PANDIT DEENDAYAL PETROLEUM UNIVERSITY

SCHOOL OF TECHNOLOGY

COURSE STRUCTURE FOR B.TECH. ELECTRICAL ENGINEEING

SEMESTER VI			B.TECH. ELECTRICAL ENGINEEING											
Sr. No	Course Code	Course Name	Teaching Scheme					Exam Scheme						
			L	T	P	C	Hrs/wk	Theory			Practical		Total Marks
								MS	ES	IA	LW	LE/Viva	
1	EE 318T	Switchgear and Protection	3	1	--	7	4	30	60	10	--	--	100
	EE 318P		--	--	2	1	2	--	--	--	25	25	50
2	EE 319T	High Voltage Engineering	3	0	--	6	3	30	60	10	--	--	100
	EE 319P		--	--	2	1	2	--	--	--	25	25	50
3	EE 320T	Renewable Energy Engineering	3	0	--	6	3	30	60	10	--	--	100
	EE 320P		--	--	2	1	2	--	--	--	25	25	50
4	EE 321T	Power System Design and Practice	3	1	0	7	4	30	60	10	--	--	100
	EE 321P		--	--	--	--	--	--	--	--	--	--	--
5	EE 322T	Testing and Commissioning of Electrical Machines	3	0	--	6	3	30	60	10	--	--	100
	EE 322P		--	--	2	1	2	--	--	--	25	25	50
6	HS 3xxT	Elective – HM	2	0	--	4	2	30	60	10	--	--	100
			--	--	--	--	--	--	--	--	--	--	--
		Total	**17**	**2**	**8**	**40**	**27**						800

MS = Mid Semester, ES = End Semester; IA = Internal assessment (like quiz, assignments etc)
LW = Laboratory work; LE = Laboratory Exam

EE 318T Switchgear and Protection										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	1	--	7	4	30	60	10	--	--	100

UNIT I **10**

THEORY OF CIRCUIT INTERRUPTION: Introduction, Physics of arc phenomena, Maintenance of the arc, Losses from plasma, Essential properties of arc, Arc interruption theories.

CIRCUIT CONSTANTS IN RELATION TO CIRCUIT BREAKING: Introduction, Circuit breaker rating, Circuit constants and circuit conditions Re-striking voltage transient Characteristics of re-striking voltage, Interaction between the breaker and circuit, Current chopping, The duties of switchgear.

THEORY AND PRACTICE OF CONVENTIONAL CIRCUIT BREAKERS: Automatic switch, Air-break circuit breakers, Oil circuit breakers, Single and multi break construction, Air-blast circuit breaker, Performance of circuit breakers and system requirements, Modification of circuit breaker duty by shunt resistors, Power factor correction by series resistance, Comparative merits of different types of conventional circuit breakers.

RECENT DEVELOPMENTS IN CIRCUIT BREAKERS: Modern trends, Vacuum circuit breakers, Sulphur hexafluoride (SF6) circuit breakers DC circuit breaker.

UNIT II **05**

INTRODUCTION AND PHILOSOPHY OF A PROTECTIVE RELAYING SYSTEM: Types of Faults – Abnormalities – Functions of Protective Relay Schemes – major Components of Power system – Basic Tripping Circuit – Testing and Maintenance of Relays – Zones of Protection – Requirements of Protective Systems – Relay Operating Criteria – Main and Backup Protection – Historical Review of Protective Relay Technology.

PROTECTIVE CURRENT and POTENTIAL TRANSFORMER: CT Equivalent Circuit, Vector diagram, Construction, magnetization Curve, Core, Errors, accuracy, Specifications, Factors affecting selection PT: Equivalent circuit, Construction, CVT, Specifications.

DIFFERENT TYPES OF RELAYS: ELECTROMAGNETIC RELAYS: Classification, Thermal O/L Relays, Types Over Current Relays, Differential Relay, Directional Relay, Impedance Relays.

STATIC RELAYS: Advantages and Limitations, basic Elements, Static Relays Architecture.

UNIT III **30**

GENERATOR PROTECTION : Differential Protection , Inter-turn fault Protection, stator E/F, Rotor E/F, NPS, Field Failure, Over Load, Over Voltage, Reverse Power, Pole-Slipping, Back-up Impedance, Under Frequency , Miscellaneous Protection.

TRANSFORMER PROTECTION: Faults in Transformer – Gas operated relays – Over Current Protection – REF Protection – Differential Protection – Protection against over fluxing – Protection of Grounding transformers – Protection Against Overheating - Protection for small transformers.

