



Distribution System Training Series (78 NERC CE Hours)

Overview:

After a brief review of electrical fundamentals, this program moves on to cover various aspects of distribution system technology. Topics include distribution networks and equipment, system protection, control and automation, equipment testing and maintenance, and the distribution system operator's role. It is presented on the technician level and a knowledge of basic electrical theory is assumed.

Who Benefits:

Operations and maintenance technicians of all levels will benefit from the reinforcement and updating of skills related to hardware and new operational techniques. Additionally, a number of the programs are appropriate for management and administrative personnel.

Program Segments

CLUSTER 1 REVIEW OF ELECTRICAL FUNDAMENTALS FOR DISTRIBUTION SYSTEMS

8001 AC Voltage Generation

Induced AC voltage, rotating magnetic field, frequency, Resistive load, voltage & current sine waves, RMS value; Active power & energy

8002 Power Factor

Effect of inductive reactance, current flow, phase angle; Effect of capacitive reactance; Power consumed by inductance and capacitance; Reactive power (VARs), apparent power (VA); Power factor.

8003 Impedance and Voltage Drop

Resistance, inductance & capacitance series circuits; Voltage drop across individual elements; Phase angle, impedance triangle, voltage triangle, power triangle; Voltage drop across line, effect of power factor on voltage drop.

8004 Three Phase Power Systems

Three phase generation, common neutral; Balanced three phase load, three phase equipment; Characteristics of wye and delta connections, current & voltage relationship; Three-phase power.

CLUSTER 2: DISTRIBUTION NETWORKS

8005 System Layout

Elements of the distribution system single, double, and triple in-feeds; Primary feeder arrangements, radial and open loop, voltage levels; Customer classification; Single phase and 3-phase secondary connections; Alternate primary and secondary feeds; Temporary and permanent faults, re-closing arrangements; System diagrams.

8006 Overhead Lines

Use of bare conductors and covered conductors; Characteristics of overhead construction; Conductor support, towers, poles, insulators; Characteristics of copper and aluminum conductors; Ampacity tables, factors affecting ampacity; Conductor tension and line sag; Primary feeder overhead connections; Line taps to feed customers; Overhead secondary feed to customers; Pole mounted equipment, i.e. distribution transformers, disconnects, etc.

8007 Underground Distribution Systems

Construction of underground cables; Characteristics of solid dielectric and PILC cables; Function of conductor and insulation shields; Cable splices and terminations; Direct buried primary and secondary cables; Pad mounted transformers and switchgear; Features of elbow disconnects; Protection of URD systems, fault indicators; Underground distribution in city areas Ducts, manholes, and vaults, and primary risers; The spot network arrangement; The secondary grid network, network protectors.

8008 Substations

Substation bus arrangements; Switching devices, characteristics; Location of protection relays; Substation equipment; Substation service supply AC & DC; Instrument transformers, CTs & PTs Handling monitored data; Substation grounding mat and grounding connections; Voltage control equipment.



8009 Distributed Generation

The role of distributed generation; The cost factor; Types & characteristics of small generators; Hydro, steam, gas turbine, combined cycle; Reciprocating engines, co-generation; Effect of distribution system equipment Coordination with bulk power supply; Operation and protection.

CLUSTER 3: DISTRIBUTION SYSTEM EQUIPMENT

8010 Substation Transformers

Construction; Cooling arrangements; Winding connections, primary, secondary, tertiary; BIL Basic Insulation Level; Overload Short circuit capability; winding temperature; internal fault detection; Parallel operation of transformers; Transformer losses.

8011 Distribution Transformers

Distribution transformer sizing; Types of construction and mounting; 3-phase winding connections, delta, wye; Polarity test; Transformer taps; Parallel operation limitations; Internal fault protection; CSP Self protected transformer; Grounding connections.

8012 Fault Interrupting Devices

Interrupting the current flow; Quenching the arc; Typical circuit breaker capacities; Circuit breaker construction; OCB, ACB, SF₆, vacuum; Metal enclosed, and metal glad switchgear; Oil operated reclosers, vacuum reclosers. Characteristics of fuses.

8013 Non-Fault Interrupting Devices

Interrupting the current flow; Quenching the arc; Typical circuit breaker capacities; Circuit breaker construction; OCB, ACB, SF₆, vacuum; Metal enclosed, and metal glad switchgear; Oil operated reclosers, vacuum reclosers. Characteristics of fuses.

8014 Voltage Control Devices

Voltage drop along the line; Effect of power factor on voltage drop; Voltage standards; Transformer on-load tap changers construction; Step voltage regulators series connected; SVR control systems; Application of shunt capacitors along the line; Switching of shunt capacitors.

CLUSTER 4: DISTRIBUTION SYSTEM PROTECTION

8015 Fundamentals of Protection

Need for protection, hazardous conditions; Types of fault; Circuit breaker control circuits; Protection relay fundamentals, inputs & outputs; Instantaneous operation, pick-up current intentional time delay; Solid state relays; Digital protection devices.

8016 Overcurrent Protection

Fuses, inverse time characteristic; Instantaneous over-current relays; Inverse time over-current relays; Application to line protection; Function of directional relays; Relay settings; Examples of electromagnetic, solid state, and digital relays.

8017 Differential Protection

Principle of differential relays; Application to transformer protection; Application to generator protection; Application to bus protection; Connection of restraint coils; Pilot wire differential protection.

8018 Coordination of Protection Devices

Primary protection and back-up; Need for coordination of settings; Relay/fuse coordination; Relay/recloser coordination; Fuse/recloser coordination.

