ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

LIST OF ELECTRICAL SYSTEMS, DESIGN COURSES BY P. NANDAKUMAR	
COURSE 7A	DESIGN OF PLANT ELECTRICAL POWER SYSTEM AND PLANT ELECTRICAL POWE DISTRIBURTION WITH CAPTIVE GENERATION & GRID HOOK UP.
COURSE 7B	SWIYCHYARD DESIGN BASIS
COURSE 7C	SWIYCHYARD EQUIPMENT OVERVIEW
COURSE 7D	SWIYCHYARD DESIGN CALCULATIONS AS PER IECC / IEEE STANDARDS
COURSE 7E	SAFETY EARTHING IN PLANT AND SWITCHYARD/SUBSTATION
COURSE 7F	ELECTRICAL EQUIPMENT: - TRANSFORMER
COURSE 7G	ELECTRICAL EQUIPMENT: - HV & LV SWITCHGEAR
COURSE 7H	ELECTRICAL EQUIPMENT: - GENERATOR
COURSE 7I	ELECTRICAL EQUIPMENT: - MOTOR
COURSE 7J	ELECTRICAL EQUIPMENT: - VFD
COURSE 7K	ELECTRICAL EQUIPMENT: - POWER CABLES
COURSE 7L	ELECTRICAL EQUIPMENT: - DC UPS SYSTEM
COURSE 7M	ELECTRICAL EQUIPMENT: - POWER & VOLTAGE QUALITY
COURSE 7N	ELECTRICAL EQUIPMENT: - HAZARDUOUS AREA CLASSIFICATION AND ELECTRICAL EQUIPMENT SELECTION IN HAZARDUOUS AREA

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7A :- **DESIGN OF PLANT ELECTRICAL POWER SYSTEM AND PLANT ELECTRICAL POWE DISTRIBURTION WITH CAPTIVE GENERATION & GRID HOOK UP**	
	POWER SOURCES
	Electrical Import from a Public Utility
	On-site Generation with no Public Utility Connection
	On-site Generation Run in Parallel with a Public Utility covering steam turbine (back-pressure steam turbine-driven generator, extraction – condensing steam turbine – driven generators, full condensing steam turbine – generator, gas turbine – driven generator, combined cycle generation with waste heat boliers, diesel engine generators)
	On-site Renewable Generation Run in Parallel with a Public Utility covering Solar PV, Wind Turbine, Battery Energy Storage System with grid tie Inverters
	Emergency Power Supply Equipment
	Primary Substation
	Frequency and Voltage Control & Regulation
	Active & Reactive Power & Power Factor Control & Regulation
	Power System feeder Control aspects
	Synchronizing & Synchro Checking
	POWER DISTRIBUTION
	Reliable system design and operation methodology
	Main power supply sources- in plant or external or both`
	In plant generation (captive power plant) design concepts
	Type of electrical loads-vital, essential & non-essential electrical loads
	Plant process and utility load centres, load list and load estimates covering area wise load estimate, HV, MV & LV motor load classification, Total plant load estimate Diversity factor

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7A :- DESIGN OF PLANT ELECTRICAL POWER SYSTEM AND PLANT ELECTRICAL POWE DISTRIBURTION WITH CAPTIVE GENERATION & GRID HOOK UP	
	Unit and station auxiliary loads in power plant
	Layout & Geographical disposition of sub plants/load centres size of individual motor/loads as per load list in each area
	Plant electrical distribution system configuration covering Radial distribution Duplication Radial System, Ring main system, circuit redundancy requirement selection, meshed system and combination radial and ring systems
	Assessment of pros and cons and details evaluation and selection of radial distribution systems and preparation of key and detailed SLD and protection diagrams
	Assessment of pros and cons and details evaluation and selection of ring distribution systems and preparation of key and detailed SLD and protection diagrams
	Assessment of pros and cons and details evaluation and selection of meshed distribution systems and preparation of key and detailed SLD and protection diagrams
	Assessment of pros and cons and details evaluation and selection of two single radial systems with auto-changeover
	Instrument power supply using uninterruptible power requirements covering static inverter and dc battery UPS scheme rotary converter scheme
	Electrical distribution substation covering main intake station, distribution substation, process / pumping unit substation.
	System faults, type of fault conditions and their effects ie thermal effects, voltage disturbances. calculation of fault currents covering ac symmetrical sine wave, asymmetrical current including dc component of fault, motor contribution to fault current
	equipment short circuit rating covering the first half cycle peak and asymmetric current, break current and thermal fault withstand current and withstand time.
	Fault reduction scheme covering increase of transformer impedance, series current limiting reactors, fault limiting devices both resonant type and is – limiters
	Starting of motors & motor recovery from faults and effects of faults on distribution systems covering synchronous generators and motors instability issues like lose of e synchronism, Induction motors stall, voltage recovery after the transient, LV motor contactors with holding coils will drop out, requiring a manual or automatic restarting

ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7A :- DESIGN OF PLANT ELECTRICAL POWER SYSTEM AND PLANT ELECTRICAL POWE DISTRIBURTION WITH CAPTIVE GENERATION & GRID HOOK UP	
	sequence, A transient voltage dip of sufficient magnitude causing tripping of sensitive with several minutes of time lost for restart
	System earthing covering Solidly Earthed Neutral, Impedance Earthed Neutral, Resonant Earthed Neutral (Peterson Coil), Earthing Transformers
	HV Distribution System and LV Distribution System and Generator Grounding:
	Neutral inversion assessment, impact of rotating machine core internal earth fault damage and withstand, cable and overhead line feeder capacitive charging current in selection of grounding system including the feeder cable/line sheath/shield earth fault return current withstand
	Low Resistance System Grounding covering calculations and assessment of temporary over voltage (TOV) & earth fault factor (EFF) and their impact on surge protection, equipment/cable voltage specification and protections
	High Resistance Grounding covering calculations and assessment of temporary over voltage (TOV) & earth fault factor (EFF) and their impact on surge protection, equipment/cable voltage specification and protections
	Solidly Earth System Grounding covering calculations and assessment of temporary over voltage (TOV) & earth fault factor (EFF) and their impact on surge protection, equipment/cable voltage specification and protections
	Ungrounded System covering calculations and assessment of temporary over voltage (TOV) & earth fault factor (EFF) and their impact on surge protection, equipment/cable voltage specification and protections
	Classification of grounding practice for systems for HV transmission and distribution system, Plant HV & LV distribution systems with generators, motors and cables
	Neutral Grounding Power System Design Considerations & Protection
	Earth fault detection and protection and fault clearance time for plant and human safety
	Intermittent ground fault arcing or re-striking ground fault cvreating a high frequency oscillator(RLCcircuit), independent of LandC values,causing high transient OVs

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7B :- SWIYCHYARD DESIGN BASIS	
	Switchyard bus bar configuration, general, design considerations. System/Equipment Voltage Ratings, Nominal Voltage, Rated Voltage, Rated Lightning & Switching Overvoltage Insulation Level. Criteria for switchyard configuration and basic Requirement of switchyard switching schemes
	Types of switchyards switching schemes covering Single Busbar Scheme, Main and Transfer Bus Scheme, Two Main and Transfer Bus, Two Main and By-Pass Isolator, Double Main Bus, Single Circuit Breaker Scheme, Double Bus, Double Breaker Scheme, One-and-half Circuit Breaker Scheme, Inverted Bus Scheme, Ring Bus Scheme
	Principles of substation layout, General, busbar phase dispositions, Electrical Phase to earth & Phase to phase Clearance, Busbar zone Security. Switchyard clearances covering Ground Clearance (also called Insulation Height (Pedestrian Access) , Phase clearance, Earth clearance, Section clearance (also called Safety working clearance vertical), Isolating Distance, Maintenance Zoning
	Switchyard layout basis covering Minimum height of bottom of insulator Minimum distance from live part to any earthed part from ground, Minimum distance between live parts of different phases, minimum distance Section clearance between live part and safe point from where work can be carried out Minimum height of busbars above ground level, Minimum distance of live part from Fence, Height of busbars above roads, Bus spacing, Preferred minimum distanced between equipment in same phase, shield wires and shielding lightning protection, lightning Arrestors shall be located as close as possible to the transformers.
	Equipment requirements for layout covering aspects related circuit breaker, isolator power transformer lightning arrestor, Capacitor VTs (CVTs) current transformer (CTs), cable trenches, control and relay room location, roads, compressor room, substation earthing (for details refer earthing), civil interface, lightning protection, structures, fence

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7B :- SWIYCHYARD DESIGN BASIS	
	Characteristics of busbar materials of busbars and busbar types covering stranded conductors' advantages & disadvantages, tubular conductor advantages & disadvantages, flexible conductors on post insulators, earth wires
	Insulators covering selection of tension & post insulator strings standard & fog type disc insulators, bus post insulators, poly cone insulators and insulator hardware, clamps & connectors. Comparison of insulator types (Porcelain or glass or composite) can be made by their advantages and disadvantages
	Hybrid outdoor switchyard pass (plug & switch systemn). pros & cons of pass & ais & gis switching substation. comparison of space requirement of conventional outdoor ais versus hybrid substation

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7C:- SWIYCHYARD EQUIPMENT	
	Substation equipment and their covering Bus-Bar Circuit Breaker CB Isolators Earthing switches, current transformer, voltage transformer VT, lightning arrester shunt reactor, neutral earthing resistor, coupling capacitor CVT, line trap, shunt capacitors. power transformers, series capacitors, auxiliary power supply system, substation earthing system comprising earth mats, spikes, risers, overhead earth wire shielding and lightning masts, PLCC with line or wave trap, coupling capacitor & PLCC Control & protection equipment. power cables, firefighting systems Telephones, telex, faxes and lighting
	Transformers types, auto transformer and specification, ratings tap change control and control/protection.
	Circuit breakers types and duty general, rated voltage, rate Insulation voltage Level rated normal current, rated short circuit breaking current, bus fault, short line fault, switching of unloaded line, restriking onto unloaded lines, switching of unloaded transformers and reactors. closing on to a fault up to its rated making capacity, capacitive and low Inductive current switching, disconnecting two systems or two parts of a system which are out of synchronism due to instability or severe system disturbance.
	Maintenance earth switch, Isolator or disconnector of various types covering center break type, double break type, vertical reach type and pantograph isolators
	Circuit breaker, isolator and earth switch close or open operation interlock
	Instrument transformer, CTs, VTS, CVTs, comparison of dead tank & live tank cts and location of cts
	Lightning arrestors and insulators type polymeric composite, glass and porcelain types including pedestal post insulators, solid core cylindrical posts, Hollow insulators, Cap and pin and porcelain/composite long rod insulators.
	Insulator Design characteristics and insulator selection, Electrical characteristics- the principal electrical characteristics of Power frequency voltage withstand, lightning impulse withstand voltage (LIWV), Switching impulse withstand voltage (SIWV), Pollution withstand (typically expressed as equivalent salt solution density for the system voltage concerned), radio interference; Mechanical characteristics -Tensile strength (string insulators), Cantilever strength (rigid insulators). The mechanical ratings are determined by the factor of safety (usually three or greater), the wind span, the weight span, the uplift and the broken wire requirements. Pollution control, Environment / creepage distance, Pollution Remedial measures, specification of specific creepage path

