity returns.
Q.14 What is the importance of transmission pricing under open access condition State and explain major components of transmission costs.
Q.15 State and explain various methods of transmission pricing.

Electric and Hybrid Vehicles (403144-D)

Elective II: 403144 (D): Electric and Hybrid Vehicles

Weekly Work Load (in Hrs.)	Lecture	Tutorial	Practical
	03	-	-

Online/ In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	-	-	100	03

.

Syllabus:

Unit 01: Introduction (05 Hrs.)
Conventional Vehicle: Basic of Vehicle performance, vehicle power source characterization, transmission characterization. Need and importance of transportation development. History of Electric Vehicle, Hybrid Electric Vehicle and Fuel cell Vehicle. Social and environmental importance of Hybrid and Electric vehicles. Impact of modern drive-trains on energy supplies.

Unit 02: Energy Storage Systems (07 Hrs.)
Introduction to energy storage requirements in Hybrid and Electric vehicles, battery-based energy storage and its analysis, Fuel cell based energy storage and its analysis, Ultra capacitor based energy storage and its analysis, flywheel based energy storage and its analysis. Hybridization of energy sources for Hybrid and Electric vehicle: - Hybridization of drive trains in HEVs, Hybridization of energy storage in EVs. Selection of energy storage technology**.**

Unit 03: Battery charging and Management systems (06 Hrs.)
Introduction, charging algorithm, balancing method for battery pack charging. Battery management system representation: - battery module, measurement unit block, battery equalization balancing unit, MCU estimation unit, display unit, fault warning block. SoC and SoH, estimation of SoC, battery balancing, Thermal monitoring of Battery unit.

Unit 04: Hybrid and Electric vehicles (05 Hrs.)
Electric vehicles: - Components, configuration, performance, tractive efforts in normal driving, Advantages and challenges in EV design. Hybrid Electric vehicles: - Concept and architecture of HEV drive train (Series, parallel and series-parallel).Energy consumption of EV and HEV

Unit 05: Drives and control systems (07 Hrs.)
Drives: - Application of BLDC drives and switched reluctance motor drive for HEV and EV, performance characteristics of drives. Instrumentation and control system related to Hybrid and Electric vehicles, speed control, acceleration characteristics, Electric steering, motion control, braking mechanism, Vehicle tracking through GPS, over speed indicating systems, Auto-parking systems

Unit 06: Vehicle to Home, Vehicle to Vehicle and Vehicle to Grid energy systems (06 Hrs.)
Vehicle to Home (V2H): PHEV control Strategies to V2H applications, V2H with demand response. Vehicle to Vehicle (V2V): - Concept and structure of EV aggregator, control method for EV aggregator for dispatching a fleet of EV. Vehicle to Grid (V2G): - planning of V2G infrastructure in the smart grid, ancillary services provided by V2G, cost emission optimization.

Text Books:

[T1] James Larminie and John Lowry, "Electrical Vehicle", John Wiley and Sons, 2012.
[T2] Ronald K. Jurgen, "Electric and Hybrid-Electric Vehicles", SAE International Publisher.
[T3] K T Chau, "Energy Systems for Electric and Hybrid Vehicles", the institution of Engineering and Technology Publication
[T4] D.A.J Rand, R Woods, R M Dell, "Batteries for Electric Vehicles", Research studies press Ltd, New York, John Willey and Sons
[T5] Electric and Hybrid Vehicles-Design Fundamentals, CRC press
[T6] Mark Warner, The Electric Vehicle Conversion handbook –HP Books, 2011.

Reference Books:

[R1] Mehrdad Ehsani, Yimin Gao and Ali Emadi,"Modern Electrical Hybrid Electric and Fuel Cell Vehicles: Fundamental, Theory and design", CRC Press, 2009.
[R2] Junwei Lu, Jahangir Hossain "Vehicle-to-Grid: Linking Electric Vehicles to the Smart Grid", IET Digital Library.
[R3] "Automobile Electrical and Electronic systems", Tom Denton, SAE International publications.
[R4] "Automotive handbook 5th edition", Robert Bosch, SAE international publication.

Unit	Text Books	Reference Books
1	All	R1
2	All	R1, R3
3	T2, T3, T4	R1
4	T1, T2, T5	R1
5	T1, T2, T5	R1
6	T3	R2

Reference Web Links/ Research Paper/ Referred Book other than Mention in Syllabus:

1. http://nptel.iitm.ac.in
2. http://nptel.ac.in/courses/108103009/
3. www.Howstuffworks.com

Course Objectives

The course aims:-

1. To make students understand the need and importance of Electric, Hybrid Electric Vehicles and Fuel cell vehicle.
2. To differentiate and analyze the various energy storage devices and battery charging and management systems.
3. To impart knowledge about architecture and performance of Electric and Hybrid Vehicles
4. To classify the different drives and controls used in electric vehicles.

Course Outcome

Upon successful completion of this course, the students will be able to: -

C404.E2D.1: Describe history, Social and environmental importance of Hybrid and Electric vehicles.

C404.E2D.2: Analyze the performance and selection of energy storage systems required for hybrid electrical vehicle.

C404.E2D.3: Explain battery management and charging system

C404.E2D.4: Distinguish between the performance and architecture of various drive trains.

C404.E2D.5: Illustrate the different Instrumentation and Control used for electric vehicles.

C404.E2D.6: Classify Vehicle to Home, Vehicle to Vehicle and Vehicle to Grid energy systems concepts.