8019 Overvoltage Protection

Lighting surges; Overvoltage protection relays; Surge arresters, ratings and classes; Insulation coordination; Capacitance switching; Ferro resonance.

CLUSTER 5: DISTRIBUTION SYSTEM CONTROL & AUTOMATION

8020 Communication Techniques

Modes of communication, priorities; Communication techniques; Hard wired systems; Radio and microwave systems; Power line carrier; Carrier waves, AM & FM signals; Multiplexing; Analog & digital signals; Fibre optic systems.

8021 SCADA Systems



Function of SCADA systems; Remote data collection, transmission, processing and display; RTU (Remote Terminal Units), inputs, outputs; Analog sensing points, transducers, A to D conversion; Polling RTU and reporting; Control commands, select check-operate; Rate of signal transmission; Master processor and peripherals; Operators display and interface; Logging and reporting; On-line diagnostics.

8022 Distribution Automation

Auto-control equipment; Auto-control programs; Line loading optimization; Auto switching; Event recording and reporting; Condition monitoring reporting; The automatic substation; Recent developments in auto control.

8023 Programmable Logic Controllers

Process logic, logic programs; Industrial PLCs, rack mounted; Types of memory, RAM, ROM, EPROM; CPU operation, canning time; Input and output signals and interfaces; External programming modules; Programming functions.

CLUSTER 6: DISTRIBUTION EQUIPMENT TESTING AND MAINTENANCE

8024 Personnel Safety

Personnel hazards; Mechanism of electric shocks; Clearance procedures; Grounding; Safe practice & procedures; Principles of Hot-line maintenance; Regulatory requirements; Handling hazardous materials; Housekeeping, fire prevention; Responsibility for safety.

8025 Insulation Testing

Characteristics of insulation, causes of deterioration; Measuring insulation resistance with Megger; P.I. (Polarization Index) significance; Condition of winding on test results; Hipot testing.

8026 Rotating Equipment Maintenance

Doble testing; Electric loss; Insulation power factor; Partial discharge on-line measurement; Partial Discharge Analysis (PDA); Interpretation of test results.

8027 Transformer Maintenance

Monitoring winding temperatures; Monitoring cooling system; Monitoring insulation oil physical condition; Monitoring insulating oil dissolved gas content; Significance of test results; Examples of DGA; Measuring winding insulation condition; Transformer testing; turns ratio, winding resistance; Maintenance of transformer auxiliaries and attachments.

8028 Switchgear Maintenance

Operational data; Functional testing; Internal inspection, cleaning; Electrical test; contact resistance, insulation; Mechanical tests; timing, gas/air leakage; Maintenance of reclosers, pole mounted switches.

8029 Line Maintenance

Walking the line; Line inspection; poles, guys, pole-top assembly; Conductor inspection; clearances, slack, sag, connections; Equipment inspection; oil leaks, contacts, fuses; Capacitor maintenance; Riser pole maintenance; Distribution transformer maintenance; Grounding connections.

8030 Maintenance Management

Schedule for planned maintenance & inspection; Maintenance and inspection procedures; Recording and reporting results; Trending inspection data, predictive maintenance; Maintenance control program; Spare parts inventory; Issue of work orders; Access to drawings, manuals, and parts lists; Corrective maintenance.

CLUSTER 7: DISTRIBUTION SYSTEMS - CUSTOMER SERVICE

8031 Load Characteristics and Utilization

Types of industrial load; Variable speed drives; Electric arc furnaces; Rolling mills; Traction loads (i.e. railways) Welding; Induction heating; Load factor and power factor; Diversity factor.

8032 Demand Management

System load profile; Economic significance of load factor; Economic significance of power factor; Significance of peak demand; Improving load factor and power factor; Load management incentives; Load management techniques; Interruptible power contracts; Load shedding; Time of day rates.

8033 Metering

Distinction between energy, demand and reactive; Measuring energy (kWh), demand (kW) and reactive (kVAR); Meter connections, 1-phase, and 3-phase; Statutory requirements governing metering;



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Electromechanical meters; Digital metering techniques; Remote metering and reporting; Time of day metering; Handling billing complaints metering disputes; Potential future developments.

8034 Utility Rate Structure

The utility's monopoly; Recovery of operating costs; Rate of return on investment; Rate design for different customer classification; Two-part tariff, capacity and energy; Block rates, differential rates; Time of day rates; Marginal pricing; Interruptible rates.

8035 The Effects of Deregulation and Competition

Competition between generators; Open access transmission, transmission charges; The distribution company as wholesale purchaser; Marginal pricing for wholesale power; Consumer choice of supplier; Supply entities (including distribution companies); Bilateral power contracts hedging; Distribution system delivery charges.

8036 Power Quality

Power quality issues; Voltage sag and swell, flicker; Harmonics; Causes and effect of low quality power; Solutions to power quality problems; Filtering techniques, isolation, grounding; Role of customer and utility.

CLUSTER 8: THE OPERATOR'S ROLE IN DISTRIBUTION SYSTEMS

8037 Function of the Operator

Coordination with other operators and personnel; Economic operation; Record keeping & documentation; Safety of personnel, equipment and general public; Communication with customers, press, and civic authorities; Coordinating bulk power supply to meet load forecast.

8038 Abnormal Operating Conditions

Deficiencies in bulk power supply; Overload conditions; Voltage reduction; Load shedding; Load management; Equipment outages; Alternate feed arrangements; Cold load pick-up after outage.

8039 Service Interruptions

Planned outages and forced outages keeping customer informed; Responding to customer at complaints; Fault location; Dispatch of line repair crews; Implementing clearance procedures; Records and documentation.