Substation Design & Operation Using ETAP

Course Description

This comprehensive course covers the essential aspects of substation design and operation within power networks. Participants will gain insights into the role of substations, detailed equipment knowledge, system studies, protection and control strategies, as well as safety practices. The course also incorporates practical training using ETAP software for modeling and analysis to enhance understanding and application.

Audience Profile

- Electrical engineers involved in power system design, operation, and maintenance
- Utility professionals seeking to improve substation design skills
- Protection and control engineers
- Graduate students specializing in power systems

Prerequisite

- Basic knowledge of electrical power systems and circuit analysis
- Familiarity with complex numbers and engineering mathematics

Course Objective

- To understand the fundamental roles and components of substations in power networks
- To learn about major substation equipment and their applications
- To develop skills in substation studies and calculations including load flow and fault analysis
- To gain proficiency in substation protection and control principles
- To explore safety considerations and grounding system design
- To acquire hands-on experience with ETAP software for substation modeling, analysis, and protection coordination

Table of Contents (TOC)

- Power System Principles & Circuit Analysis
- Complex Numbers and Engineering Math
- Substation Types
- Substation Drawings and Diagrams (SLD, Layout, Schematics, Auxiliary AC & DC)
- Substation Main Components
- Substation Location
- Soil Parameters and Calculations
- Substation Busbar Configuration
- Substation Voltage Selection
- Environmental Issues in Switchyard Location and Mitigation Techniques
- Introduction to Digital Substation Design Tools (Overview of ETAP, DIgSILENT PowerFactory, and why ETAP is used in utility systems)

Day 2: Substation Major Equipment

- Circuit Breaker Types & Applications
- Switchgear Types, Components, and Applications
- Auto-reclosers
- Sectionalizers
- Disconnect Switches
- RMUs
- Earthing Switches
- SF6 Properties
- GIS Substations
- HV Cables Types & Calculations
- Power & Distribution Transformers
- Batteries & Battery Chargers
- Power Conditioner

- ETAP Practical: Substation Equipment Modeling
    - Create one-line diagram with transformers, breakers, switches
    - Define busbars, CTs/VTs, and instrument transformers
    - Model GIS vs AIS switchgear

Day 3: Substation Studies & Calculations

- Power System Studies
- Power System Planning
- Substation Load Studies
- Per Unit System
- Fault Calculations
- Switchyard Lightning Protection
- Instrument Transformers (CTs & VTs)
- Earthing Systems
- ETAP Modules:
    - ETAP Load Flow Analysis (Voltage profile, real & reactive power loss, bus voltages)
    - ETAP Short Circuit Analysis (3-phase, L-G, L-L-G, L-L fault types – ANSI/IEC standards)
    - ETAP Ground Grid Modeling (Touch and step potential calculations)

Day 4: Substation Protection & Control

- Power System Studies
- Power System Planning
- Protection Zones, Local & Backup Protection
- Sequence Networks
- Fuse Types, Applications, Selection, and Coordination
- Protection Relay Types and Functions
- Protection Relaying Technology

- Overcurrent Protection
- Earth Fault Protection
- IDMT O/C & E/F Protection
- Definite Time (DT) Protection
- High-set Instantaneous Protection
- Transient Overreach
- Transformer O/C and E/F Protection
- Transformer Unit Protection (REF and Differential)
- Buchholz & Pressure Relief
- Transformer Differential Protection Complexities & Solutions
- Interposing CTs
- Transformer-Feeder Protection Schemes
- ETAP Relay Coordination Study
    - Time-Current Characteristic (TCC) Curve plotting and relay grading
    - Protection coordination between relays, breakers, fuses
    - ETAP Protection Zone Simulation (Create overlapping primary and backup zones)

Day 5: Substation Safety Issues

- Ungrounded vs. Grounded Systems
- Touch & Step Voltages, Mesh Voltage
- Earth Potential Rise (EPR), Transferred Voltages
- Soil Resistivity
- Verification of Adequacy
- Lightning Protection Techniques (Rolling spheres, cone of protection)
- Embedded Generation
- Power Factor Compensation (PFC)
- Power Quality (harmonics, voltage flicker)

- Clearance Distances
- ETAP Ground Grid Safety Simulation (Mesh voltage, Step/Touch analysis, EPR mitigation)
- ETAP Report Generation & Project Wrap-Up
    - How to export one-line diagrams, study reports, TCC plots

Hands-On Labs Using ETAP (Suggested Daily)

- Day 2: Equipment modeling & one-line diagram
- Day 3: Load Flow & Fault Study
- Day 4: Protection coordination with TCC
- Day 5: Grounding system analysis