- **Academic Activity Planner**

Units	Class Test 1 (20 Marks)	Class Test 2 (30 Marks)
1	√	
2	√	
3	√	
4		√
5		√
6		√

Teaching Plan

Teaching plan as per University Syllabus:

Sr.No.	Unit	Broad Topics to be Covered	Total Lecture Planned
1	I	**Introduction**	05
2	II	**Energy Storage Systems**	07
3	III	**Battery charging and Management systems**	06
4	IV	**Hybrid and Electric vehicles**	05
5	V	**Drives and control systems**	07
6	VI	**Vehicle to Home, Vehicle to Vehicle and Vehicle to Grid energy systems**	06

Unit wise Lecture Plan

Unit 01: Introduction

Pre-requisites:-Interest and motivation to learn Electric and Hybrid Vehicles

Objectives:-
To make students understand the need and importance of Electric, Hybrid Electric Vehicles and Fuel cell vehicle

Outcomes: After successfully completing this unit students will be able:
Describe history, Social and environmental importance of Hybrid and Electric vehicles.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Conventional Vehicle: Basic of Vehicle performance, vehicle power source characterization, transmission characterization.	T1, T3, R1, NPTEL	Chalk &Talk, PPT, Animated Video
2	Need and importance of transportation development.		Chalk &Talk, PPT,
3	History of Electric Vehicle, Hybrid Electric Vehicle and.		Chalk &Talk, PPT, Animated Video
4	History of Fuel cell Vehicle		Chalk &Talk, PPT
5	Social and environmental importance of Hybrid and Electric vehicles.		Chalk &Talk, PPT
6	Impact of modern drive-trains on energy supplies.		Chalk &Talk, PPT

Question Bank: Theory

- Write a short note on History of Electric Vehicle
- Write a short note on Hybrid Electric Vehicle.
- Why EVs Emerged and Failed in the 1990s?
- Write a short note on Fuel cell Vehicle.
- What are the Social and environmental importance of Hybrid and Electric vehicles?
- What is the Impact of modern drive-trains on energy supplies?
- Define transmission and Describe basic types of transmission for automobile applications.
- What do you mean by Power Plant Characteristics? What is its importance for on road performance of vehicles?
- Write a short note on Manual Gear Transmission.
- Write a short note on Hydrodynamic Transmission.
- Write a short note on Continuously Variable Transmission.
- Describe the Vehicle performance.
- Mention the techniques by which vehicle fuel economy can be improved.

Unit 02: Energy Storage Systems

Pre-requisites:- Basic concept of Battery and types of Battery

Objectives:-
To differentiate and analyze the various energy storage devices and battery charging and management systems

Outcomes:-After successfully completing this unit students will be able:
Analyze the performance and selection of energy storage systems required for hybrid electrical vehicle.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction to energy storage requirements in Hybrid and Electric vehicles, Hybridization of energy sources for Hybrid and Electric vehicle	T1,T3, R1, NPTEL	Chalk &Talk, PPT
2	Hybridization of drive trains in HEVs, Hybridization of energy storage in EVs.		Chalk &Talk, PPT, Animated Video
3	Battery-based energy storage and its analysis		Chalk &Talk, PPT, Animated Video
4	Fuel cell based energy storage and its analysis,		Chalk &Talk, PPT, Animated Video
5	Ultra capacitor based energy storage and its analysis.		Chalk &Talk, PPT, Animated Video
6	Flywheel based energy storage and its analysis		Chalk &Talk, PPT, Animated Video
7	Selection of energy storage technology		Chalk &Talk, PPT

Question Bank: Theory

- Write short note on various sources of energy used in transportation and their characteristics.
- Explain Different types of Batteries & their operation and performance.
- Explain need of energy storage in HV and EHV.
- Write a note on Hybridization of energy sources for EV and EHV.
- Compare Battery based and Fuel cell based energy storage system for EV and EHV.
- Write a selection criteria for energy storage technology.
- State different types of energy storage system and explain ultra-capacitor based or Flywheel based energy storage system in detail with performance parameters.
- Explain Different types of Batteries & their operation and performance.
- Explain about energy storage requirements in Hybrid and Electric vehicles.
- Explain battery-based energy storage and its analysis w.r.t application in EV and EHV.
- Explain Fuel cell based energy storage and its analysis w.r.t application in EV and EHV.
- Explain Ultra capacitor based energy storage and its analysis w.r.t application in EV and EHV.
- Explain flywheel based energy storage and its analysis w.r.t application in EV and EHV.
- Write the importance of Hybridization of energy sources for Hybrid and Electric vehicle.
- Write a short note on Hybridization of energy storage in EVs.
- Explain the Hybridization of drive trains in HEVs.

Unit 03: Battery Charging and Management Systems

Pre-requisites:-Basic concept of Batteries

Objectives:-
To differentiate and analyze the various energy storage devices and battery charging and management systems.

Outcomes:-After successfully completing this unit students will be able to:
Explain battery management and charging system

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction,	T1,T3, R1, NPTEL	Chalk &Talk, PPT
2	Charging algorithm.		Chalk &Talk, PPT, Animated Video
3	Balancing method for battery pack charging.		Chalk &Talk, PPT, Animated Video
4	Battery management system representation: - battery module, measurement unit block, battery equalization balancing unit, MCU estimation unit, display unit, fault warning block.		Chalk &Talk, PPT, Animated Video
5	SoC and SoH, estimation of SoC, battery balancing,		Chalk &Talk, PPT, Animated Video
6	Thermal monitoring of Battery unit.		Chalk &Talk, PPT, Animated Video

Question Bank: Theory

- Write a short note on Battery charging system
- Write a short note on Battery Management system
- Write a short note on charging algorithm.
- Explain Following Charging algorithm

a) Constant Current (CC) charging for NiCd/NiMH batteries
b) Constant Voltage (CV) charging
c) CC/CV charging
d) MSCC charging
e) TSCC/CV charging

