Substation Design, Operation and Maintenance: HV/MV Busbars, Equipment and Switching

12 – 23 September 2027
Riyadh - KAFD district five-star



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Introduction:

Substation design, operation and maintenance decisions are often made bay by bay, so busbar schemes, equipment ratings, auxiliary supplies, automation and switching rules drift apart as a site grows, and a single breaker failure or switching error can drop several feeders. This Core Concept course equips engineers and senior operators to treat the HV and MV substation as one system: selecting busbar arrangements and primary equipment, checking insulation, clearances and auxiliaries, interfacing control and protection, and running safe switching and condition-based maintenance. Participants produce a Substation Design and Operations Review for their own site.

Course Objectives:

- Select substation types and busbar arrangements that balance supply security, maintainability and cost for a given network role
- Specify primary equipment for each bay, including power transformers, circuit breakers, disconnectors, instrument transformers and surge arresters, and justify GIS or AIS construction
- Check substation layouts against insulation coordination, clearance, earthing and auxiliary AC and DC supply requirements
- Evaluate control, SCADA and protection interfaces built on IEC 61850 station and process bus architectures
- Direct switching programmes, interlocking and safety documentation for outages, extensions and commissioning of new bays
- Build a condition-based maintenance and performance review for a substation using diagnostic data, health indices and reliability KPIs

Target Audience:

- Substation design engineers who prepare single-line diagrams, layouts and equipment specifications for new and extended sites
- Transmission and distribution engineers accountable for substation performance, outages and network security
- Senior operators and control engineers who authorise switching programmes and safety documents
- Asset managers who set maintenance strategy and renewal priorities for substation equipment
- Project and commissioning leads who coordinate substation extensions with network operators and contractors

Course Outline:

Day 1: Substation Types, Functions and Single-Line Diagrams

- Transmission, Distribution, Collector, Converter and Switching Substation Functions
- Mobile Substations for Emergency Supply and Planned Outage Cover
- Single-Line Diagram Reading: Bays, Feeders, Couplers and Device Designations
- Voltage Level Selection and Transformation Ratio Choices Across HV and MV Busbars
- Substation Functional Specification Checklist for a New or Extended Site

Day 2: Busbar Arrangements and Primary Equipment Selection

- Single, Sectionalised and Double Busbar Arrangement Comparison
- Breaker-and-a-Half and Ring Bus Schemes: Supply Security Versus Capital Cost
- Power Transformer Rating, Cooling Mode and Tap Changer Choices at Station Level
- Circuit Breaker, Disconnector and Earthing Switch Duty Allocation per Bay
- Current and Voltage Transformer Cores, Burdens and Accuracy Classes for Metering and Protection

Day 3: Insulation Coordination, Surge Arresters and GIS Versus AIS

- Lightning and Switching Overvoltage Sources in HV Substations
- Insulation Level Selection and Coordination Principles Overview
- Metal-Oxide Surge Arrester Placement, Protective Distance and Energy Ageing
- Air-Insulated Substation Footprint, Extension Flexibility and Environmental Exposure
- Gas-Insulated Substation Compartments, Insulating Gas Choices and Land Area Saving

Day 4: Layout, Clearances, Earthing Grid and Auxiliary Supplies

- Substation Layout Drawing: Bay Spacing, Access Roads and Heavy Equipment Transport Routes
- Phase-to-Phase, Phase-to-Earth and Working Section Clearance Checks
- Earthing Grid Overview: Step and Touch Voltage Concepts and Fence Bonding
- Station Service AC Supply: Auxiliary Transformers, Changeover Schemes and Essential Loads
- DC System Design: Battery Duty Cycle Sizing, Chargers and Earth Fault Monitoring

Day 5: Week-One Integration: Guided Substation Design Case Study

- Case Substation Brief: Load Growth, Incoming Circuits and Outgoing Feeders
- Busbar Scheme Selection Matrix for the Case Substation
- Bay Equipment Schedule Drafted from the Case Single-Line Diagram
- Layout Sketch Review Against Clearance, Fire Separation and Access Criteria
- Week-One Design Basis Memorandum and Open Issues Register

Day 6: Substation Automation, SCADA and Protection Interfaces

- Substation Automation Hierarchy: Process, Bay and Station Levels
- IEC 61850 Station Bus, Process Bus, GOOSE and Sampled Values Overview
- Substation Configuration Language Files and IED Engineering Workflow
- SCADA Telecontrol Gateways Using DNP3 and Modbus Protocols
- Protection Zones, Zone Overlap and Bay Trip Matrix Interfaces

Day 7: Switching Operations, Safety Rules and Operational Risk

- Switching Programme Preparation, Independent Checking and Authorisation Chain
- Interlocking Logic Between Breakers, Disconnectors and Earthing Switches
- Isolation, Proving Dead, Circuit Earthing and Safety Document Issue for Substation Work
- Operational Risk Assessment for Live Substation Extensions and Busbar Outages
- Incident Case Review: Switching Error, Wrong Bay Access and Lessons Learnt

Day 8: Testing, Commissioning and Stakeholder Coordination

- Factory and Site Acceptance Test Sequence for a Substation Extension
- Bay Energisation Plan and Outage Request Coordination with the Network Control Centre
- Scheme Tests: End-to-End Protection and Interlock Verification Across Bays
- Interface Management Between Asset Owner, EPC Contractor, OEMs and Network Operator
- Operations Handover Pack: As-Built Single-Line Diagram, Settings Records and Operating Instructions

Day 9: Condition-Based Maintenance, Diagnostics and Performance KPIs

- Condition Monitoring Data Sources: Online Sensors, Routine Inspections and Test History
- Diagnostic Technique Selection by Asset Class: Thermography, Partial Discharge and Dissolved Gas Analysis
- Health Index Scoring and Criticality Ranking for Substation Assets
- Substation Reliability KPIs: Availability, Forced Outage Rate and Mean Time to Restore
- Maintenance Strategy Review: Time-Based to Condition-Based Transition Plan

Day 10: Capstone: Substation Design and Operations Review

- Participant Substation Data Pack Assembly and Single-Line Diagram Mark-Up
- Design Adequacy Review: Busbar Scheme, Equipment Ratings and Clearances
- Operations Review: Switching Procedures, Auxiliary Supply Resilience and Automation Status
- Maintenance and Risk Action Register With Owners and Priorities
- Substation Design and Operations Review Presentation and Peer Challenge

Skills You Will Gain:

- Busbar Scheme Selection
- Primary Equipment Specification
- Insulation Coordination Judgement
- Substation Layout Checking
- Auxiliary Supply Design
- Substation Automation Interfacing
- Switching Programme Authorisation
- Condition-Based Asset Prioritisation

Why Attend This Course:

- Return with a Substation Design and Operations Review for your own site, marked up on its single-line diagram
- Recognise where a busbar scheme, bay rating or auxiliary supply leaves a single point of failure before it causes a multi-feeder outage
- Challenge switching programmes, interlocks and automation interfaces with the questions an experienced substation engineer asks
- Compare substation practice with engineers from transmission and distribution utilities, generation, oil and gas, and heavy industry

Conclusion:

A substation performs as intended when its busbar scheme, equipment, insulation, auxiliaries, automation and operating rules are designed and managed together. Week one builds design capability, from substation types and single-line diagrams through busbar arrangements, equipment selection, GIS and AIS construction, layout and auxiliary supplies, closing with a guided design case study. Week two adds automation interfaces, switching and safety rules, commissioning coordination and condition-based maintenance, and the final day produces a Substation Design and Operations Review for each participant's own site.