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

	COURSE 7D:- SWIYCHYARD DESIGN CALCULATIONS AS PER IECC / IEEE STANDARDS
	Bu bar sizing for thermal current carrying capacity and short time short circuit current withstand
	Calculation of surface voltage gradient
	Sag & tension calculation at equal height and at unequal height
	Short circuit force calculation for single and multiple rigid and slack, flexible and tubular bus conductors covering maximum forces on the main conductors, conductor dynamic bending stresses and dynamic bending forces and inner insulator support and evaluation of support spans, calculation of natural frequency.
	Corona loss calculation
	Lightning protection calculation for switchyard based on angle of protection
	Multi conductor spacer span calculations
	Switchyard ground mat sizing to ensure ground resistance and mat step/touch potentials are with limits of the standards

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

	COURSE 7E:- SAFETY EARTHING IN PLANT AND SWITCHYARD/SUBSTATION
	Purpose of earthing and sensitive earth fault protection, earthed and unearthed systems, equipment earthing or protective
	Safety earthing, earth connection and protective earth conductors as protection against fire and shock hazard (ie protection against damage to equipment and danger to human life)
	Ventricular fibrillation from electric shock and range of tolerable current allowed through vital parts of a human body and its dependence on the duration, magnitude, and frequency. Safe current and supply frequency the humans are very vulnerable to the effects of electric current
	Electric shock protection based on equipotential bonding and automatic disconnection of supply, during earth fault, within permissible time proposed in IEC standard.
	IEC 60364 classification of earthing arrangements like TN−S. TN−C TN−C−S, TT, IT
	Equipment Class 0, I, II & III from safety earthing and shock protection view point based on insulation with and without protective conductors
	Assessment of earth fault loop Impedance (ie maximum cable length from safety point of view) safe earth fault disconnection time related to phase conductor cable and the protective earth conductor sizing. Schematic of earthing and protective conductors and earth fault loop paths schematic for all 5 earthing arrangements covering TN−S. TN−C TN−C−S, TT, IT
	Sensitive earth fault protective device and fault clearance time within a maximum disconnection time for protection against shock due any inadvertent contact to exposed live parts. Maximum disconnect time for earth fault interruption in relation type of risk based on system, circuit and equipment type
	Earth fault protection in LV installations covering protection against direct contact (Basic protection) and measures for protection against direct contact, protection against indirect contact protection against indirect contact based on earthed equipotential bonding and automatic disconnection of the supply to achieve a high degree of protection against both shock and fire hazards.

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COURSE 7E:- SAFETY EARTHING IN PLANT AND SWITCHYARD/SUBSTATION	
	Earth fault disconnecting times for different touch voltage limits based on IEC standard of disconnection time limits for different touch voltages for dry and wet conditions as applied for safety of human beings. Selection of protective devices and it earth fault pick up and tripping setting based on the tripping time w.r.t the prospective fault current dependent on system voltage and fault loop impedance
	Earth electrodes in intimate contact with and providing an electrical connection to earth covering aspects related to effect of shape on electrode resistance. Types of earth electrodes like plate electrode, pipes or rods electrode, strip or conductor electrode. Other means of earthing through cable sheaths, structural steelwork, reinforcement of piles and water pipes.
	IEEE 80 earthing calculation covering earth resistance calculation-based earthing layout and on-site soil resistivity reports including spreadsheet calculation of voltage gradient around earth electrodes during earth fault conditions that raises earth electrode potential with respect to the general earth. Assessment of earth current and split factor and earthing grid for substation electrical safety as per IEEE Std. 80 by spreadsheet evaluation of ground potential rise, step and touch potential and their permissible limits for designing a safe substation grounding and earthing grid, as per IEEE Std. 80.
	Lv motor and sub board feeder sizing based on earth loop impedance and disconnection within the safe time in the standard
	Overview of computational tools for earthing calculations
	Sensitive earth fault (SEF) relay with a core-balance current transformer (CBCT) is the best suited for 3 phase motor feeder for balancing human safety with nuisance tripping avoidance. For domestic panels, a Residual Current Breaker with Overcurrent (RCBO) on each circuit is the most effective solution.