- Describe charging termination techniques
- Describe balancing method for battery pack charging.
- Describe Battery sorting balancing method for battery pack charging.
- Describe active balancing method for battery pack charging.
- Describe passive balancing method for battery pack charging.
- Write a short note on Battery Management system.
- Describe component and blocks of Battery management system representation.
- What do you mean by SoC and SoH
- Compare methods of estimation of SoC.
- List out battery balancing methods and describe any one in detail.
- Write a short note on Thermal monitoring of Battery unit.
- Describe Basic terms for charging performance evaluation and characterization

a) SOH
b) C rate
c) Cut off current
d) Nominal ampere hour Capacity
e) energy efficiency

Unit 04: Hybrid and Electric vehicles

Pre-requisites:- Basic of control system

Objectives:-
To impart knowledge about architecture and performance of Electric and Hybrid Vehicles

Outcomes: -After successfully completing this unit students will be able to:
Distinguish between the performance and architecture of various drive trains.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Electric Vehicles: - Components, configuration, performance, tractive efforts in normal driving, Advantages and challenges in EV design.	T1,T3, R1, NPTEL	Chalk &Talk, PPT
2	Electric Vehicles: - Components, configuration, performance, tractive efforts in normal driving, Advantages and challenges in EV design.		Chalk &Talk, PPT
3	Electric Vehicles: - Components, configuration, performance, tractive efforts in normal driving, Advantages and challenges in EV design.		Chalk &Talk, PPT
4	Hybrid Electric Vehicles: - Concept and architecture of HEV drive train (Series, parallel and series-parallel).		Chalk &Talk, PPT
5	Energy consumption of EV and HEV.		Chalk &Talk, PPT

Question Bank: Theory

- Explain the components of Electrical Vehicles.
- Describe in brief configuration used for electrical vehicles.
- Write a short note on performance of electrical vehicles.
- Write a short note on concept of Hybrid Electric Vehicles.
- Write a short note on architecture of HEV drive train.
- Explain in detail series hybrid drive train configuration.
- Explain in detail Parallel hybrid drive train configuration.
- Explain in detail series-parallel hybrid drive train configuration.
- Write a short note about Energy consumption of EV and HEV
- What are the advantages and challenges in electrical vehicle design?
- Write a short note on tractive efforts in normal driving.

Unit 05: Drives and control systems

Pre-requisites:- Basics of Electrical motors (AC and DC Motors)

Objectives:-
To classify the different drives and controls used in electric vehicles.

Outcomes: -After successfully completing this unit students will be able to:
Describe the different Instrumentation and Control used for electric vehicles**.**

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Drives: - Application of BLDC drives for HEV and EV	T1,T3, R1, NPTEL	Chalk &Talk, PPT
2	Switched reluctance motor drive for HEV and EV		Chalk &Talk, PPT
3	Performance characteristics of drives		Chalk &Talk, PPT
4	Instrumentation and control system related to Hybrid vehicles		Chalk &Talk, PPT
5	Instrumentation and control system related to Electric vehicles, speed control		Chalk &Talk, PPT
6	Acceleration characteristics, Electric steering, motion control, braking mechanism		Chalk &Talk, PPT
7	Vehicle tracking through GPS, over speed indicating systems, Auto-parking systems		Chalk &Talk, PPT

Question Bank: Theory

- Describe the Brushless dc Motor drives used for EV and HEV
- Describe the Switched reluctance Motor drives used for EV and HEV.
- Compare performance characteristics used for EV and HEV.
- Write a short note on Instrumentation and control system related to Hybrid and Electric vehicles
- Describe the speed control for EV and HEV.
- Describe the motion control for EV and HEV.
- Describe the breaking mechanism for EV and HEV.
- Write a short note on Electrical steering and also mention advantages of electrical steering.
- Explain acceleration characteristics of EV and HEV.
- Write a short note on Vehicle tracking through GPS,
- Write a short note on over speed indicating systems,
- Write a short note on Auto-parking systems.

Unit 06: Vehicle to Home, Vehicle to Vehicle and Vehicle to Grid energy systems

Pre-requisites:- Basics of Vehicle & Electric Grid

Objectives: -
To demonstrate the knowledge about Vehicle to Home, Vehicle to Vehicle and Vehicle to Grid energy systems

Outcomes: -After successfully completing this unit, students will be able to:
Classify Vehicle to Home, Vehicle to Vehicle and Vehicle to Grid energy systems concepts.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Vehicle to Home (V2H): PHEV control Strategies to V2H applications,	T3, NPTEL	Chalk &Talk, PPT
2	V2H with demand response.		Chalk &Talk, PPT
3	Vehicle to Vehicle (V2V): - Concept and structure of EV aggregator,		Chalk &Talk, PPT
4	Control method for EV aggregator for dispatching a fleet of EV.		Chalk &Talk, PPT
5	Vehicle to Grid (V2G): - planning of V2G infrastructure in the smart grid, ancillary services provided by V2G,		Chalk &Talk, PPT
6	Cost emission optimization.		Chalk &Talk, PPT

Question Bank: Theory

- Describe Vehicle to Home(V2H) concept.
- Describe following in Vehicle to Home(V2H)
    a) PHEV control Strategies to V2H applications
    b) V2H with demand response.
- Describe the concept of Vehicle to Vehicle(V2V)
- Write a short not on Concept and structure of EV aggregator and its control methods.
- Explain control method for EV aggregator for dispatching a fleet of EV.
- Describe the concept of Vehicle to grid (V2G) and its planning of V2G infrastructure in the smart grid.
- Explain ancillary services provided by V2G,
- Explain the concept of cost emission optimization.

