Department of Electrical Engineering

B. Tech. Electrical Engineering With Multidisciplinary Minor

Course Code	Name of Course	Course Category	Teaching Scheme				Credits	Evaluation Scheme					
								Theory			Practical		Total Marks
			L	T	P	Total Hours		TAE	CAE	ESE	INT	EXT	
SEMESTER-VII													
23BTEEL401 23BTEEP401	Switchgear and protection	PCC11	3	-	2	5	4	10	15	50	25		100
23BTEEL402 23BTEEP402	High Voltage Engineering	PCC12	2	-	2	4	3	10	15	50	25	25	125
23BTEEL403 23BTEEP403	Power System Dynamics	PCC13	2	-	2	4	3	10	15	50	25	-	100
23BTEEL4XX	Program Elective-IV	PEC4	4	-		4	4	10	15	50	-	-	75
23BTXXLXXX	Multidisciplinary Minor V	MDM5	4	-	-	4	4	10	15	50		-	75
23BTEEP404	Project	P	-	-	8	8	4	-	-	-	50	50	100
TOTAL			**15**	**0**	**14**	**29**	**22**	**50**	**75**	**250**	**100**	**75**	**575**

Offered From Department of Electrical Engineering

Course Code	Name of Course	Course Category
23BTEEL415	Multidisciplinary Minor V (Hybrid Electric Vehicle)	MDM5

Department of Electrical Engineering

Switchgear and Protection

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	3Hrs.	.	2Hrs.	04	10	15	50	25	--
Course Code	23BTEEL401 23BTEEP401									
Teaching Mode	Conventional	2 Hrs			Total	75			25	
Duration of ESE	03:00					100				

Course Objectives	1. To introduce the construction, working and applications of different relays & protective schemes like distance protection, differential, over current & overvoltage protection.
	2.To study different types of circuit breaker used and practical application
	3. Introduction to static and numerical relays.
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1:Understand various switchgears for protection
	CO2:Know philosophy of Protective Relaying
	CO3:Identify different types of relays for protection of transmission line
	CO4: Apply different protective schemes for transformer generator and busbar.
	CO5:Compare different types of Relays

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	2	3	2	1							2	2	2	3
CO2	2	2	3	2	1							2	2	2	3
CO3	2	2	3	2	1							2	2	2	3
CO4	2	2	3	2	1							2	2	2	3
CO5	2	2	3	2	1							2	2	2	3

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Unit	Contents	Hours
I	**Unit-I:- Circuit Breakers and Protection:** Circuit Breakers and Protection: Circuit breakers. Arc interruption theory, recovery and restricting voltages, RRRV, breaking of inductive and capacitive currents, C.B, ratings, different media of arc interruption, overview of oil circuit breakers, construction and operation of Air blast, SF6 and vacuum breakers, Gas Insulated Substation, Advances in industrial power system protection. DC Circuit Breaker	6
II	**Unit –II:- General Philosophy of Protective Relaying** Protective zones, primary protection, Back up protection Remote and Local Back up selectivity Need for protective system, nature and causes of fault, types of faults, effects of faults, evolution of protective relaying, classification of relays, essential qualities of protective relaying. Trip circuit of circuit breaker. Various basic operating principles of protection- over current, (current graded and time graded), torque equation in induction type relay directional over current, differential, distance, induction type relay, current and time setting in induction relay, Numerical on TSM , PSM and operating time of relay.	6
III	**Unit III:- Line Protection** Over current relaying, directional- over current relay, High Voltage Line Protection: Distance relays, carrier distance Schemes. Unit carrier schemes for transmission lines.	7
IV	**Unit IV: Equipment Protection:** Principles of differential relaying, protection of generators, transformers and bus Bars by differential relaying and other relays. Protection Induction Motors against overloads, short circuits. Thermal relays miniature circuit breaker.	8
V	**Unit V: -Introduction to Digital and numerical relays:** Comparison of Digital and electro mechanical relays, two input amplitude and phase comparator and their duality. Generation of various distance relay characteristics using above comparators.	6

Text Books	1.	Mason, Art and science of Protective Relaying, 3rd Edition, Wiley Easter, 1992
	2.	Paithankar & Bhide, Power system protection, 2nd Edition, PHI, 2012
E-Books	1.	Sunil S. Rao, Switchgear and Protection, 10th Edition, Khanna Publication, 2002
	2.	B.Ram, Power System Protection and switchgear, 29th Edition, TMG, 2008
Reference Books	1.	Sunil S. Rao, Switchgear and Protection, 10th Edition, Khanna Publication, 2002

	2.	Ravindranath and chander, Power system Switchgear Protection, 4th Edition, New Age publications, 1977
	3.	B.Ram, Power System Protection and switchgear, 29th Edition, TMG, 2008
Online TL Material	1.	NPTEL videos