INDUCTION MOTOR PROTECTION: Starting of IM – Faults in IM – Abnormalities of IM – Protection of small IM – Protection of Large IM.

PROTECTION OF TRANSMISSION LINES: Protection of Lines by Over Current Relays-Protection of Lines by Distance Relays-Carrier Current Protection for lines.

BUS ZONE PROTECTION: Protection Requirements-Non unit protection-Unit protection schemes-Breaker Back-up Protection.

UNIT IV **07**

MICROPROCESSOR BASED DIGITAL PROTECTION: Advantages of Numerical Relays – Numerical Relay Hardware - Digital Signal Processing – estimation of Phasors – Full Cycle Fourier Algorithm – Half Cycle Fourier Algorithm – Practical Consideration for Selection of Algorithm – DFT- FFT.

NUMERICAL APPROACH TO APPARATUS PROTECTION (OVERVIEW): Generator Protection – Transformer Protection – Induction Motor Protection.

TOTAL HOURS	**52**

Texts and References:

1. Y. G. Parithankar and S. R. Bhide, "***Fundamentals Of Power System Protection***" 2nd edition, PHI.
2. S. S. Rao, "***Switchgear And Protection***" Khanna publication.
3. Oza, Nair, Mehta, Makwana, "***Protection and switchgear***",
4. C. Russell Masson, "***Art And Science Of Protective Relaying***"
5. B. Ravindranath And M. Chander, "***Power System Protection And Switchgear***"
6. B. Ram, "***Power System Protection***" TMH Publication.
7. Patra and Basu, "***Power System Protection***"
8. Divyesh Oza, "***Modern Power System Protection***" TMH Publication.
9. Bhavesh Bhalja, Nilesh Chothani, "***Protection and switchgear***", Oxford Publication 2011.

EE 318P Switchgear and Protection										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
--	--	2	1	2	--	--	--	25	25	50

List of Experiments:

1. Checking characteristic and operation of Fuse, MCB and ELCB.
2. Checking characteristic and operation of Inverse Time Over Current relays having following characteristic Electromechanical relays.
   A. Extremely Inverse relay (EI)
   B. Very Inverse Relay (VI)
   C. Normal Inverse Relay (NI)
3. Checking characteristic and operation of Parallel Feeder Protection (Numerical Relay Type)
4. Checking characteristic and operation of Protection of Induction Motor (Numerical relay)
5. Checking characteristic and operation of Over voltage and Under Voltage protection (Numerical relay)
6. Checking characteristic and operation of Comprehensive protection of Transformer (Numerical Relay)
7. Checking characteristic and operation of Generator Unit Protection (Numerical relay)
8. Checking characteristic and operation of Distance Protection Function (Numerical relay)
9. Understanding SCADA System for the above Protection Systems setups having IEC 61850 open protocol.

EE 319T HIGH VOLTAGE ENGINEERING										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	--	6	3	30	60	10	--	--	100

UNIT I **13**

BREAK DOWN IN GASES: Ionization processes, Townsend's criterion, breakdown in electro negative gases, time lags for breakdown, streamer theory, Paschen's law, breakdown in non uniform field, breakdown in vacuum.

BREAKDOWN IN LIQUID DIELECTRICS: Classification of liquid dielectric, characteristic of liquid dielectric, breakdown in pure liquid and commercial liquid.

BREAKDOWN IN SOLID DIELECTRICS: Intrinsic breakdown, electromechanical breakdown, breakdown of solid, dielectric in practice, breakdown in composite dielectrics.

UNIT II **12**

GENERATION OF HIGH VOLTAGES AND CURRENTS: Generation of high direct current voltages, generation of high alternating voltages, generation of impulse voltages, generation of impulse currents, tripping and control of impulse generators.

UNIT III **08**

MEASUREMENT OF HIGH VOLTAGES AND CURRENTS: Measurement of high direct current voltages, measurement of high alternating and impulse voltages, measurement of high direct, alternating and impulse currents, Cathode Ray Oscillograph for impulse voltage and current measurements.

UNIT IV **06**

NON-DESTRUCTIVE TESTING: Measurement of direct current resistivity, measurement of dielectric constant and loss factor, partial discharge measurements.

HIGH VOLTAGE TESTING: Testing of Insulators and Bushings, testing of Isolators and Circuit Breakers, testing of Cables, testing of Transformers, testing of Surge Arresters, leakage current monitoring test of Surge Arrester, Testing of CVT and VT, radio interference measurement.