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7F:- ELECTRICAL EQUIPMENT - TRANSFORMER	
	3-phase transformer winding arrangements & vector group (short-circuit impedance or impedance voltage, vector group, angular displacement, and terminal markings), delta star & zig zag windings.
	Transformer construction, normal (usual) service conditions and unusual service conditions related to altitude correction factors and unusual cooling air and water temperature Winding materials & current density. Transformer ratings & types. Generator Transformer and other transformer type duty specification. voltage, power rating, and temperature rise and winding insulation levels
	Insulation temperature class for liquid filled transformers
	Transformer Core-CRGO & Maximum flux density. Transformer B-H curve, core saturation and harmonics and peaky transformer magnetizing current during switching. Core & Shell Type Transformer.
	Transformers for nonlinear loads, standard design, transformer losses, K-rated transformers
	Transformer heat generation. Transformer temperature rise and derating and rating selection for site ambient
	Classification of mineral-oil-immersed transformers. Transformer Cooling designation. oil or liquid preservation system covering sealed-tank system, gas-oil seal system, conservator design, conservator diaphragm. Transformer conservator & sealed type design & Silica Gel & refrigerating elements
	Transformer losses and capitalization of losses
	Transformer Types Oil filled or dry type and insulation class selection and permissible temperature rise for oil filled and dry type
	Transformer Noise level
	Transformer Tap changers – On load & Off load tap changers.
	Transformer protection devices & fire protection. Transformer mounted protection devices & accessories and mounting accessories, terminal box, bushing and bushing CT.
	Overview of non-flammable liquid-filled transformers covering askeral immersed transformers, silicone-immersed transformers, other available transformer types. Corrosion & Water ingress

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7F:- ELECTRICAL EQUIPMENT - TRANSFORMER	
	Dry-type transformers. type and rating, insulation class and temperature rise, primary system fault level for short-circuit withstand, insulation level, impedance, tap changer or taps, accessories, surge arresters for dry-type transformer
	inspection and testing, factory routine and type tests, routine power transformer inspection internal inspection of transformer
	Transformer equations, equivalent circuit and modelling as in Course 1 on ELECTRICAL POWER SYSTEM COMPONENT AND MODEL AND CONTROL BASICS

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COURSE 7G:- ELECTRICAL EQUIPMENT - HV & LV SWITCHGEAR	
	Design and specification of HV switchgear, classification of HV switchgear as Air-insulated switchgear (AIS) vs. gas-insulated switchgear (GIS). Switchgear single-line diagrams, design basics and review
	Principle of circuit breaker breaking of circuits, AC & DC current interruption, restriking voltage theory. Switchgear role in electrical safety, operational capabilities of all types of break devices such as ACBs, MCCBs, Switches, Fuses, Contactors, MCBs, RCD
	HV Switchgear standard requirements for personal safety at work place, safer products and safer tools, safety concepts covering IAC classifications (IAC means “Internal Arc Classified”), Loss service continuity and partition classes as well as incorporation of safety using concepts related to Bay control units, Arc eliminators and use of Use of sensors to act as the brain of the switchboard
	HV switchgear Loss of service continuity classification LSC1, LSC 2A, LSC 2B, Partition classification PM & PI. Designation of IAC classification and Internal arc kA & sec designation for access to front (F), Back (B) & Lateral(L) to Authorized personal (A) or to public(B) or no access (C)
	HV switchgear IAC test criteria, fault factors, fault consequences. Specification of measures for limiting arc fault consequences.
	HV switchgear CB control, CB trip circuit supervision, circuit & bus earthing.HV Switchgear compartments such as Busbar compartment, Circuit breaker compartment, LV compartment, cable compartment, interlocking & shutters
	Guidelines and criteria for switchgear selection and design considerations relevant for fault rating, switching and isolation, utilization category A & B, Derating for Insite panel ambient temperature, pollution degree, selection of conductors and terminals, neutral conductor cross section., safety features, earthing and maintenance.
	HV & LV Switchgear Components and Systems covering Circuit breakers, disconnectors, contactors, and busbars, Instrument transformers (CTs, PTs), protection relays, and control devices, Auxiliary systems, metering, and monitoring equipment. Switchgear Operation and Control Operational procedures for normal and emergency conditions.
	HV & LV Switchgear Protection Systems Protection principles, schemes, and relay coordination, Fault detection, isolation, and restoration techniques. Protection against overcurrent, overvoltage, and other electrical faults.

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	COURSE 7G:- ELECTRICAL EQUIPMENT - HV & LV SWITCHGEAR
	Low-voltage switchgear standards, construction details, circuit breakers and their electronic tripping units, section configuration/dimensions, intelligent or smart low-voltage switchgear, arc resistant low-voltage switchgear and arc flash solutions
	Low voltage switchgear technology of circuit breaking cover MCCBs, insulated case circuit breakers, power circuit breakers and fused power circuit breakers and control protection and monitoring units
	Low voltage Power & control circuits for motor starter, different starting techniques of motor, motor protection concepts & type 2 co-ordination, control schemes for motor starters. Concepts of and iMCC & Soft Starters
	Low voltage Power & control circuits for ACB incomers & bus coupler schemes - auto source transfer, DG synchronization & load sharing schemes, CT/PT circuits, redundant control supply schemes, electrical/mechanical safety interlocks in control circuits and design/selection of control devices
	Selectivity applicable to LV switchgear feeder MCCB releases and their settings based on current and time coordination and/or energy-based discrimination and logical coordination
	Sensitive earth fault (SEF) relay with a core-balance current transformer (CBCT) is the best suited for 3 phase motor feeders for balancing human safety with nuisance tripping avoidance. For domestic panels, a Residual Current Breaker with Overcurrent (RCBO) on each circuit is the most effective solution.