Special Purpose Machines (403144-E)

PROGRESSIVE EDUCATION SOCIETY'S

MODERN COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

Name of the Subject –Special Purpose Machines

Weekly Work Load(in Hrs)	Lecture	Tutorial	Practical
	03	-	-

Online/ In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	-		100	03

Syllabus:

Unit I
Generalised Machine Theory
08Hrs
Energy in singly excited magnetic field systems, determination of magnetic force and torque from energy. Determination of magnetic force and torque from co-energy, Forces and torques in systems with permanent magnets. MMF of distributed winding, Magnetic fields production of EMFs in rotating machines.

Unit II:
Permanent Magnet Synchronous and brushless D.C. Motor Drives
08Hrs
Synchronous machines with PMs, machine configurations. Types of PM synchronous machines Sinusoidal and Trapezoidal. EMF and torque equations Torque speed characteristics Concept of electronic commutation, Comparative analysis of sinusoidal and trapezoidal motor operations. Applications

Unit III : Control of PMSM Machine
08Hrs
abc-αβ and αβ-dq transformations, significance in machine modelling, Mathematical Model of PMSM (Sinusoidal), Basics of Field Oriented Control (FOC), Control Strategies: constant torque angle, unity power factor.

Unit IV : Reluctance Motor
08Hrs
Principle of operation and construction of Switch Reluctance motor, Selection of poles and pole arcs, Static and dynamics Torque production, Power flow, effects of saturation, Performance, Torque speed characteristics, Synchronous Reluctance, Constructional features; axial and radial air gap motors; operating principle; reluctance torque; phasor diagram; motor characteristics Introduction to control of Reluctance Drive. Applications.

Unit V : Stepper Motor
8Hrs

Construction and operation of stepper motor, hybrid, Variable Reluctance and Permanent magnet, characteristics of stepper motor; Static and dynamics characteristics, theory of torque production, figures of merit; Concepts of lead angles , micro stepping , Applications selection of motor.

Unit VI : Linear Electrical Machines
08 hrs

Introduction to linear electric machines. Types of linear induction motors, Constructional details of linear induction motor, Operation of linear induction motor. Performance specifications and characteristics Applications.

Text Books:

[T1] K. Venkatratnam, 'Special Electrical Machines', University Press
[T2] A.E. Fitzgerald Charles Kingsley, Stephen Umans, 'Electric Machinery', Tata McGraw Hill Publication
[T3] T.J.E. Miller, 'Brushless Permanent magnet and Reluctance Motor Drives' Clarendon Press, Oxford 1989.
[T4] V. V. Athani, 'Stepper Motors: Fundamentals, Applications and Design', New age International, 1997

Reference Books:

[R1] R Krishnan, 'Permanent Magnet Synchronous and Brushless D.C. Motor Drives' CRC Press.
[R2] Ion Boldea, 'Linear Electric Machines, Drives and maglevs' CRC press
[R3] Ion Boldea S. Nasar, 'Linear Electrical Actuators and Generators', Cambridge University Press.

Unit	Text Books	Reference Books
1	T2	-
2	T1,T3	R1
3	T1	-
4	T1	-
5	T1,T4	-
6	-	R2,R3

Course Objectives

1. To explain operation and performance of synchronous reluctance motors.
2. To describe operation and performance of stepping motors.
3. To elaborate operation and performance of switched reluctance motors.
4. To familiarize with operation and performance of permanent magnet brushless D.C. motors.
5. To illustrate operation and performance of permanent magnet synchronous motors.

Course Outcomes

After successfully completing the course students will be able to:

1. Students will be able to describe generalized machine theory
2. Students will be able to reproduce principle of operation of PMSM & brushless DC motor drives
3. Students will be able to demonstrate control of PMSM drive
4. Students will be able to understand operation and performance of Switched reluctance motor
5. Students will be able to reproduce operation and applications of stepper motor
6. Students will be able to explain performance specifications and characteristic applications of linear induction motor

- **Academic Activity Planner**

Units	Unit Test1 (10marks)	Unit Test2 (10marks)	Unit Test3 (10marks)	Assignment1 (10marks)	Assignment2 (10marks)	Assignment3 (10marks)
I	√					
II		√				
III			√			
IV				√		
V					√	
VI						√

Teaching Plan

Teaching plan as per University Syllabus

Sr.No.	Unit	Broad Topics to be Covered	Total Lecture Planned
1	I	Generalized Machine Theory	6
2	II	Permanent Magnet Synchronous and brushless D.C. Motor Drives	6
3	III	Control of PMSM Machine	6
4	IV	Reluctance Motor	6
5	V	Stepper Motor	6
6	VI	Linear Electrical Machines	6

Unit wise Lecture Plan
Unit No.-I: General.

Pre-requisites:-

- Basic concepts of different electric motors
- Laws related to energy conversion in electrical machines
- Knowhow of D-Q axis theory related to electrical machines

Objectives :-

- To understand basic concepts of energy conversion and production of force/torque.
- To understand bacics of magnetic circuits.

Outcomes :

- Students will be able to Reproduce fundamentals of magnetic circuits.
- Students will be able to describe generalized machine theory.

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Energy in singly excited magnetic field systems	T2	Chalk and Talk
2	determination of magnetic force and torque from energy	T2	Chalk and Talk
3	Determination of magnetic force and torque from co-energy	T2	Chalk and Talk
4	Forces and torques in systems with permanent magnets	T2	Chalk and Talk
5	MMF of distributed winding	T2	Chalk and Talk
6	Magnetic fields production of EMFs in rotating machines	T2	Chalk and Talk

Question Bank: Theory
Unit 1

1. Obtain magnetic force and torque from co-energy.
2. Derive the relationship for energy stored in singly excited magnetic system.
3. Explain process of development of force and torque in a system employing permanent magnets with suitable mathematical expressions.
4. Explain development of MMF produced by three phase balance and distributed winding.
5. Explain forces and torques in systems with permanent magnets.