TOTAL HOURS	**39**

Texts and References:

1 M. S. Naidu and V. Kamaraju, "***High Voltage Engineering***", Tata Mc-Graw Hill.
2 E. Kuffel and W. S. Zacngai, "***High Voltage Engineering***", Pergamon Press.
3 M. P. Chaurasia, "***High Voltage Engineering***", Khanna Publishers.
4 R. S. Jha, "***High Voltage Engineering***", Dhanpat Rai and Sons.
5 C. L. Wadhwa, "***High Voltage Engineering***", Wiley Eastern Ltd.
6 M. Khalifa, "***High Voltage Engineering Theory and Practice***", Marcel Dekker.
7 Subir Ray, "***An Introduction to High Voltage Engineering***", Prentice Hall of India.

EE 319P HIGH VOLTAGE ENGINEERING										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
--	--	2	1	2	--	--	--	25	25	50

List of Experiments:

1. To study layout, design and equipments of high voltage laboratory.
2. To measure dielectric strength of insulating oil used in electrical equipment.
3. To study breakdown characteristic of sphere gap and to measure gap voltage.
4. Impulse Voltage generation through Marx generator.
5. Generation and Visualization of corona in corona cage.
6. To study impulse testing using impulse generator.
7. Study of partial discharge test.
8. Capacitance and tanδ measurement.
9. To study high voltage testing of insulators and bushing.
10. A report on High Voltage Testing Laboratory.

EE 320T RENEWABLE ENERGY ENGINEERING										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	--	6	3	30	60	10	--	--	100

UNIT I **12**

INTRODUCTION: Basics of energy**,** unit conversions**,** Trends of energy consumption, developed and developing country, Indian and world energy scenario, environmental concern importance of renewable energy, Fossil fuel, availability and limitations. Need to develop new energy sources-energy conservation method.

UNIT II **12**

SOLAR ENERGY: **GENERAL TERMS:** Solar radiation, Basics of Solar Generation, Basic Sun and Earth relationships, Solar Constant, Direct or Beam Radiation, Diffuse Radiation, Irradiance, Irradiation, Elliptical orbit of earth's revolution, Extraterrestrial Radiation, Terrestrial Radiation, Air mass, Sun angles (Earth's Equator, Meridian, Longitude, Latitude, Declination angle (δ), Hour angle, Latitude or angle of latitude, Solar Altitude angle, Solar Zenith angle, Solar Azimuth angle, Surface azimuth angle, Slop or Tilt angle)

SOLAR TO THERMAL CONVERSION: Global, direct and diffuse solar radiation, solar energy applications, concepts of solar to thermal conversion, concept of flat plate collector, different types of flat plate collectors, concentrating collectors.

SOLAR TO ELECTRICAL CONVERSION (PV): Cell, module, array, equivalent circuit, IV characteristics of cell, module, array, Hot spot generation, Standard test conditions (STC) of PV module, Physics of shading and comparison of characteristics, bypass and blocking diode, calculation of balance of PV inverter systems, MPPT, introduction of PV grid connected systems

MISCELLANEOUS: Solar Dryers, Solar Cookers, Solar Refrigeration System, PV Lantern, Solar Street Lights, Solar Pumping System.

UNIT III **12**

WIND ENERGY: Motion of wind, conversion of wind power, efficiency of wind power conversion, Types of rotors, horizontal axis and vertical axis systems, system design and site selection. Types of wind generators, capacitor and reactive power requirements, islanding of self excited induction generator, control of windmill.

UNIT IV **03**

BIOMASS PLANTS: Types, parameters affecting plant performance, plant design.

TOTAL ENERGY CONVERSION: Total energy concept, tidal plants, cogeneration plants, geothermal plant. **DIRECT ENERGY CONVERSION**: Fuel cell, thermoelectric, thermionic and MHO system.

TOTAL HOURS	**39**

Texts and References:

1 Garg, H. P. and Prakash J., "***Solar Energy – Fundamental and Applications***", Tata McGraw Hill Ltd. New Delhi, 1997

2 Sukhatme S. P., "***Solar Energy***", Tata McGraw Hill Ltd. New Delhi, 1989

3 Duffie and Beckman, "***Solar Energy Thermal Processes***", John Wiley, 1974

4 Sutlon, "***Direct Energy Conversion***", Tata McGraw Hill Ltd. , New Delhi, 1966

5 S. Rao and Dr. B.B.Parulekar, "***Energy Technology***", Khanna Publishers, 2009

6 N.K. Bansal, "***Renewable energy sources and conversion technology***" , Tata McGraw-Hill Publishing Company, 1990

7 G. D. Rai, "***Renewable Energy Sources***", Khanna Publishers

EE 320P RENEWABLE ENERGY ENGINEERING										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
--	--	2	1	2	--	--	--	25	25	50