S.N.	Name of Experiments / Mini Projects/ Case Studies
1	Overview of Lab equipment.
2	To determine PSM and plot the characteristic of Definite Time over current Relay.
3	To determine PSM and plot the characteristic of I.D.M.T. Over Current relay
4	To analyze and plot the characteristic of Single Pole Static I.D.M.T. Over Current relay during earth fault.
5	To plot the Magnetization Characteristics of C.T and analyze the significance of knee and ankle point.
6	To Plot The Characteristics of Fuse Wire
7	To analyze and plot Percentage Differential Protection Scheme
8	To simulate Fault in electrical power system using MATLAB Software
9	Open Ended
Details of on line Laboratory Resource Material Instruction / Operating Manuals	
1. Virtual lab	

High Voltage Engineering

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	2Hrs.	.	2Hrs.	03	10	15	50	25	25
Course Code	23BTEEL402/ 23BTEEP402									
Teaching Mode	Conventional	2 Hrs			Total	75			50	
Duration of ESE	03:00					125				

Course Objectives	1. To introduce the conduction and electrical breakdown phenomena in liquids, solids. Gases or vacuum.
	2. To introduce Generation of high voltage, high current and their measurement.
	3. To introduce testing units required for the installation of electrical equipment

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Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Analyze the dielectric material for insulation according to breakdown mechanism.
	CO2: Understand the phenomenon of lightning and Travelling switching over voltages along with protection.
	CO3: Analyze systems for generation of high voltage and current.
	CO4: Measure high voltage and current.
	CO5: Design and conduct nondestructive and high voltage test of electrical apparatus

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	-	-	-	-	-	-	-	-	1	2	3	2	-
CO2	3	2	2	-	1	2	2	-	-	-	1	2	3	2	-
CO3	3	2	2	2	2	-	-	-	-	-	1	2	3	3	2
CO4	3	2	-	3	3	-	-	-	-	-	1	2	3	3	2
CO5	3	2	3	3	2	-	1	2	1	1	1	2	3	3	3

Unit	Contents	Hours
I	**Unit-I:- Breakdown Mechanism** Introduction to different aspects of high voltage Engineering, Types and features of Insulation used in transformers, rotating machines, circuit breakers, cable power capacitors and bushings., Need for Breakdown Studies, Practical Consideration of Insulation, Breakdown mechanism in Gaseous Di-electric : Ionization process; Townsend's criterion for B.D. Break down in electro-negative gases, Streamer theory for B.D in gases, Paschen's law; Penning effect, Breakdown in non-uniform fields, principles of breakdown in solid and liquid dielectrics. Breakdown Mechanism in vacuum insulation; B.D. in composite dielectrics.	8
II	**Unit –II:- Lightning and switching phenomenon** Types of Overvoltage Lightning and switching over voltages: Mechanism of lightning, types of strokes, parameter and characteristics of lightning strokes, characteristics of switching surges, power frequency over voltages. Control of overvoltage due to switching. Protection of lines by ground wires, protection by lightning Arrester, gap type and gapless L.A., surge-absorbers.	8

III	**Unit III:- Generation of high voltage and currents** Generation of High D.C voltages by rectifiers, voltage doubler and multiplier circuits (Derivations of expression not required), electrostatic machines, Generation of high AC voltages by Cascaded transformers, Resonant transformers, generation of high frequency AC high voltage. Generation of impulse voltages: Standard impulse wave shapes, wave shape control, Marx circuit, tripping and control of impulse generation, generation of switching surges, generation of impulse current	8
IV	**Unit IV: Measurement of high voltage and current** Measurement of high AC and DC voltage by micro ammeter, generating voltmeter, resistance and capacitance potential divider, series impedance voltmeter, CVT, Magnetic type potential transformers, electrostatic voltmeter. Peak reading AC voltmeter, Sphere gap arrangement. Measurement of impulse voltage by potential dividers and peak reading voltmeters, Fortes cue method, resistive and capacitive voltage dividers, measurement of high DC/AC and impulse currents by resistive shunt.	8
V	**Unit V: -High voltage & Non-destructive testing of electrical apparatus** Layout of high voltage laboratory with major testing and measuring equipment's, Determination of their ranges and ratings, earthing system, electromagnetic shielding and protective fencing; Nondestructive testing, Measurement of DC Resistivity, measurement of Dielectric constant and dissipation factor, Schering bridge for high charging circuits, high dissipation factor, three terminal measurement, transformer ratio arm bridges, partial discharge measurements by straight detectors & by balance detectors, Testing of insulators, bushings, Isolators, circuit breakers, cables, transformer, lightning arresters and power capacitors.	8