Unit No.-II: Permanent Magnet Synchronous and brushless D.C. Motor Drives

Objectives :-
To understand basic concepts of Permanent Magnet Synchronous and brushless D.C. Motor

Outcomes:- After successfully completing this unit students will be able to:
reproduce principle of operation of PMSM & brushless DC motor drives

Lecture No.	Details of the Topic to be covered	References
1	Synchronous machines with PMs, machine configurations.	**T1,T3,R1**
2	Types of PM synchronous machines Sinusoidal and Trapezoidal	**T1,T3,R1**
3	EMF and torque equations	**T1,T3**
4	Torque speed characteristics	**T1,T3**
5	Concept of electronic commutation	**T1,T3,R1**
6	Comparative analysis of sinusoidal and trapezoidal motor operations. Applications	**T1,T3**

Question Bank: Theory

1. What are the difference between sinusoidal and trapezoidal PMSM
2. Explain the process of electronic commutation in PMSM
3. Explain block diagram constant torque angle operation of PMSM
4. Explain block diagram of field oriented control of PMSM Machine

Unit No.-III: Control of PMSM machine

Objectives:-
To understand Control strategies of PMSM machine.

Outcomes:- After successfully completing this unit students will be able to:
Demonstrate control of PMSM drive.

Lecture No.	Details of the Topic to be covered	References
1	abc-αβ and αβ-dq transformations	T1
2	significance in machine modelling	T1
3	Mathematical Model of PMSM (Sinusoidal)	T1
4	Basics of Field Oriented Control (FOC)	T1
5	Control Strategies: constant torque angle	T1
6	unity power factor	T1

Question Bank
Unit No.-III

1. Explain with block diagram unity pf operation of PMSM
2. Develop Mathematical model of PMSM
3. Compare BLDC machine with PMSM
4. Derive expression for electromagnetic torque developed in PMSM Machine
5. Obtain the abc-αβ transformation to get αβ-dq transformation clearly state the meaning of each notation used and assumptions made

Unit No.-IV: Reluctance motor

Objectives:- To elaborate operation and performance of reluctance motors.

Outcomes:- After successfully completing this unit students will be able to:
reproduce principal of operation of PMSM, Stepper motor, SRM, Switch reluctance and linear motors.

Lecture No.	Details of the Topic to be covered	References
1	Principle of operation and construction of Switch Reluctance motor,	T1
2	Selection of poles and pole arcs, Static and dynamics Torque production	T1
3	Power flow, effects of saturation, Performance, Torque speed characteristics,	T1
4	Synchronous Reluctance, Constructional features; axial and radial air gap motors;	T1
5	operating principle; reluctance torque; phasor diagram;	T1
6	motor characteristics Introduction to control of Reluctance Drive. Applications.	T1

Question Bank
Unit No.-IV

1. Explain difference between operational characteristics and constructional features of SRM
2. With the block diagram explain control of reluctance motor
3. Obtain mathematical expression for static and dynamic torque production in reluctance machine
4. Discuss section of number of poles and pole arc in SRM
5. What are the different control methods of reluctance motor. Explain anyone in detail.
6. What are the axial and radial gap reluctance machine? Derive equation for mechanical torque developed in plain reluctance machine
7. Discuss construction and operation of SRM.

Unit No.-V: Stepper Motor

Objectives:- To describe operation and performance of stepping motors.

Outcomes:- After successfully completing this unit students will be able to reproduce operation and applications of stepper motor

Lecture No.	Details of the Topic to be covered	References
1	Construction and operation of stepper motor	**T1,T4**
2	hybrid, Variable Reluctance and Permanent magnet	**T1,T4**
3	characteristics of stepper motor; Static and dynamics characteristics	**T1,T4**
4	theory of torque production	**T1,T4**
5	figures of merit; Concepts of lead angles	**T1,T4**
6	micro stepping , Applications selection of motor.	**T1,T4**

Question Bank:
Unit No.-V

1. Write in detail on close loop control of stepper motor
2. With block diagram explain control of stepping motor by using micro-stepping method
3. Derive equation for mechanical torque produced in VRM stepping motor
4. Explain various applications of stepping motor
5. Compare VRM with PM type stepper motor also explain different characteristics of stepper motor
6. Explain process of torque production in stepper motor

Unit No.-VI: Linear Electrical Machines

Objectives:- To explain operation and performance of linear Induction machines.

Outcomes:- After successfully completing this unit students will be able to explain performance specifications and characteristic applications of linear induction motor

Lecture No.	Details of the Topic to be covered	References
1	Introduction to linear electric machines.	**R2,R3**
2	Types of linear induction motors,	**R2,R3**
3	Constructional details of linear induction motor,	**R2,R3**
4	Operation of linear induction motor.	**R2,R3**
5	Performance specifications and characteristics Applications	**R2,R3**
6	Rubrics	**R2,R3**

Question Bank: Theory
Unit No.-VI

1. Explain different constructions of LIM
2. Explain important characteristics of LIM
3. Explain requirements of LIM for applications like high speed traction, missile launcher
4. Explain the process of torque production in LIM
5. Explain principal of operation of LIM also state important characteristics.

Control System-II
(403145)

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Name of the Subject – Control System-II

Weekly Work Load(in Hrs)	Lecture	Tutorial	Practical
	3	-	02

Online/ In-sem	Theory	Practical	Oral	Term-work	Total Marks	Credit
30	70	-	25	25	150	

Syllabus:

Unit 01 : Digital Control System (06Hrs)

Introduction, Configuration of the basic digital control system. Advantages and limitations of digital control; data conversion and quantization, Sampling and Reconstruction processes, Shannon's Sampling theorem, practical aspects of choice of sampling rate. Zero order hold (ZOH) and it's transfer function, Basic concepts and transfer function of first order hold.