List of Experiments:

1. To calculate the power consumption of various electrical appliances using energy analyzer
2. To study the electricity bill for home/hostel
3. To study and investigate the electricity bill of PDPU for one year
4. To study and compare incandescent lamps, CFL and LED lamps
5. To calculate and compare efficacy the incandescent lamps and CFL
6. To calculate efficacy of the lamp with and without reflectors
7. To improve the power factor of induction motor using capacitor
8. To calculate efficiency of induction motor at various load
9. To study induction motor as induction generator
10. To calculate IV characteristics of PV cell, PV module and PV array
11. To study the PV inverter system located in the campus
12. To study the performance of PV-wind hybrid system in the campus

EE 321T POWER SYSTEM DESIGN and PRACTICE										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	1	--	7	4	30	60	10	--	--	100

UNIT I **13**

TRANSMISSION LINE DESIGN: Overview of Electrical design of transmission line (Design philosophy, voltage level selection and choice of conductors, spacing of conductor and corona, insulators and SIL, design problem. Mechanical design of transmission line: Considerations, loading on conductors, span, sag and tension clearance, stringing, problems.) Transmission line tower design: Location of tower, earth wires, reduction of tower footing resistance, design of tower, examples. EHV transmission line design: Considerations, selection, spacing of conductors, corona and radio interference, shunt and series compensation, tuned power lines, insulation coordination and different types of EHV towers, EHV systems in India.

UNIT II **13**

AC AND DC LOW TENSION DISTRIBUTION DESIGN: Types of distribution systems: arrangements, selection and size of feeders using Kelvin's law, design of cables in distribution systems considering ampere capacity, voltage drop during starting and running load, primary distribution design, secondary distribution design. HV distribution design concept, load balancing Distribution substation, Calculation of distributor size and its examples, calculation of voltage drops and size of distributor in ring system. Voltage regulation and lamp flicker.

UNIT III **13**

SUBSTATION DESIGN: Determination of voltage regulation and losses in power system, shifting of distribution transformer centre, Substation layout, sizes and locations of sub stations, Substation equipments specifications ratings and its operation from design view point, Cathodic Protection, Gas Insulated Substation (GIS).

POWER SYSTEM EARTHING – POWER STATION AND SUB STATION EARTHING: Objectives, definitions, tolerable limits of body currents, soil resistivity, measurement of soil resistivity, earth resistance, measurement of earth resistance, tolerable step and touch voltage, actual step and touch voltage, design of earthing grid, impulse behavior of earthing system.

UNIT IV **13**

DESIGN OF POWER STATION: Introduction, selection of sizes and location of generating stations, interconnections issues with wind and Solar PV.

INSULATION COORDINATION AND LOCATION OF LIGHTNING ARRESTOR : Introduction, definitions, insulation-co-ordination curves, determination of line insulation, Basic Insulation level (BIL), Insulation levels of substation equipments, Lightning arrestor selection and location, Selection of arrestor voltage rating, arrestor discharge voltage and arrestor discharge current, protective margin.

TOTAL HOURS 52

Texts and References:

1 M. V. Deshpande, "***Electrical Power System Design***", TMH publication

2 B. R. Gupta, "***Electrical Power System Design***", S. CHAND

3 A. S. Pabla, "***Electrical Power System Planning***", TMH publication

4 Satnam and Gupta, "***Substation Design***", Dhanpat Rai and Co

5 Soni, Gupta and Bhatnagar, "***A course in Electrical Power***", Dhanpat Rai and Sons

EE 322T TESTING AND COMMISSIONING OF ELECTRICAL MACHINES										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	--	6	3	30	60	10	--	--	100

UNIT I **12**

TRANSFORMERS: Testing procedure for HV testing ,Phase shifting/ phase group , Radio interference, Ratio Test , Load loss ,Separate source voltage testing ,Induced voltage testing , Impulse and Surge testing , Noise level and vibration testing , Short circuit withstand test ,Tan Delta test , Core insulation voltage test, Measurement of impedance ,Testing of auxiliaries and safety device , Oil testing , Classification of testing methods , Testing of bushing. DC and AC Resistance measurement, Temp. Rise test, Short circuit test, Dielectric test, Partial discharge, Insulation resistance testing. Polarity testing, Short time current rating, Impulse and surge testing, Determination of error and accuracy class, Power frequency voltage withstand test, over voltage inter-turn test. Determination of polarization index for transformer. Drying out procedure for transformer. Commissioning steps for transformer, Purification and Filtration Procedure, Overview of DGA, Sweep Frequency Analysis, Furan Analysis.