Text Books	1.	M.S. Naidu and V Kamaraju, High Voltage Engineering, 3rd Edition, Tata McGraw Hill, 1995
	2.	C.L.Wadhwa, High Voltage Engineering, 3rd Edition, New Age International, 2010
	3.	Arrilage, High voltage direct current, 2nd Edition, New York IEEE, 2002
E-Books	1.	High Voltage Engineering Fundamentals Kindle Editionby John Kuffel (Author), Peter Kuffel
	2.	High-Voltage Engineering: Theory and Practice,By Mazen Abdel-Salam
Reference Books	1.	D.Ruber, High voltage circuits breakers design and application, 2nd Edition, Dakker, 1997
	2.	Ray S.,An introduction to high voltage engineering, 2nd Edition, PHI, 2004
	3.	Advances in High Voltage Engineering edited by A. Haddad, Manu Haddad, D.F. Warne,IET publications

Online TL Material	1.	NPTEL videos
	2.	IEEE standards for high voltage testing
	3.	High voltage training ,UDEMY classes

S.N.	Name of Experiments / Mini Projects/ Case Studies
1	Study of insulating equipments (LA, insulators,...)
2	Determination of breakdown strength of transformer oil
3	Measurement of Breakdown Voltage of Paper Insulation.
4	Determination of Breakdown Voltage of Horn Gap Apparatus
5	To Determine Flash Over Voltage Across Pin Type Insulator.
6	Calibration of Voltmeter By Using Sphere Gap Method. 1. 10cm Dia 2) 2. 5cm Dia
7	Determination of Fault Location By Digital Cable, Fault Locator Model 2000 A
8	To Study Different Type of Insulator Used In High Voltage Engineering
9	Study Of Impulse Generator
10	Effect of Electrode Configuration on Breakdown of An Air(Non Uniform Gaps)
11	Effect of Electrode Configuration on Breakdown of An Air(Uniform Gaps)
12	Capacitance And Tanδ Measurement of Insulator.
Open Ended Experiments / New Experiments	
1	To study the working of Cockroft Walton Voltage Multiplier
2	To Study the functioning of Voltage Doubler.
3	To generate a long duration pulse current(for testing surge protector devices) by varying the circuit parameters like inductance and capacitance.
Details of on line Laboratory Resource Material Instruction / Operating Manuals	
1	http://vlabs.iitkgp.ac.in/vhv/#

Power System Dynamics

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	2Hrs.	.	2Hrs	03	10	15	50	25	---
Course Code	23BTEEL403 23BTEEP403									

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Teaching Mode	Conventional	4 Hrs	Total	75	25
Duration of ESE	03:00			100	

Course Objectives	1. To introduce the techniques to control the system voltage, voltage regulation, real and reactive power, power quality, efficiency, practical stability limits during healthy and faulty conditions.
	2. To make students familiar with energy management and environmental issues associated with transmission grids/power system
	3. To introduce the techniques to analyze the faults in power
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Apply the concept of symmetrical components.
	CO2: Analyze the power system under different type of symmetrical & unsymmetrical fault conditions.
	CO3: Analyze the transient stability condition of Power System.
	CO4: Analyze the economic power flow in power system.
	CO5: Understand Basics of Compensation System

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	2	3	3	2	-	-	-	-	1	-	3	3	3	2
CO2	2	2	3	3	2	-	-	-	-	1	-	3	2	3	2
CO3	1	1	3	2	2	-	-	-	-	1	-	3	2	3	2
CO4	2	2	3	2	2	-	-	-	-	1	-	2	2	3	2
CO5	1	1	2	1	1	-	-	-	-	1	-	2	2	3	2

Unit	Contents	Hours
I	**Unit I: Symmetrical Component Transformation:** Three phase power in unbalanced circuit in terms of symmetrical components, Sequence impedances of Generator, Transformers, Transmission line & Passive loads. Phase Shift in Star/Delta 3 phase transformer (YdI, YdII connection)	8
II	**Unit II: Fault Analysis:** Without and with prefault load current. Selection of Circuit Breaker rating, current limiting reactors. Unsymmetrical Fault Analysis: L-G, L-L-G, L-L, open conductor fault analysis using symmetrical components.	8

III	**Unit III: Stability of Power System:** Steady state, Dynamic and Transient stability definitions. Dynamics of Synchronous machine, Swing Equations, Swing equations for machines swinging coherently and non-coherently. Power angle equation. Steady state studies. Basic introduction to voltage Stability Aspects. Transient Stability Studies: Swing curve, Equal Area Criterion, for transient Application of equal criteria for different disturbances. Solution of swing equation by point by point method. Method of improving transient stabilities	10
IV	**Unit IV:** Fundamental Concepts of Stability of Dynamic Systems, State space representation, Stability of dynamic system, Small signal stability in SMIB including AVR and PSS Effects of Excitation System, Equations with definitions of appropriate K-constants, Simple Thyristor excitation system, AVR modeling, Analysis of excitation system with AVR, Numerical example for excitation system with AVR, Principle of Power System Stabilizer, Block diagram with the excitation system, Analysis of effect of AVR on synchronizing and damping components, Illustration of principle of PSS application with numerical example	8
V	**Unit V:** Sub synchronous Oscillations in Power Systems, Turbine generator torsional characteristics, Torsional interaction with power system controls: Generator excitation, speed governors, Sub synchronous resonance, Characteristics of series compensated transmission systems, Self-excitation due to induction generator effect, Torsional interaction, Countermeasures to SSR problems, Impact of network switching disturbances, Hydro generator torsional characteristics.	8