Unit 02 : Z-transform and Pulse-transfer-function (06Hrs)

Review of z-transform, Inverse z-transform, difference equations and solution using z transform method. Pulse transfer function and Z-transfer function, General procedure for obtaining Pulse-transfer-function, pulse transfer function of ZOH,

Unit 03 : Stability Analysis (06Hrs)

Sampled data closed loop systems, characteristic equation, causality and physical realizability of discrete data system, realization of digital controller by digital programming, direct digital programming, cascade digital programming, parallel digital programming. Mapping between S-plane and Z-plane, stability analysis of closed loop system in z-plane using Jury's test, Bilinear Transformation.

Unit 04 : Introduction to state space analysis (06Hrs)

Important definitions – state, state variable, state vector, state space, state equation, output equation. State space representation for electrical and mechanical system, nth order differential equation and transfer function. Conversion of transfer function to state model and vice versa. State model of armature control DC motor

Unit 05 : Solution of state equations (06 Hrs)

Concept of diagonalization, eigen values, eigenvectors, diagonalization of system matrices with distinct and repeated eigen values, Vander Monde matrix.

Solution of homogeneous and non-homogeneous state equation in standard form, state transition matrix, its properties, Evaluation of STM using Laplace transform method and infinite series method Cayley Hamilton theorem.

Unit 06 : Design of Control System Using State Space Technique: (06 Hrs)

Concept of controllability and observability, controllability and observability Tests, condition for controllability and observability from the system matrices in Canonical form, Jordan canonical form, effect of pole zero cancellation on the controllability and observability of the system, duality property. Pole placement design by state variable feedback. Necessity of an observer, design of full order observer

Text Books:

[T1] K. Ogata, "Discrete Time Control System", 2nd Edition, PHI Learning Pvt. Ltd. 2009
[T2] Benjamin C. Kuo "Digital Control System", Prentice Hall of India Pvt. Ltd.
[T3] J. Nagrath, M. Gopal "Control System Engineering", 5th Edition. New Age International Publishers
[T4] R.Anandanatarajan and P.Ramesh Babu "Control System Engineering",4th Edition, SCITECH Publications, India Pvt. Ltd.

Reference Books:

[R1] K. Ogata, "Modern Control Engineering", Prentice Hall of India Pvt. Ltd.
[R2] M. Gopal, "Digital Control and State Variable Methods", Tata McGraw-Hill.
[R3] M. N. Bandyopadhyay, "Control Engineering – Theory and Practice", Prentice Hall of India Ltd. Delhi.

Unit Text Books Reference Books

1 T1,T2 R1,R2
2 T1,T2 R2,R3
3 T1,T2 R2
4 T3, T4 R1, R3
5 T3, T4 R1, R3
6 T3, T4 R1, R3

Course Objectives

 To learn the concept of compensation and to realize compensator for a system using active and passive elements.
 To understand the concept of state and to be able to represent a system in the state space format and to solve the state equation and familiarize with STM and its properties.
 To design a control system using state space techniques including state feedback control and full order observer.
 To familiarize with various nonlinearities and their behaviour observed in physical system and to understand the Describing function method and phase plane method.
 To understand the basic digital control scheme, the concept of sampling and reconstruction. To be able to analyze and design a digital control system including realization of digital controllers.

Course Outcomes

After successfully completing the course students will be able to:

 Design and realize a compensator for a physical system,
 Represent a physical system in state space format and analyze the same and to realize a controller using state space technique.
 Analyze understand the various nonlinearities in a physical system.
 Realize digital control schemes.

- **Academic Activity Planner**

Units	Unit Test1 (10marks)	Unit Test2 (20marks)	Assignment (Each 20marks)
I	✓		
II	✓		
III		✓	
IV		✓	
V			✓
VI			✓

Teaching Plan

Teaching plan as per University Syllabus

Sr.No.	Unit	Broad Topics to be Covered	References/ Text book	Total Lecture Planned
1	I	Digital Control System	T1,T2 R1,R2	6
2	II	Z- Transform and Pulse Transfer function	T1,T2 R2,R3	6
3	III	Stability Analysis	T1,T2 R2	6
4	IV	Introduction to State Space Analysis	T3, T4 R1, R3	6
5	V	Solution of State Equation	T3, T4 R1, R3	6
6	VI	Design of Control System Using State Space Technique	T3, T4 R1, R3	6

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.Unit wise Lecture Plan

Unit No.-I: Digital Control System

Pre-requisites:- Analog to Digital Conversion and vice versa

Objectives:-

To understand the basic digital control scheme, concept of sampling and reconstruction.

Outcomes:

Realize and analyze digital control scheme

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Introduction to digital control system, History of development of control system. Configuration of the basic digital control system.	**T1**	Video and PPT
2	Configuration of the basic digital control system. Advantages and limitations of digital control	**T1,T2**	PPT
3	System data conversion and quantization, Sampling and,	**T3,R1**	Chalk and Talk
4	Reconstruction processes, Shannon's Sampling theorem	**T1,T3**	Chalk and Talk
5	Practical aspects of choice of sampling rate, Zero order hold (ZOH) and it's transfer function	**T2,T3**	Chalk and Talk
6	Basic concepts and transfer function of first order hold	**T1,T2,R1**	Chalk and Talk

Question Bank: Theory

Unit :I

Q1 Explain basic configuration of basic digital control scheme.

Q2 Explain data conversion and Quantization in digital control scheme.

Q3Explain ZOH and its transfer function.

Q4Explain Sampling theorem and Reconstruction process.

Q5Explain practical aspects of choice of sampling rate.