DC MACHINE: Voltage drop test or bar to bar test, Load test, Open circuit and magnetizing test, Insulation resistance, Starting performance, Dielectric test. Swinburne's test, Hopkinson's test, Field test, Separation of losses in DC shunt machine. Temp. rise test and Heat run test Drying out process Commissioning steps for DC machines Troubleshooting and maintenance.

UNIT II **12**

INDUCTION MOTOR: TESTING (3-PHASE and 1-PHASE): Hammer test, Testing against variation of voltage/current/frequency, Load test, NL and BR test, DC and AC, Resistance measurement, Insulation measurement, Starting test, Temp. Rise test, Slip measurement, HV test, Testing on auxiliaries, Vibration Test, Noise level test. Drying out methods / Polarization Index / Hot Temperature measurement Degree of protection (IP Grade) Commissioning steps for Induction motor, Heat Run Test. Commissioning of Induction Generator. Troubleshooting and maintenance of induction motor.

SYNCHRONOUS MACHINE: Testing OC and SC test, Characteristics, Loss measurement, Temp. rise test , Over speed test , HV testing , Insulation resistance wave form interference , DC and AC Resistance of armature and field winding measurement , Dielectric testing on armature and field winding , Mechanical balance , Magnetic balance , Current balance , Phase sequence , Harmonic analysis , reactance and time constant , Speed torque current , Vibration and noise measurement , SC test , Synchronizing circuit testing , Testing of voltage regulators , Excitation circuit testing ,Voltage recovery test , Retardation test on load / no load .Drying out procedure Commissioning steps for synchronous machines Troubleshooting and maintenance, Natural Frequency Test.

UNIT III **12**

SUBSTATION EQUIPMENTS: Bus bar Temp. Rise test, Rated short time current test, HV test, Power frequency voltage withstand test, Impulse / surge testing, Vibration.

EARTHING: Earthing resistance measurement, Substation grid Earthing, Soil resistivity measurement.

ISOLATOR TESTING: Temp. Resistance test, Short circuit test, charging current making and breaking test, Inductive current making and breaking test.

CIRCUIT BREAKER: TESTING OF HV/LV CIRCUIT BREAKER: No load Mechanical Operation, Mechanical endurance test, Temp. Rise test, Impulse and surge testing, short time current test. Short circuit making and breaking test, Line Charging current making and breaking test, Cable charging and capacitor bank making and breaking test, Out of phase switching, Short line fault test, and Electrical and Mechanical endurance test for LT switch gear like MCB / MCCB / ELCB etc. C.T. and P.T. Testing, Relay testing, Coupling capacitors, Station Batteries for DC Supply, Fire Shifting Equipments. Testing and Commissioning of Lightning Arrestor, Substation Commissioning by Thermograph. Troubleshooting and maintenance of circuit breakers.

UNIT IV **03**

COMMISSIONING OF TRANSMISSION LINE and CABLE: De-rating of cable capacity, HV test, AC and DC Resistance check, Insulation resistance, Impedance measurement, Location finding technique for fault in underground cables (Murray loop test and Warley loop test), Testing of open circuit faults in cables. Line charging, loading and Dropping.

TOTAL HOURS	**39**

Texts and References:

1 R C H Richardson, "***The Commissioning of Electrical Plant***", Chapman and Hall

2 S. Rao, "***Testing, Commissioning, Maintenance and Operation of Electrical Equipments***", Khanna Tech. Publications.

EE 322P TESTING AND COMMISSIONING OF ELECTRICAL MACHINES										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
--	--	2	1	2	--	--	--	25	25	50

List of Experiments:

1. Measurement of IR Value for Three Phase and Single Phase Transformer.
2. Measurement of IR Value for Three Phase IM.
3. Measurement of IR Value for Synchronous Machine.
4. Measurement of X0 and X2 for synchronous Machines.
5. Measurement of Poles for IM.
6. Tan (δ) Measurement Test for Transformer.
7. Measurement of Direct axis Sub-transient and Transient Reactance for synchronous Machines .
8. Measurement of Quadrature axis Sub-transient and Transient Reactance for synchronous Machines.
9. Separation of Iron losses for Transformer.
10. Testing of Induction Motor.