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7H:- ELECTRICAL EQUIPMENT - GENERATOR	
	Guidelines for selection & specification of generators Generator technical parameters and other characteristics. basic generator capability requirements. Basics of machine construction and operation, round motor and salient-pole machines, saliency effect and two-reaction theory. machine size and utilization, electromagnetics generated voltage example of 4-pole, armature-wound machine armature reaction magnetic circuit and material.
	Mechanical construction, stator construction, rotor construction, critical speeds, bearings
	Generation insulation systems materials, temperature measurements, temperature ratings, armature-winding insulation, field-winding insulation, insulation maintenance, stator-core insulation
	Machine operation capability diagram, saturation curves and excitation, armature windings winding forms, stranding and transposition. Generator power chart, Generator unbalanced loading, stator current limit, rotor current limit, prime mover power limit, theoretical stability limit. load angle limit, manual operation limit, core end heating limit, continuously acting AVR limit
	Generator neutral earthing., generator construction, bearing and generator cooling detailed information on ga, civil details, weight and foundation loading data, including data on space requirement and weight of the largest part of the generator that can be dismantled quick starting requirements of generating machines and requirements of machines for standby and emergency power requirements
	Generator rating and generator reactance and their time constants. Generator rated output and rated power factor, Generator rated voltage, Generator rated speed and frequency
	Generator sub transient reactance, transient reactance and synchronous reactance values, negative sequence and zero sequence reactance values. Dynamic models per unit systems represented circuits, equivalent circuits parameters, voltages simulation model, approximate analysis, static and transient torque-angle curves and stability by equal area faults
	Generator parallel operation, speed droop governor or isochronous governor, reactive power control.
	Generator excitation system-static rectifier system, brushless exciters, main exciter, automatic voltage regulators

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COURSE 7H:- ELECTRICAL EQUIPMENT - GENERATOR	
	Generator construction comprising prime mover, stator windings, damper windings, service conditions & enclosures and others like enclosures, cooling, space heaters, humidity detectors. Enclosures with ventilation for static, brushless or commutator type exciters
	Cooling system, cooling media, ventilation paths, stator-core ventilation, rotor ventilation, direct and indirect cooling, indirect air cooling, indirect stator/direct rotor cooling, closed air circuit air cooled, closed air circuit water cooled, hydrogen cooled; hydrogen and/or water cooled.
	Station & site details, the dimensional requirement, over all weight supplier for civil requirement. Weight of the heaviest component part of the generator i.e. stator or rotor part or individual parts of the stator and frame as applicable must be coordinated to finalize maintenance / laydown area and for evaluating the equipment / part handing crane capacity as applicable. Space considerations for ensuring no limitation overall length of the prime mover, generator and its exciter and for ensuring no length limitations required to install and withdraw the rotor or any other dismantling part of the generator
	Oil lubricated pedestal bearings, bearing pedestal earthing any one with insulation at other insulated from the bed plate of the machine.
	Quick staring of machines Steam & Gas turbine generators and diesel generators for emergency standby duty
	Generator losses and efficiency- stator copper loss, rotor copper loss, exciter loss, stray loss, fan and windage loses, the total bearing friction loss and other losses
	Testing of ac generators, resistance, open-circuit saturation, short-circuit saturation curve, zero power factor saturation curve, deceleration, heat runs
	Generator protection, monitoring and supervisory equipment, temperature and vibration detectors, temperature measurement bearing temperature measurement by RTDs(resistance temperature detectors) installed in thermowells close to the bearing pads, stator winding temperature measurement, stator core temperatures, rotor winding temperature, lubricating oil temperature and also flow should be monitored for all sleeve type bearings with forced or pressure lubrication as well as stator core vibration measured, Generator over load protection and stator temperature detectors

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COURSE 7H:- ELECTRICAL EQUIPMENT - GENERATOR	
	Review of typical vector diagram of cylindrical rotor generator on lagging power factor load, typical power chart for synchronous generator, phase diagram of synchronous generator full d & q axis representation, typical power angle curve for salient pole governor performance curves.
	Review of generator chart showing sharing of active power between two generators with different rated outputs. arrangement of AVR cross compounding signal circuits. quadrature droop compensation scheme with AVR, diagram of typical brushless exciter with rotating diode, detail of typical diode unit for brushless exciter, typical excitation system with brushless exciter, generator cooling system for indirectly cooled stator winding and directly cooled rotor winding, ventilation of salient pole synchronous generator, generator excitation system response, generator voltage vector diagram for lagging, leading & zero power factor load currents
	Generator equations, equivalent circuit and modelling as in Course 1 on ELECTRICAL POWER SYSTEM COMPONENT AND MODEL AND CONTROL BASICS

