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# Substation Design Course - Arrangements, Grounding, Protection and Construction

[View Course Details](#)

## COURSE DATES AND TIMES

### Why Substation Design Training Matters

Substations are the critical junction points of the power system. A single design decision, such as the bus arrangement, the ground grid, the BIL or the station service, can determine whether a station rides through a fault or causes a wide-area outage, whether crews can work safely, and whether the station can be expanded decades later without a costly rebuild.

Substation design is also a multidisciplinary job. Electrical, civil, structural, protection and automation decisions all interact. Engineers and designers need to understand the complete design process and the standards behind each decision, not just individual pieces of equipment.

### Course Overview

This 12-hour instructor-led course is organized into 12 practical modules over two days. Each module ends with a short design exercise built on one course substation.

**Day One** covers planning, site development and major apparatus:

- substation arrangements and their reliability, benefits and consequences
- reading single-line diagrams and the substation design process
- the codes and standards that govern substation design
- site improvements, drainage, surface materials, roadways and access
- foundation design, soil test reports and structural design
- the role of typical substation apparatus in the station and the power system
- BIL, insulation coordination and lightning protection

**Day Two** applies that knowledge to electrical design and the station life cycle:

- substation layout for operations and maintenance
- high-voltage bus design, conductors and underground cables
- ground grid design and grounding/bonding requirements
- AC/DC station power and control system supplies
- system protection objectives, philosophies and relay schemes
- protection and control systems, substation automation and SCADA
- feasibility of expanding and upgrading existing substations, construction, and operations and maintenance

The course closes with an expansion feasibility case study.

The course references current codes and standards, including IEEE 80, IEEE 81, IEEE 605, IEEE 998, IEEE 525, IEEE 693, the IEEE C37, C57 and C62 series, the NESC (IEEE C2), the 2026 NEC, NFPA 70E (2027), ASCE 113, IEC 61850, the 2024 CE Code and CSA C22.3.

## **Learning Outcomes**

Upon completion of this Substation Design Course, participants will be able to:

- Compare single bus, main-and-transfer, ring bus, breaker-and-a-half, breaker-and-a-third and double-breaker arrangements for reliability, flexibility, cost and expansion
- Interpret single-line diagrams and convert them into substation arrangements and physical layouts
- Evaluate site development, foundation and structural requirements using soil test reports and design criteria
- Explain the role and key ratings of transformers, circuit breakers, disconnect switches, instrument transformers, surge arresters and switchgear
- Apply BIL, insulation coordination, lightning shielding and IEEE 605 bus design principles
- Follow an IEEE 80 ground grid design from soil resistivity data to step and touch voltage checks
- Size AC/DC station service and describe protection schemes, SCADA, and the feasibility of expanding existing substations

## **WHO SHOULD ATTEND**

This Substation Design course is ideal for professionals working in electrical engineering and the utility industry who are responsible for the design, implementation, or management. It is particularly beneficial for:

- Utility Substation Engineers And Engineers-In-Training
- Consulting And EPC Engineers
- Substation Designers And Drafters
- Protection And Control Engineers And Technologists
- Transmission And Distribution Planning Engineers

- Construction, Commissioning And Maintenance Professionals
- Industrial And Customer-Owned Substation Engineers
- Renewable Energy And Interconnection Engineers
- Project Managers And Planners Responsible For Substation Projects
- Other Electrical Personnel Responsible For The Design, Construction Or Operation Of High-Voltage Substations

## **STUDENTS RECEIVE**

- Substation Design Course Certificate
- 1.2 Continuing Education Unit (CEU) Credits (12 Professional Development Hours)
- Substation Standards Quick-Reference Map (IEEE, NESC, NEC, ASCE, IEC And CSA)
- 100-Page Digital Electrical Safety Handbook - Value \$20
- A **FREE** Magazine Subscription (Value \$50)
- **\$100** Coupon Toward Any Future Electricity Forum Event (Restrictions Apply)
- Course Materials In Paper Format

## **COURSE OUTLINE**

# **Substation Design Course Outline**

## **DAY ONE**

### **SUBSTATION PLANNING, SITE DEVELOPMENT AND MAJOR APPARATUS**

#### **MODULE 1 – SUBSTATION ARRANGEMENTS AND RELIABILITY**

- Transmission, Distribution, Switching, Collector And Customer-Owned Substations
- Single Bus, Sectionalized Bus And Main-And-Transfer Bus
- Ring Bus, Breaker-And-A-Half And Breaker-And-A-Third
- Double Bus, Double Breaker
- Reliability, Benefits And Consequences Of Each Configuration
- Outage Exposure, Contingency Strategy And Future Expansion
- Design Exercise: Ranking Arrangements For A 138/25 kV Station

#### **MODULE 2 – SINGLE-LINE DIAGRAMS, THE DESIGN PROCESS AND STANDARDS**

- Interpreting Single-Line Diagrams To Match Substation Arrangements
- The Project Scope Document And Design Criteria

- Environmental Factors: Altitude, Wind, Ice, Temperature And Seismic Zone
- Design Deliverables: Single-Line, Three-Line, Plan And Section, Grounding And Wiring Drawings
- Equipment Procurement, Long Lead Times And Delivery Schedules
- Which Code Governs: NESC, NEC, CE Code And CSA C22.3
- IEEE/ANSI Versus IEC Frameworks (IEC 61936-1)
- Design Exercise: Identifying Arrangement, Equipment And Protection Zones On A Single-Line