Text Books	1.	"Power System Stability and Control" – Prabha Kundur
	2.	"Power System Dynamics: Stability and Control" – Jan Machowski, Janusz W. Bialek, James R. Bumby
e-Books	1	"Power System Control and Stability" by Paul M. Anderson and A. A. Fouad (Available as e-book on Wiley Online Library)
	2	"Power System Dynamics and Stability" by Peter W. Sauer and M. A. Pai (Available on SpringerLink or other academic platforms)
Reference Books	1.	"Power System Control and Stability" by Paul M. Anderson and A. A. Fouad (Available as e-book on Wiley Online Library)
	2	"Power System Control and Stability" by Paul M. Anderson and A. A. Fouad (Available as e-book on Wiley Online Library)
Online TL Material	1.	NPTEL Course – Power System Dynamics by Prof. A. M. Kulkarni, IIT Bombay (nptel.ac.in)
	2	MIT OpenCourseWare – Electrical Engineering and Computer Science Courses (ocw.mit.edu) – search for Power Systems

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S.N.	Name of Experiments / Mini Projects/ Case Studies
1	To study the 3 phase balanced & unbalanced system using PSIM software
2	To study the symmetrical and unsymmetrical fault analysis Using PSCAD software
3	To study load flow analysis using power world simulator.
4	To Study Transient stability analysis using ETAP software
5	To study characteristics of TSC (Thyristor switched capacitor)
6	To study transient analysis of a linear circuit using MATLAB.
7	To Study characteristic TCR (Thyristor control Reactor)
8	To Study Ferranti Effect
9	To Study characteristic of GCSC
10	To Study characteristic of TSSC
11	To Study characteristic of UPFC
12	Open ended experiment
Open Ended Experiments / New Experiments	
1	Formation of Ybus and Zbus matrices for a given single line diagram using MATLAB
2	Stability analysis of a two machine system using power world software
Details of on line Laboratory Resource Material Instruction / Operating Manuals	
1	https://vemu.org/uploads/lecture_notes/27_01_2024_1330929383.pdf
2	https://mrcet.com/downloads/Labmanuals/EEE/POWER%20SYSTEM.pdf

Flexible AC Transmission System (Professional Elective-IV)

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	4Hrs.	-	-	04	10	15	50	-	-
Course Code	23BTEEL406									
Teaching Mode	Conventional	4 Hrs			Total	75			-	
Duration of ESE	03:00					75				

Course Objectives	1. To introduce various Power Electronics controllers used in the Power Systems for the fast real and reactive power control.
	2. To Understand the fundamentals of FACTS Controllers, Importance of controllable parameters and types of FACTS controllers & their benefits

	3. To analyze performance of advanced FACTS devices for system stability and control.
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Understand the concepts of transmission line interconnections and ability to apply knowledge of FACTS Controllers.
	CO2: Apply the principles of series and shunt compensation using voltage source and current source converters.
	CO3: To analyze various methods of controllable reactive power (VAR) generation and the operation of shunt devices such as TCR, TSC, and TSC-TCR.
	CO4: To analyze objectives, control strategies, and dynamic performance of series compensation systems like TCSC and TSSC.
	CO5: Understand the concept of operation and control of advanced FACTS controllers such as STATCOM, SSSC, UPFC, and IPFC for effective power flow management.

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	1						1	3	2	1
CO2	3	3	3	2	3	1						1	3	2	1
CO3	3	2	3	2	3	1						1	3	2	1
CO4	3	2	3	2	3	1						1	3	2	1
CO5	3	3	3	2	3	1						1	3	2	1