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7I:- ELECTRICAL EQUIPMENT:- MOTOR	
	Types of ac electric motors. induction and synchronous motor. Types of dc electric motors. brushed and brushless dc motors. Special motors=Stepper motors, Brushless DC motors, Permanent magnet synchronous motors (PMSM), Switched reluctance motors (SRM), Linear motors
	IEC, IEEE, NEC, NEMA standard for motors
	Principle of operation of induction and synchronous motor Functional elements of a motor- stator, rotor, windings, magnetic materials, electromagnetic components involving magnetic circuits, air gap and flux distribution, heat generation and methods for cooling motors and managing thermal performance. mechanical components covering structural components, bearings and mountings, terminal box and others. Motor enclosures and cooling. Standard enclosure types and their characteristics like pen drip or splash proof, totally enclosed ventilated or fan cooled and others
	Equivalent circuit of induction motor, rated power, torque, current and power factor versus speed characteristics of induction motors. AC fault contribution open and short circuit time constant and its decay from induction motor d & q axis sub transient, transient and synchronous reactance equivalent circuit of synchronous motor, rated power, staring and running torque versus speed characteristics of synchronous motors
	Control systems of induction motors. starting and control methodology. Control systems of synchronous motors starting, synchronising and control methodology
	Motor rated power, service factor, load torque versus characteristics and assessment of motor and load starting time based on terminal voltage, motor and load torque and inertia of both motor and load's rotor
	Motor failures modes and their causes, along with corrective actions related to bearing failure, stator Winding Failure, external failure, rotor winding failure, shaft coupling failure and others.
	Motor control, motor protection incorporating multi-functional numerical relays and motor monitoring/supervision including vibration and noise monitoring. Motor control and power schematic, DOL & reduced voltage starter schemes Thermal imaging calculations, Case studies and practical applications.Motor testing

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7I:- ELECTRICAL EQUIPMENT:- MOTOR	
	Overview of dc motor speed control and dc motor design that achieves by perpendicular alignment of current carrying armature conductors and stator magnetic field Basics of dc motor being easiest for speed control because of its torque being cross product of magnetic field density and armature current (F=BxI= BI*sin(angle between field and current)) and the motor design that has the orthogonality between them that maximises dc motor torque per given field and armature current. The concept thus of decoupling nature of flux and current in dc motor thereby achieving torque by either varying armature current by maintaining flux constant or vice versa. Basic concept of dc motor field and current orthogonality as applied to vector control VFD or field orient control of VFD for ac induction motor, where ac motor field producing current vector and torque producing current vectors are aligned orthogonally in the project rotating dq axis to achieve decoupling of flux current and torque current vectors and to simplify and achieve fast and precise control of torque and speed of ac induction motor Close parallel between torque control of dc motor and vector control of ac induction motor
	Motor equations, equivalent circuit and modelling as in Course 1 on ELECTRICAL POWER SYSTEM COMPONENT AND MODEL AND CONTROL BASICS

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COURSE 7J:- ELECTRICAL EQUIPMENT:- VFD
Overview of dc motor speed control and dc motor design that achieves by perpendicular alignment of current carrying armature conductors and stator magnetic field Basics of dc motor being easiest for speed control because of its torque being cross product of magnetic field density and armature current (F=BxI= BI*sin(angle between field and current)) and the motor design that has the orthogonality between them that maximises dc motor torque per given field and armature current. The concept thus of decoupling nature of flux and current in dc motor thereby achieving torque by either varying armature current by maintaining flux constant or vice versa. Basic concept of dc motor field and current orthogonality as applied to vector control VFD or field orient control of VFD for ac induction motor, where ac motor field producing current vector and torque producing current vectors are aligned orthogonally in the project rotating dq axis to achieve decoupling of flux current and torque current vectors and to simplify and achieve fast and precise control of torque and speed of ac induction motor Close parallel between torque control of dc motor and vector control of Overview of V/f Control (Scalar Control) technique of VFD for motor speed control based on changing frequency for speed change by maintaining constant ratio of V/f to keep the motor's magnetic flux constant & stable. Discussion of Scalar control VFD's merits/demerits, limitations and type of mechanical loads that the scalar technique can be applied. Basic concept of dc motor field and current orthogonality as applied to vector control of VFD (or field orient control of VFD) for ac induction motor, where ac motor field producing current vector and torque producing current vectors are aligned orthogonally in the rotating dq axis to achieve decoupling of flux producing current and torque producing current vectors for simplifying and achieving fast and precise control of torque and speed of ac induction motor just as that can be achieved with sdc motor Overview of Vector Control (Field-Oriented Control - FOC) technique of VFD for motor speed control based on decoupling by achieving orthogonality, as in dc motor, of the motor's current into two components (one for flux production and one for torque production) that is achieved by using Park transformation to analyse motor currents in a d q axis rotating reference frame. Over view of Direct Torque Control (DTC) **of** motor's electromagnetic torque and flux by manipulating the voltage and frequency without the decoupling of current components required in FOC. Merits and demerits of DTC over FOC vector control where DTC offers faster, more direct control strategy than vector control that can be applied for demanding applications requiring very high dynamic performance.