Q6Draw the block diagram of digital control system and explain the function of each block

Unit No.-II: Z-Transform And Pulse-Transfer-Function

Pre-requisites:- Basic concepts of z-transform and inverse z-transform

Objectives:-

- To understand the concept of z-transform and inverse z-transform used in digital control system
- To be able to represent systems pulse-transfer-function and familiarize with zero order hold.

Outcomes: - After successfully completing this unit students will be able:

- Able to solve difference equations and solution using z transform method.
- Can design pulse transfer function for digital close loop system

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Review of z-transform	T1,T2	**Chalk and Talk**
2	Inverse z-transform	**T1.T3,R2**	**Chalk and Talk**
3	Difference equations and solution using z transform method.	**T2,T3**	**Chalk and Talk**
4	Pulse transfer function and Z-transfer function	**T2,T3**	**Chalk and Talk**
5	General procedure for obtaining pulse-transfer-function	**T1**	**Chalk and Talk**
6	pulse transfer function of ZOH	**T1,T2**	**Chalk and Talk**

Question Bank: Theory

Q.1. Define pulse transfer function and state procedure for obtaining pulse transfer function.

Q.2. Obtain direct and cascade realization from given TF
D(z)=(z^3+0.9z^2+0.26z+0.024)/(z^3+5z^2+8z+6)

Q.3. Solve the following difference equation by using z transforms method
X(k+2)+4X(k+1)+3X(k)=U(k+1) Where X(0)=0 X(1)=1
The input fraction U(k) is given by U(k)=1, k=0,1,2,…

Q.4. Solve the following difference equation using z-transform method
x(k+2)+5x(k+1)+6x(k)=0 for ,x(0)=0,x(1)=1

Q.5. Obtain Direct realization of
D(z) = (z^2 +5z +2) / (z^3 +6z^2 + 4z + 1)

Q.6. Obtain Cascade Realization of
D(z) = (z^3+3z^2+7z+5) / (z^3+3z^2+9z+14)

Unit No.-III: Stability Analysis

Pre-requisites:- Stability Analysis of S-Plane

Objectives:-

- To Realize digital controller by digital programming.
- To understand stability of digital control system.

Outcomes: - After successfully completing this unit students will be able to:

- Analyze digital controllers programming
- Able to Comment on stability of digital control system

Lecture No.	Details of the Topic to be covered	References	Mode of Delivery
1	Sampled data closed loop systems, characteristic equation, causality and physical realizability of discrete data system	T1,T3,R1	Chalk and Talk
2	Realization of digital controller by digital programming, direct digital programming,	T1,T3,R1	Chalk and Talk
3	Cascade digital programming, Parallel digital programming.	T1,T3,R1	Chalk and Talk
4	Mapping between S-plane and Z-plane	T1,T3,R1	Chalk and Talk
5	Stability analysis of closed loop system in z-plane using Jury's test	T1,T3,R1	Chalk and Talk
6	Stability analysis of closed loop system in z-plane using Bilinear Transformation	T1,T3	Chalk and Talk

Question Bank: Theory Unit :III

Q1 Show how a mapping of Left Half of the S-plane is done into the Z-plane with Stable and unstable regions.

Q2 Examine the stability of the system by Bilinear transformation method, whose characteristic equation is: F(z) = Z3+3Z2+2Z-3=0

Q3The characteristic equation of discrete time unity feedback control system is given by : Z3+(3K)Z2+(K+2)Z + 4=0. Determine the range of gain K for stability of the system by use of Jury's stability test.

Q4 Examine and comment on the stability of the system represented by its characteristics equation as given below using Jury's Stability criterion. p(z) =z^2-1.2z^3+0.07z^2+0.3z – 0.08 = 0

Unit No.-IV: Introduction to state space analysis

Pre-requisites:- Transfer Function Theory

Objectives:- After successfully completing this unit students will be able to:

- Understand the concept of state and able to represent a system in the state space format
- Able to Comment on stability of digital control system

Outcomes:-

Lecture No.	Details of the Topic to be covered	References
1	Important definations- state,State variable, state vector,state space,state equation,Output equation.	**T3,T4**
2	State space representation for electrical network	**T3,T4**
3	State space representation for mechanical system.	**T3,T4**
4	Conversion of transfer function to state space and vice-versa	**T3,T4**
5	State model of armature control DC Motor	**T3,T4**
6	Problems on Conversion of transfer function to state space and vice-versa	**T3,T4**

Question Bank
Unit No.-IV

Q1 a) Find the T.F.

$$\dot{X}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -6 & -11 & -6\end{bmatrix}X+\begin{bmatrix}0\\0\\1\end{bmatrix}u(t)$$

$$Y=[4 \quad 5 \quad 1]X$$

Q2 Define following terms.

a) State
b) State Variable
c) State vector
d) State Equation
e) State Space.

Q3 State advantages of state variable method over conventional method.

Q4 Obtain State model of the system

$$\frac{d^3y}{dt^3}+6\frac{d^2y}{dt^2}+11\frac{dy}{dt}+10y=3U(t)$$

Q5 Obtain state model of differential equation

$$4\frac{d^3c(t)}{dt^3}+3\frac{d^2c(t)}{dt^2}+\frac{dc(t)}{dt}+2c(t)=5r(t)$$

Unit No.-V: Solution of State Equations

Pre-requisites:- Matrix basics.

Objectives:- After successfully completing this unit students will be able to:
To solve the state Equation and familiarize with STM & its properties.

Outcomes:- Student should able to solve state equation.