Unit	Contents	Hours
I	**Unit-I:- Basics of power flow in AC systems:** Steady state and dynamic problems in AC systems, Reactive power control and voltage regulation in power systems, Dynamic power flow control, Transmission line loading Advantages of FACTS, Compensation of uncompensated transmission line, shunt and series compensation, and phase angle control.	8
II	**Unit –II: Introduction to Voltage source and Current source converter** Voltage Source Converters: Single phase three phase full wave bridge converters, transformer connections for 12, 24 and 48 pulse operation, Current source converter: basic concept of current source Converters, Three level voltage source converters, pulse width modulation converter, and comparison of current source converters with voltage Source converters.	7
III	**Unit III: Static Shunt Compensator**: Objectives of shunt compensation, controllable methods for VAR generation - Variable impedance type VAR Generators and their	8

	configuration, principle of operation and control -TCR, TSR, FC-TCR, TSCTCPAR, TCVR.	
IV	**Unit IV: Static Series Compensator**: Objectives of series compensation, controllable methods for VAR generation - Variable impedance type VAR Generators and their configuration, principle of operation and control TCSC, TSSC - Regulation slope calculation, Transfer function representation; dynamic performance and power oscillation damping.	8
V	**Unit V: VSC based FACTS Devices:** STATCOM, SSSC, UPFC, and IPFC: Principles of operation with circuit arrangement, Real and reactive power flow control, Control scheme for P and Q control.	5

Text Books	1.	N G Hingorani and L Gyugyi, "Understanding FACTS", IEEE Press, Wiley India Pvt. Ltd., 2011.
	2.	K. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International Publishers, 2007
	3	Mathur, R.M. and Verma, R.K, "Thyristor-Based FACTS Controllers for Electrical Transmission Systems", Wiley-IEEE Press, 1st edition, 2002.
Reference Books	1.	T.J.E. Miller, "Static Reactive Power Compensation", Wiley India Pvt. Ltd., 2010.
	2.	Song, Yu, "FACTS for Transmission lines"
Online TL Material	1.	NPTEL Videos on FACTS Devices by Dr. Avik Bhattacharya from IIT Roorkee https://nptel.ac.in/courses/108107114

Power Quality (Professional Elective-IV)

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	4Hrs.	--	--	04	10	15	50	--	--
Course Code	23BTEEL407									
Teaching Mode	Conventional	4 Hrs			Total	75				
Duration of ESE	03:00					75				

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Course Objectives	1. To understand the basics of power quality.
	2. To understand the various mathematical tools required for power quality analysis.
	3. To analyze the harmonic spectrum and the output of various tools user for power quality monitoring.
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Understand the power quality issues in modern power system
	CO2: Describe reasons and mitigation of power quality issues.
	CO3: Appraise the effects of power quality phenomena in various equipment.
	CO4: Evaluate various harmonic indexes and its effect over power quality.
	CO5: Summarize the importance of power quality monitoring and its methods.

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes													
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	2			2	2			2		3	3	3	2
CO2	3	3	2	3	2	3	3					3	3	3	2
CO3	3	3	3	3	2	3	3					3	3	2	2
CO4	3	3	3	2	3	2							3	3	2
CO5						2	2		3	3	2				3

Unit	Contents	Hours
I	**Unit-I:- Introduction :** Importance of power quality, terms and definitions of power quality as per IEEE std. 1159.such as transients, short and long duration voltage variations, interruptions, short and long voltage fluctuations, imbalance, flickers. Symptoms of poor power quality. Definitions and terminology of grounding. Purpose of groundings. Good grounding practices and problems due to poor grounding	6

II	**Unit –II:- Flickers & Transient Voltages:** RMS voltage variations in power system and voltage regulation per unit system, complex power. Principles of voltage regulation. Basic power flow and voltage drop. Various devices used for voltage regulation and impact of reactive power management. Various causes of voltage flicker and their effects. Short term and long-term flickers. Various means to reduce flickers, Transient over voltages, sources, impulsive transients, switching transients, Effect of surge impedance and line termination, control of transient voltages	6
III	**Unit III:- Interruptions:** Voltage sags versus interruptions. Sources of sags and interruptions, Economic impact of voltage sag. Voltage sag characteristics. Voltage sag assessment. Influence of fault location and fault level on voltage sag. Voltage sag performance, areas of vulnerability. Assessment of equipment sensitivity to voltage sags. Voltage sag limits for computer equipment, CBEMA, ITIC, SEMI F - 42 curves. Voltage sag mitigation methods	8
IV	**Unit IV:- Waveform Distortion:** Definition of harmonics, inter-harmonics, sub harmonics. Causes and effect of harmonics. Voltage versus current distortion. Overview of Fourier analysis. Harmonic indices and other indices for assessing impacts of harmonics. A.C. quantities under non-sinusoidal conditions. Triplen harmonics, characteristics and non-characteristics harmonics. Power assessment under waveform distortion conditions. Harmonics resonances - series and parallel resonances. Consequences of harmonic resonance. Principles for controlling harmonics. Reducing harmonic currents in loads. K-rated transformer. Harmonic study procedure. Computer tools for harmonic analysis. Locating sources of harmonics. Modifying the system frequency response. Harmonic filtering, passive and active filters. IEEE Harmonic standard 519-1992	8
V	**Unit V:- Power Quality Monitoring and Assessment:** Need of power quality monitoring and approaches followed in power quality monitoring. Power quality monitoring objectives and requirements. Initial site survey. Power quality instrumentation. Selection of power quality monitors, selection of monitoring location and period. Selection of transducers. Harmonic monitoring. Transient monitoring, event recording and flicker monitoring. Power Quality assessment, Power quality indices and standards for assessment disturbances, waveform distortion. Power quality Improvement	8