### **MODULE 3 – SITE IMPROVEMENTS AND CIVIL DESIGN**

- Site Selection: Transmission Access, Transportation, Flood Plain And Zoning
- Environmental, Permitting And Zoning Issues
- Grading, Drainage And Erosion Control
- Surface Materials: Crushed Rock And Its Role In Step And Touch Safety
- Roadways, Accessibility, Equipment Delivery And Heavy-Lift Access
- Fencing, Gates And Physical Security
- Oil Containment And Fire Separation
- Design Exercise: Site Plan Mark-Up For Access, Drainage And Containment

### **MODULE 4 – FOUNDATION DESIGN, SOIL STRUCTURES AND STRUCTURAL DESIGN**

- Reading Soil Test (Geotechnical) Reports: Bearing Capacity, Frost Depth And Water Table
- Spread Footings, Drilled Piers And Transformer Slab Foundations
- Steel Structures For Bus, Switches, Instrument Transformers And Arresters
- Wind, Ice, Short-Circuit And Seismic Loads (ASCE 113, ASCE 7, IEEE 693)
- Design Exercise: Selecting A Foundation From A Soil Report

### **MODULE 5 – TYPICAL SUBSTATION APPARATUS AND THEIR ROLE IN THE POWER SYSTEM**

- Power Transformers: Ratings, Cooling Classes, Windings And Load Tap Changers (IEEE C57)
- Circuit Breakers: Interrupting Media, Mechanisms And Ratings (IEEE C37)
- Disconnect And Grounding Switches
- Current Transformers, Voltage Transformers And CVTs
- Surge Arresters, Capacitor Banks And Reactors
- Metal-Clad Switchgear; Air-Insulated Versus Gas-Insulated Substations
- Design Exercise: Building An Equipment List With Key Ratings

### **MODULE 6 – BIL, INSULATION COORDINATION AND LIGHTNING PROTECTION**

- Lightning And Switching Overvoltages
- BIL, BSL And Equipment Withstand Levels

- Surge Arrester Selection, Placement And Protective Margins (IEEE C62)
- Shielding Masts And Shield Wires: Fixed-Angle And Electrogeometric Methods (IEEE 998)
- Design Exercise: Arrester Selection And Protective Margin Check

## **DAY TWO**

### **ELECTRICAL DESIGN, SECONDARY SYSTEMS AND THE STATION LIFE CYCLE**

#### **MODULE 7 – SUBSTATION LAYOUT FOR OPERATIONS AND MAINTENANCE**

- Electrical Clearances, Phase Spacing And Working Space (NESC)
- Low-Profile Versus High-Profile Layouts
- Maintenance Access And Equipment Removal
- Mobile Transformer And Mobile Substation Connections
- Control Building Location And Cable Routing
- Planning For Future Bays And Expansion
- Design Exercise: Converting A Single-Line To A Plan View

#### **MODULE 8 – HIGH-VOLTAGE BUS DESIGN – CONDUCTORS AND UNDERGROUND CABLES**

- Rigid Versus Strain Bus; Conductor Materials And Shapes
- Ampacity, Short-Circuit Forces And Thermal Expansion (IEEE 605)
- Insulator Loading, Support Spacing, Wind And Ice
- Underground Power Cables, Trenches, Duct Banks And Terminations
- Control Cable Routing, Separation And Shielding (IEEE 525)
- Design Exercise: Rigid Bus Ampacity And Support Spacing

#### **MODULE 9 – GROUND GRID DESIGN AND GROUNDING/BONDING REQUIREMENTS**

- Purpose Of Grounding: Personnel Safety, Equipment Protection And Fault Return
- Soil Resistivity Measurement And Soil Models (IEEE 81)
- Fault Current, Current Division And Ground Potential Rise
- Tolerable Step And Touch Voltages And The Surface-Layer Effect (IEEE 80)
- Grid Conductor Sizing And Mesh Voltage Calculations
- Bonding Equipment, Structures And Fences
- Ground Impedance Testing And Grounding-System Verification
- Design Exercise: Worked IEEE 80 Ground Grid

## **MODULE 10 – AC/DC STATION POWER AND CONTROL SYSTEM SUPPLIES**

- Load Classification: Vital, Essential And Non-Essential Loads
- AC Station Service Sources, Transformer Sizing And Transfer Schemes
- Station Batteries, Chargers And DC Distribution
- Battery Duty Cycles And Sizing Basics
- Redundancy For Protection And Control Supplies
- Design Exercise: Sizing A Station Service Transformer And Station Battery

## **MODULE 11 – SYSTEM PROTECTION OBJECTIVES, PHILOSOPHIES AND PROTECTION AND CONTROL SYSTEMS**

- Speed, Selectivity, Sensitivity, Security And Dependability
- Protection Zones And Overlap
- Typical Relay Types: Overcurrent (50/51), Differential (87T, 87B), Distance (21), Breaker Failure (50BF) And Reclosing (79)
- Transformer, Bus, Line And Feeder Protection Schemes
- Control Panels, Interlocking, Control House Design And DC Control Circuits
- Design Exercise: Assigning Protection Zones And Relay Functions

## **MODULE 12 – SUBSTATION AUTOMATION, SCADA, EXPANSION, CONSTRUCTION AND O&M**

- RTUs, IEDs, Gateways And SCADA Communications (DNP3)
- IEC 61850: Station Bus, Process Bus And GOOSE Messaging
- Feasibility Of Expanding And Upgrading Existing Substations: Short-Circuit Duty, Ratings, Space, Grounding And Outages
- Construction Considerations: Sequencing, Outages And Safety
- Testing, Start-Up And Commissioning
- Operations And Maintenance Considerations Built Into The Design
- Expansion Feasibility Case Study And Course Review

## **COURSE TIMETABLE**

### **Both days:**

Start: 10:00 a.m. Eastern Time

Finish: 4:30 p.m. Eastern Time

Contact us Today for a FREE quotation to deliver this course at your company's location.

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