COURSE 7J:- ELECTRICAL EQUIPMENT:- VFD
Challenges with VFD applications covering electrical noise such as harmonic, including high frequency noise, harmonic generation, harmonic calculation, harmonic management, special cable requirements, VFD cable installation and termination requirements The variable frequency drives with various configuration such as six pulse drive, 12 pulse drive, 18 pulse drive, Active front end, Pulse width modulation. The higher pulses do not generate lower harmonic orders. Understanding harmonic noise management (to meet the regulatory body requirements) that includes use of low pass power system filter, band pass power system filter, hybrid power system filter, active power system filter and combinations thereof. Generation of EMI & need to study up to 100th harmonic for Study of Active Front End (AFE) PWM rectifier VFD. VFD motor cable type and maximum length issues arise from voltage doubling due to voltage reflections of PWM switching frequencies and from increased electromagnetic interference (EMI) (EMI) caused by long cables demanding need for use of shielded motor cables, output filters, such as load reactors or more complex LC filters, for longer runs. Understanding need for VFD cable with drain wires and shielding due to VFD generated voltage spikes and current imbalance for which VFD cable needs proper insulation rating, drain wires, and foil/braid shielding for EMI reduction. Issues with VFD motor bearing current due to high-frequency current through motor bearings caused by the common-mode voltage (CMV) and high-frequency pulse-width modulation (PWM). Need for insulated bearings or a shaft grounding ring to provide a safe path for the current to earth, bypassing the bearings.

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7K:- ELECTRICAL EQUIPMENT:- POWER CABLES	
	Theory, design and principles, materials used in cables, conductors, armour and protective finishes. Technical Data Applicable to Cable Planning and Usage. Cable Standards and Quality Assurance Categories of cables covering HV & LV power cables, control Cables, Special Cables e.g communication and data transmission signal cables. Cable voltage class selection (Earthed /Unearthed Grade) based on system earthing, cable voltage rating, continuous and emergency current carrying capacity and short-circuit current ratings Power cables design and general construction with central conductors surrounded by conductor semiconductor, insulation, insulation screen, copper tape/braids/metallic screen, inner sheath, and wrapped by armour for protection, outer insulation sheath covering and stress relief and cable stress relief Plant and utility supply cable distribution systems and cables selection covering details of distribution cable types, design and applications, paper insulated distribution cables, PVC Insulated cables, XLPE & EPR, thermoset insulated cables up to 3.3 kV as well as insulated distribution cables for 6-30 kV. Submarine Cables and Systems covering 6.6 kV to 220 kV 600/1000 V cables with combined neutral and earth for public supply and service distribution cables
	Basic cable types for a.c. transmission covering self-contained fluid-filled cables, gas pressure cables, high pressure fluid-filled pipe cables, polymeric insulated cables for transmission voltages Sustained cable temperature, voltage and current ratings as well as short time current temperature/current ratings, voltage drop and electrical characteristics of XLPE cables, EPR cables, PVC cables. Techniques for Increasing Current Carrying Capacity Cable Accessories and Jointing for Pressure-assisted and Polymeric Cables D.C. Cables

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7K:- ELECTRICAL EQUIPMENT:- POWER CABLES	
	High Temperature Superconducting Power Cables, basics of superconductivity and its application to cables Basics of Optical Fibre Cable Construction, Composite Overhead Conductors and All-dielectric Self-supporting Cables as well as Wrap Cable Communication Systems cables for Data communication and Twisted Pair Telecommunication Cables Minimum installation bending radii applicable to general wiring cables, cables for fixed wiring, EPR insulated cables, PVC and EPR insulated wire armoured mining cables, Distribution Cables, Paper insulated cables, PVC and XLPE insulated cables rated at 600/1000 V and 1.9/3.3 kV, XLPE insulated cables for 6.6-22 kV, Transmission Cables, Fluid-filled cables, XLPE insulated cables Application and basics as well as Sustained temperature, voltage and current ratings as well as short time current temperature/current ratings, Voltage drop and Electrical characteristic of Light Duty and heavy duty Mineral Insulated Wiring Cables
	Cables in fires - material and design Considerations. Flame retardant & fire-resistant cabling requirements Flame retardant HV & LV power cables, control & lighting cables with specification of flame retardant oxygen index, temperature index low acidic emission Fire resistant cables with low smoke zero halogen (lszh) characteristics with with an oxygen index and emperature index Water treeing issues. Moisture impact on long term performance of XLPE. Dry cure cable manufacturing facilities for effective cable designs incorporating high performance cable sheaths.Steam Cure CV (Continuous Vulcanization) of cables Measures of preventing the water and moisture penetrating into the cable Alternative cable materials to protect the cable covering inclusion of a metal sheath on the cable to provides an impervious barrier to water ingress dry cable Addition protection by moisture swellable tapes under the sheath

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7L:- ELECTRICAL EQUIPMENT:- AC DC UPS SYSYTEMS

Overview of ac & dc uninterrupted power systems (ups)

Single and dual redundant ac and dc ups supply system description with detailed SLD covering protection control, alarms, and indication

Static AC ups system to serve critical AC loads. Operation of UPS in normal mode, upset mode and bypass mode

Common static ups system configurations covering offline ups or standby power systems, online protection ups or line interactive ups, double conversion ups (on-line).