Text Books	1.	Understanding power quality problems, voltage sag and interruptions - M. H. J. Bollen IEEE press, 2000, series on power engineering.
	2.	Electrical power system quality - Pogei C. Dugan, Mark F. McGranghan, Surya santoso, H. Wayne Beaty, second edition, McGraw Hill Pub
Reference Books	1.	Derek A. P., —Power Electronic Converter Harmonics, IEEE Press
	2.	Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., —Power System Harmonic Analysis‖, 2nd 2008 Ed., Wiley India.
	3.	Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System

		Quality‖, McGraw-Hill International Book Company
Online TL Material	1.	https://onlinecourses.nptel.ac.in/noc21_ee56/preview

Renewable & Distributed Energy System (Professional Elective-IV)

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	4Hrs.	---	---	04	10	15	50	---	---
Course Code	23BTEEL408									
Teaching Mode	Conventional	4 Hrs			Total	75			---	
Duration of ESE	03:00					75				

Course Objectives	1. To develop fundamental understanding about Solar Thermal and Solar Photovoltaic systems.
	2. To provide knowledge about development of Wind Power plant and various Operational as well as performance parameter/characteristics.
	3. To study concept of distributed generation and installation
	4. To describe different Storage systems, Integration and Future Trends and Emerging Technologies of Renewable Energy System.
Course Outcomes	**Upon successful completion of this course, student will be able to:**
	CO1: Understand solar photovoltaic system, new emerging technology in SPV & Hydrogen fuel.
	CO2: Understand the operation of various renewable energy sources such as Wind, Biomass.
	CO3: Understand the concept of distributed generation and Microgrid.
	CO4: Understand & Analyse distributed generation and grid interconnection of DGs.
	CO5: To explore new renewable energy technologies, understand how they operate, and propose real-world applications."

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	**Program Outcomes**														
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	1	2	--	--	2	--	--	--	--	1	3	3	1

CO2	3	2	1	2	--	--	2	--	--	--	--	1	3	3	1
CO3	3	2	2	2	--	--	2	--	--	--	--	1	3	2	1
CO4	3	2	2	2	--	--	2	--	--	--	--	1	3	2	1
CO5	3	2	2	1	1	--	2	--	--	--	--	1	3	2	1

Unit	Contents	Hours
I	**Unit-I:- Solar Energy System, Hydrogen as renewable Energy System** Present and Future scope of Solar Energy, Solar radiation, Type of PV cells, Electrical properties, Equivalent circuit, Cell characteristics, Effect of temperature variation, Technical and non-technical consideration-system size and module choice. Source of Hydrogen, Fuel for Vehicle Hydrogen Production, Biological & Biochemical methods of hydrogen production, Storage of Hydrogen, Fuel cell-Principle of working, construction and applications.	6
II	**Unit –II:- Wind Energy & Biomass Energy System:** Wind Energy: Wind energy system and its components, classification of wind turbines and its characteristics, Betz criteria; Control strategy of wind energy systems, Power generation, Performance calculations, Different topologies, WES with rectifier / inverter system, Doubly Fed Induction Generators (DFIG) in Wind Turbines. Biomass Energy Definition, types of biomass feedstocks, Biomass Energy Conversion: Overview of thermochemical, biochemical, and physical processes. Role of Biomass in the Global Energy Mix: Biomass as a renewable energy source for electricity, heating, and biofuels.	8
III	**Unit III:- Distributed Generation (DG) and Microgrid** Overview and technology trends of Distributed Generation, Relaying requirements for Distributed Generation (DG) system, Intentional and unintentional islanding, power converter topologies for grid interconnection. Brief introduction and Concepts of Microgrid, Types of Microgrid system, Components of Microgrid, Microgrids vs Central Conventional power system, AC and DC Microgrids, comparison between AC and DC Microgrids.	8
IV	**Unit IV Renewable Sources In Distributed Generation.** Current scenario in distributed generation – Planning, Optimal location and sizing of DGs, Optimal location selection of DGs. Grid Integration of DGs- Types of interfaces (Inverter based and rotating machine based), cluster of DG units, Different Energy storage elements - Batteries, ultra Capacitors, pumped storage, SMES, compressed air storage	8

V	**Unit V:- Future Trends and Emerging Technologies in Renewable & Distributed Energy Systems** Advanced Grid Technologies- Smart grids, demand-side management, and automated grid control, Artificial Intelligence (AI) and machine learning in renewable energy forecasting and optimization, Emerging Technologies in Renewable Energy-Floating solar PV, offshore wind, and enhanced geothermal systems, Advanced energy storage technologies: flywheels, and next-generation energy storage.	8