Lecture No.	Details of the Topic to be covered	References
1	Concept of diagonalization,eigen values, Eigen vector,VanderMonde Matrix	**T3,T4,R1 ,R3**
2	Solution of Homogeneous and non- Homogeneous state Equation	**T3,T4,R1 ,R3**
3	Concept of State Transition matrix- STM & its Properties	**T3,T4,R1 ,R3**
4	Evaluations of STM using Laplace transform method.	**T3,T4,R1 ,R3**
5	Evaluation of STM using infinite series method.	**T3,T4,R1 ,R3**
6	Evaluation of STM using Cayley Hamilton theorem method	**T3,T4,R1 ,R3**

Question Bank:

Q1 State properties of state state transition matrix.
Q2 Explain terms eigen values, eigen vector, modal matrix and vander monde matrix.
Q3 Find the state transition matrix using Laplace inverse method.

$$A=\begin{bmatrix} 0 & 1 \\ -4 & -5 \end{bmatrix}$$

Q4

Using Laplace transform method find the matrix exponential e^{At} for

i) $A=\begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix}$ ii) $A=\begin{bmatrix} 0 & 2 \\ -2 & -4 \end{bmatrix}$

Q5

Diagonalise following matrix

$$A=\begin{bmatrix} -4 & 1 & 0 \\ 0 & -3 & 1 \\ 0 & 0 & -2 \end{bmatrix}$$

Unit No.-VI: Design of Control System Using State Space Technique

Pre-requisites:- Sate Space bacics., Matrix basics.

Objectives : After successfully completing this unit students will be able to:
Design a control system using state space techniques including state feedback control and full order observer.

Outcomes:- Student should able to design observer for system.

Lecture No.	Details of the Topic to be covered	References
1	Concept of controllability and observability. Controllability and observability tests.	**T3,T4,R1,R3**
2	Condition of controllability and observability from the system matrices in canonical form,Jordon canonical form	**T3,T4,R1,R3**
3	Effect of pole Zero cancellation on controllability and observability of the system	**T3,T4,R1,R3**
4	Duality property	**T3,T4,R1,R3**
5	Pole placement design by state variable feedback.	**T3,T4,R1,R3**
6	Necessity of an observer	**T3,T4,R1,R3**
7	Design of Full order Observer	**T3,T4,R1,R3**

Question Bank: Theory
Unit No.-VI

Q1 Define controllability and observability. Explain any one method to determine it .

Q2 For the following system determine controllability and observability.

$$A=\begin{bmatrix}-1 & 1 & 0\\ 0 & -4 & 2\\ 0 & 0 & -10\end{bmatrix},\quad B=\begin{bmatrix}1\\0\\1\end{bmatrix},\quad c=[1\ 0\ 1]$$

Q3 For the following system determine controllability and observability.

$$A=\begin{bmatrix}0 & 0 & 0\\ 1 & 0 & -3\\ 0 & 1 & -4\end{bmatrix};\quad C=[0\quad 0\quad 1]$$

$$B=\begin{bmatrix}1\\0\\1\end{bmatrix}$$

Q4 Explain the procedure to design state observer.

Q5 A system is given by x=Ax+By

$$A=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 0 & -2 & -3\end{bmatrix},\quad B=\begin{bmatrix}0\\0\\1\end{bmatrix}$$

It is desired to place close loop poles at -2,-1 +- j

Q6

Derive two state models for the system described by the differential

$D^3y + 4D^2y + 5Dy + 2y = 2D^2u + 6Du + 5u$ *where* $D = d/dt$

i) One in phase variable form.

ii) Other in Jordan-Canonical form.

Practical Assessment
List of Experiments

Sr.No.	Name of the Practical
1	Plotting of discrete time wave forms a) sin, b)Unit step c) Exponential
2	Effect of sampling and verification of sampling theorem
3	Convert a continuous time system to digital control system and check response using software
4	Check for observability and Controllability in MATLAB.
5	Verify State feedback control using pole placement
6	Software programming for determination of state space representation for given transfer function and vice-versa
7	Software programming for determination of STM.
8	Design State observer and validate it by software.

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Unit No.__

Theory Paper

[Total No. of Questions = 3]

[Total No. of Pages = 1]

B.E. (Electrical) 2015-Course

Subject Code:_____ Subject Name: _____

Semester: I (2019-20) Exam: _____

[Time: 1 Hours] [Max Marks = 10]

Instructions to Candidates:

1. **Answer any __2___ Questions out of _____3__ questions**
2. **Use single answer book for all questions.**
3. **Figures to the right of each question indicate full marks.**
4. **Use of Scientific calculator is allowed.**

Q. 1	**a)**		**[ ]**
	b)		**[ ]**
Q. 2	**a)**		**[ ]**
	b)		**[ ]**
Q. 3	**a)**		**[ ]**
	b)		**[ ]**

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Tutorial

[Total No. of Questions = 5]

[Total No. of Pages = 1]

B.E. (Electrical) 2015-Course

Subject Code:_____ Subject Name: _____

Semester: I (2019-20) Exam: _____

[Time: 1 Hours] [Max Marks = 20]

Instructions to Candidates:

1. **Answer any ___4__ Questions out of __5_____ questions**
2. **Use single answer book for all questions.**
3. **Figures to the right of each question indicate full marks.**
4. **Use of Scientific calculator is allowed.**

Q. 1		**[ ]**
Q. 2		**[ ]**
Q. 3		**[ ]**
Q. 4		**[ ]**
Q. 5		**[ ]**

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DEPARTMENT OF ELECTRICAL ENGINEERING

Assignment

[Total No. of Questions = 5]
[Total No. of Pages = 1]
B.E. (Electrical) 2015-Course (Credit pattern)
Subject Code:_____ Subject Name: _____
Semester: I (2019-20) Exam: _____
[Time: 1 Hours] [Max Marks = 20] [-Credits]

Instructions to Candidates:

1. **All Questions are compulsory.**
2. **Use of Scientific calculator is allowed.**

Q. 1		**[ ]**
		[ ]
Q.2		
Q.3		
Q.4		
Q.5		

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