Major components of UPS systems covering ac to dc rectifier or battery charger, dc link L or C, dc to ac inverter, battery, and manual/auto static transfer switch

Operation of d.c. supply UPS systems serving critical dc load. Major components characteristics. controlled rectifiers, un-controlled rectifiers. Understanding float or boost charging. Recharge cycle for discharged battery

Understanding UPS performance relevant to power quality in terms of voltage regulation,

Frequency control, and surge protection

Sizing based on load capacity, battery autonomy or runtime, and efficiency

Theory, Application, Design Features, Constructional Features, Installation Requirements. Tests of battery. components of battery, AMPERE - HOUR CAPACITY, Specific gravity of acid during charge/discharge and Voltage per cell (VPC), maximum and end cell voltage.

TYPE of battery such as vent type Lead Acid (vented Plante and Tubular type), Absorbent glass mat (GM) and Gel type Valve regulated (VRLA) type, Alkaline & Ni-CD and Li-ion Type

Basics of battery charger. Boost or fast charge after battery discharge and Float (trickle) charge OF the battery to compensate for the internal discharges and keep the battery fully charged as long as s AC power is available.

DC system fault calculations covering fault current from DC battery based on number of battery cells, cell resistance and external wire resistance

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7L:- ELECTRICAL EQUIPMENT:- AC DC UPS SYSYTEMS	
	Battery care and ventilation and enclosure or in rooms Estimation of dc loads for battery sizing covering loads for Up to one minute related to Closing and tripping of Circuit breakers, starting current of automatically started DC motors, Solenoid valves for isolation, safety relief etc, In rush currents of vital controls, instrumentation, communication system etc and longer-term loads upto 2 to 10 hours related DC motors drives, Uninterrupted Power Supply (UPS) loads, Vital controls, instrumentation, Supervisory systems, annunciation etc., Communication systems, plant emergency lighting, Indicating lamps, annunciation, etc on control panels and switchgear, emergency lights in control room and other vital places and Plant communication systems Rotary UPS system configurations covering Inertia-driven ride-through system with a synchronous motor, Inertia-driven ride-through system with an induction motor and an eddy current clutch. Battery supported Motor Generator (M-G) set, Rotary systems with a transfer switch to a bypass source. Paralleling redundant rotary systems

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7M:- POWER & VOLTAGEQUALITY (PQ)	
	Overview perspective on power quality PQ. Categories and characteristics of power quality disturbance phenomena covering classes power quality disturbances related to transients, short-duration voltage variations, long-duration voltage variations, sustained interruption, .7 voltage imbalance, waveform distortion, voltage fluctuation, power frequency variations, voltage sags and interruptions on power systems.
	Waveform distortion types dc offset, harmonics, inter harmonics, notching, and noise.
	Sources of sags and interruptions, utility system fault clearing, reclosing sequence, fuse saving or fast tripping. fault-induced voltage sags, motor starting sags and its sag severity during full voltage starting, lightning, low-side surges, ferro resonance, transformer energizing, capacitor switching transient overvoltage's, magnification of capacitor switching transient overvoltage's. Options to limit magnification and options to limit capacitor switching transients based on preinsert ion and Synchronous Closing.
	Power systems harmonics harmonic distortion, voltage and current distortion, power system quantities under no sinusoidal conditions covering rms values of voltage and current active power, reactive power, power factor. harmonic phase sequence, triple harmonics, triple harmonics in transformers, total harmonic distortion, total demand distortion, system impedance versus frequency response characteristics related to system capacitance, parallel and series resonance. Effects of resistance and resistive load harmonic impacts and control of harmonics.
	PQ issues with computation software tool results using FACTS devices like DVR, STATCOM, SVC, and others.

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ELECTRICAL DESIGN ENGINEERING - MULTIPLE COURSES

COURSE 7N:- HAZARDUOUS AREA CLASSIFICATION AND ELECTRICAL EQUIPMENT SELECTION IN HAZARDUOUS AREA
Classification procedures and techniques as well as planning and design considerations for electrical installations in explosive atmospheres. Classification of hazardous locations according to CENELEC and IEC The hazardous areas classification and design. Comparison of Zone with Class and Division system. Standards, properties of explosive gases and vapours, properties of combustible dusts Basic conditions for Fire or Explosion. Flammable liquids, Flash point, Ignition temperature, Flammable (Explosive) Limits, Vapor Density Concentration of Combustible Material in Air Explosion Limits of Selected Gases and Vapors SELECTION OF ELECTRICAL EQUIPMENT IN HAZARDOUS AREAS. Selection Criteria OF ELECTRICAL EQUIPMENT based on Gas Grouping (based on ignition energy), Temperature Classification and Classified Zones Marking temperatures, gas groups and hazardous areas. Categories or classification, Classification Equipment group I and groip II, Temperature classes 1 to 6, Grouping of electrical apparatus as Group I, IIA B & C Determination of the extent of the risk. documentation of the hazardous areas zones Equipment selection general installation requirements electrical protection covering explosion-protection techniques, dust protection by enclosure (ex td), flameproof (ex d), increased safety (ex e), intrinsic safety (ex i), pressurization (ex p), Motor EEx e – temperature rise limits under normal operating conditions

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