Text Books	1.	Godfrey Boyle,"Renewable energy power for a sustainable future", Oxford University Press,Third edition, 2012.
	2.	Khan B. H., "Non-Conventional Energy Resources", McGraw Hill Education India Private Limited, Third Edition, 2017.
	3.	D.P. Kothari, K. C. Singal, Rakesh Ranjan,"Renewable energy sources and emerging technology",Prentice
	4.	N. Jenkins, J.B. Ekanayake and G. Strbac, "Distributed Generation", 1st Edition, The Institution of Engineering and Technology, London, 2010.
Reference Books	1.	Twidell, J., Tony W., "Renewable Energy Resources", 2nd Edition, ROUTLEDGE BSP, 2019.
	2.	Kreith F., KreiderJ.F.,"Solar Energy Handbook", McGraw-Hill Inc.
	3.	Nikos Hatziargyriou, "Micro-grids: Architectures and Control", Wiley, 2014.
Online TL Material	1.	https://www.vssut.ac.in/lecture_notes/lecture1428910296.pdf

Advanced Control Theory (Professional Elective-IV)

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	4Hrs.	.	-	04	10	15	50	---	---
Course Code	23BTEEL4092									
Teaching Mode	Conventional	4 Hrs			Total	75			---	
Duration of ESE	03:00					75				

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Course Objectives	1. To introduce linear dynamic systems using state-space control techniques
	2. To make students familiar with controllability and observability and techniques used to design control system.
	3. To introduce the nonlinear control systems using the various system behaviour
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Analyze linear dynamic systems using state-space techniques, develop state models for electrical and mechanical translational systems for control system applications
	CO2: Analyze and design state-space control systems by applying matrix theory, evaluating eigenvalues and eigenvectors, cayley–hamilton theorem and converting state models into various canonical forms.
	CO3: Evaluate the controllability and observability of systems using different methods
	CO4: Developed sampled data control systems by understanding the sampling process, evaluating frequency-domain effects, reconstructing sampled signals using hold circuits, Z-transform techniques and inverse Z-transform methods
	CO5: Understand nonlinear control systems using the describing function method and evaluate the effects of common nonlinearities such as saturation, dead-zone, relay, backlash, and hysteresis on system behavior.

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	3	2	2	-	-	-	-	1	-	3	3	3	2
CO2	3	2	3	2	2	-	-	-	-	1	-	3	3	3	2
CO3	3	2	3	2	2	-	-	-	-	1	-	3	3	3	2
CO4	3	2	3	2	2	-	-	-	-	1	-	3	3	3	2
CO5	3	2	2	2	2	-	-	-	-	1	-	3	3	3	2

Unit	Contents	Hours
I	**Unit I:** Review of state variable learning, analysis, controllability and Observability. Discretization of continuous time state equations. Solution of state difference equation, controllability and Observability tests for Digital Control Systems.	8

II	**Unit II:** Stability of continuous time Systems. Stability improvement by state feedback, pole placement design and observers	8
III	**Unit III: Lyapunov stability Analysis.** Basic concepts, Lyapunov's first and second methods Stability definitions, Stability theorems, Lyapunov functions for linear and non-linear systems.	8
IV	**Unit IV: Compensator:** lead, lag, and lead-lag compensators, their transfer functions, and their effects on transient and steady-state performance. Controllers: P (Proportional), I (Integral), D (Derivative), PI, PD, and PID controllers, focusing on their roles in improving system accuracy and stability, along with a brief introduction to tuning methods.	6
V	**Unit V: Introduction to Predictive Control:** Fuzzy sets and linguistic variables, The fuzzy control scheme, Fuzzy fiction and de fuzzy fiction methods, Examples, Comparison between conventional and fuzzy control. Introduction to adaptive control and variable structure control. Advanced topic on the subject: Co-ordination and integrated control of different systems in industry. Stability of Discrete time domain	8

Text Books	1.	Chalam, V.V., "Adaptive Control Systems", Techniques &Applications, Marcel Dekker, Inc.NY andBasel.1987.
	2.	Eveleigh, V.W., "Adaptive Control and Optimization Techniques". McGraw-Hill,1967.
	3	Narendra and Annasamy,"Stable Adaptive Control Systems‖, PrenticeHall, 1989.
	4	Astry, S.and Bodson, M.,"Adaptive Control", PrenticeHall, 1989.
	5	Graham C., Goodwill, S. F. GraybeardM. E. Salgado,"ControlSystem Design‖ Pearson; USedition (26September 2000).
Reference Books	1.	M.Vidyasagar, "Non linear Systems Analysis",2ndEd., PrenticeHall,1993.
	2	Hassan K.Khalil,"Nonlinear Systems‖, ThirdEdition, PrenticeHall, 2002.
	3	William S. Levine (Editor), "The Control Handbook(Electrical Engineering HandbookSeries)", CRCPress, March 1996.
	4	KirkD.E.,"Optimal control theory-an introduction", Prentice Hall, N.J.1970.
	5	Gopal.M.‖ModerncontrolsystemTheory",WileyEasternLtd. 2ndEditionReprint 1995.
Online TL Material	1.	http://www.digimat.in/nptel/courses/video/108103007/L30.html

Department of Electrical Engineering

Power Electronics for Renewable Energy System
(Professional Elective-IV)

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	4Hrs.	.		04	10	15	50	-----	---
Course Code										
Teaching Mode	Conventional	4 Hrs			Total	75			---	
Duration of ESE	03:00									

Course Objectives	1. To study various types of renewable sources and role of power conveters in solar system.
	2. To understand the power electronics for Large Wind Power Plants
	3. To learn about the concept of Power Electronics in Biomass and Micro Hydro Power Generation
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Understand different types renewable energy sources for generation of power
	CO2: Analyze role of power electronics in PV system.
	CO3: Analyze role of power electronics in large wind power plants
	CO4: Apply various conv power converters in solar and wind system.
	CO5: Understand the concept of hybrid power system of renewable energy.

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	1		2							3	3	3	2
CO2	3	2	1		2							3	3	3	2
CO3	3	2	1		2							3	3	3	2
CO4	3	2	1		2							3	3	3	2
CO5	3	2	1		2							3	3	3	2

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Unit	Contents	Hours
I	**Unit-I:- Renewable Energy Power Plants-** Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission)-Quality active study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems.	8
II	**Unit –II:- Electrical Machines For Renewable energy Conversion:** Reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG	8
III	**Unit III:- Power Converters:** Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters:- Isolated and non-isolated, selection of inverter, battery sizing, array sizing Wind: Three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters	9
IV	**Unit IV Analysis of Wind And PV Systems:** Stand-alone operation of fixed and variable speed wind energy conversion systems and solar system- Grid connection Issues - Grid integrated PMSG, SCIG Based WECS, grid Integrated solar system.	9
V	**Unit V:- Hybrid Renewable Energy Systems:** Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PV Maximum Power Point Tracking (MPPT).	5

Text Books	1.	S. N. Bhadra, D.Kastha, S.Banerjee, —Wind Electrical Systems‖, Oxford University Press, 2005.
	2.	B.H. Khan Non-conventional Energy sources Tata McGraw-hill Publishing Company, New Delhi,2009.
Reference Book	1	1 Rashid .M. H —power electronics Hand book‖, Academic press, 2001.
	2.	Ion Boldea, —Variable speed generators‖, Taylor & Francis group, 2006.
	3	Rai. G.D, —Non-conventional energy sources‖, Khanna publishes, 1993.
	4	Gray,L. Johnson, —Wind energy system‖, prentice hall linc, 1995.
	5	Andrzej M. Trzynnadlowski, ‗Introduction to Modern Power Electronics', Second edition, Wiley India Pvt. Ltd, 2012
Online TL Material	1.	http://en.wikipedia.org/wiki/Renewable_energy.
	2.	http://www.energy.ca.gov/biomass/msw.html.

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Project

Semester	VII	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	EE	--	.	8 Hrs.	04	--	--	--	50	50
Course Code	23BTEEP404									
Teaching Mode	Conventional	8 Hrs			Total	--			100	
Duration of ESE	--					100				

Course Objectives	1.To understand Electrical Engineering applications
	2.To review research literature and analyze complex engineering problem
	3.To design solutions for complex engineering problems
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Design and develop Electrical system/model/simulation/analysis to solve real life problem.
	CO2:Use and apply modern tool and techniques to investigate and solve complex engineering problems
	CO3:Work efficiently individually and team work
	CO4:Able to comprehend and write effective reports make presentation, give and receive instructions
	CO5:Able to compile professional Project Report using Latex Tool.

Mapping of Course Outcomes with Program Outcomes:

Course Outcome	Program Outcomes														
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	3	1	3	1							2	2	3
CO2	2	2	3	1	3	1	2						2	2	3
CO3	3	2	3	3	3	1			3			1	2	2	3
CO4	3	2	3	2	3	1					3		2	2	3

CO5	3	2	3	2	3	1					3		2	2	3

Guidelines:

The student shall complete the project in VIIth Semester. The change of topic has to be approved by Internal Assessment Committee consisting of Guide, Project Coordinator and Head of Department. Student should incorporate suggestions given by examiner. The student shall complete the project which consists of design, simulation, fabrication of set up required for the project, analysis and validation of results and conclusions. The student shall prepare duly certified final report of the project work in the standard format in MS Word / Latex. Students should maintain Project Workbook.