Power & Energy Training Series

April 2019

PA201

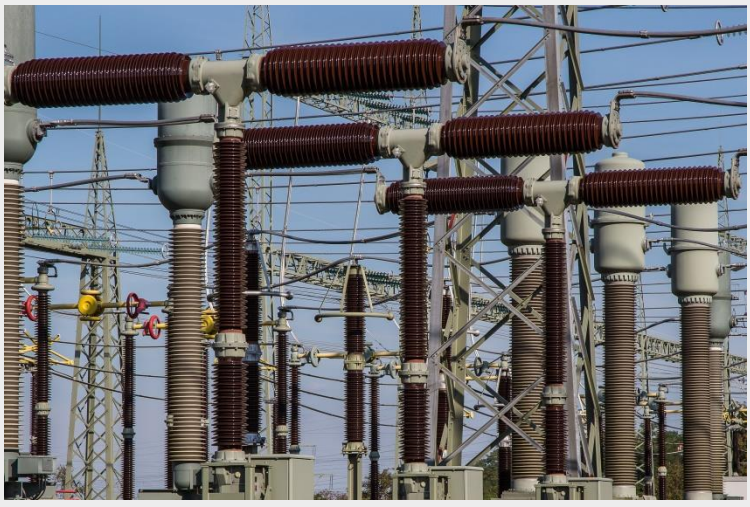
Advanced Power System Analysis

This course is a complement of the basic power system analysis training and is developed to introduce more advanced topics in power systems including transmission line modeling, faults, economic dispatch, and generator control.

The advanced power system analysis course starts with modeling of transmission lines (short lines, medium lines, and long lines), introduces the reactive power compensation of transmissions lines and ends with an overview of direct current (DC) transmission lines.

Next topic to be covered in advanced power system analysis is the solution to power flow equations using Newton's and Gauss's methods. Next, economic dispatch and optimal power flow concept will be introduced.

Faults happen every day in electric power systems, therefore, power engineers and scientists should have enough background to model the faults and analyze the system in order to protect the system against faults. The advanced power system analysis training covers modeling of balanced and unbalanced faults, and introduces various protection schemes including relays, breakers, and reclosers to protect power systems against faults.



Training Participants

Power system analysis (advanced) is a 3-day course aimed to train:

- Any individual with a basic knowledge about the power who needs to understand complex analysis and solve advanced power system problems.
- Non-power electrical engineers who are involved in the projects related to power.

- Government entities related to energy including the personnel of Deputy Assistant Secretary of the Navy-Energy; Air Force Installations, Environment & Logistics; Department of the Navy Energy Program for Security and Independence; Department of the Navy Strategy for Renewable Energy; Marine Corps Expeditionary Energy Office; Office of the Deputy Under Secretary of Defense, Installations and Environment; U.S. Army Office of Energy Initiatives (OEI); and U.S. Energy Information Administration.
- Utility engineers and technical personnel, mostly senior-level.
- The research and development personnel of energy related companies, research labs, and academic centers involved in complex power and energy systems.
- Power engineers who need an advanced training on power systems.
- Any non-electrical engineering major employees/students who would like to learn power systems.

Course Objectives

Upon completion of the power system course, the participants will be able to:

- Review three-phase balanced systems and definitions of power
- Fully understand different types of power plants.
- Learn the operation of various power system apparatus
- Model the transmission lines and understand their operation in system
- Calculate the transmission line parameters
- Understand the HVDC systems and offshore AC networks
- Analyze three-phase balanced faults in power systems
- Understand the symmetrical components
- Analyze asymmetrical faults in power systems
- Understand various types of unbalanced faults in the system
- Learn the basics of power system protection
- Understand and implement various types of protection systems for radial and mesh networks
- Protect the transmission lines, AC machines, and buses against faults using relays
- Understand the power flow and concept of economic dispatch in power systems

Course Outline

The outline of power system dynamic analysis and symmetrical components is mentioned in the following which can be revised and tailored to the client's need:

Basic principles

- Balanced three-phase systems
- Active and reactive powers
- Complex and apparent powers
- Definition of power factor
- Power factor correction
- Unbalanced three-phase systems
- Per unit (p.u.) analysis

Power System Apparatus Review

- Power plants
- Generators
- Transformers
- Transmission lines

- Substations (switchgears)
- Loads (electronic, dynamic)
- AC machines
- Distribution systems
- Supervisory control and data acquisition (SCADA)

Transmission Lines

- Introduction to transmission systems
- Overhead and underground transmission systems
- Parameters of transmission lines
- Calculation of resistance of transmission line
- Calculation of inductance
- Calculation of capacitance of the line
- Symmetrical spacing in lines
- Asymmetrical spacing in lines
- Transpose lines
- Bundle effect
- ABCD parameters of the line
- Short, medium, and long lines
- Reactive power compensation
- Maximum power transfer
- Voltage profiles in transmission lines
- Surge impedance loading
- DC transmission system
- High voltage DC (HVDC) transmission
- Offshore AC network

Power Flow Analysis

- Bus admittance matrix
- Solution to nonlinear algebraic equations
- Newton's iteration
- Power flow equations
- Transmission line flows
- Transmission line losses
- Tap changing transformers
- Newton-Raphson power flow
- Economic operation of power systems
- Economic dispatch
- Optimal power flow
- Power market
- Unit commitment
- Introduction to linear programming for power flow problems

Fault Analysis

- Definition of faults
- Main causes for faults
- Types of faults in transmission lines
- RMS fault current calculations

- Superposition approach
- Common types of faults
- Short circuit ratio (SCR) in power systems
- Point of common coupling
- Weak AC grid

Balanced Faults

- Balanced three-phase fault
- Short circuit capacity (SCC)
- Fault analysis using bus impedance matrix
- Zbus matrix

Unbalanced Fault Analysis

- Symmetrical components
- Sequence impedances
- Sequence models of transmission lines and loads
- Sequence models of transformers
- Sequence models of AC machines
- Single-line to ground (SLG) fault analysis
- Double line to ground (DLG) fault analysis
- Line to line (LL) fault analysis
- Unbalanced fault analysis using impedance matrix
- Unbalanced fault programs

Power System Protection

- Introduction to power system protection
- Circuit breakers
- Fuses
- Reclosers
- Current transformers (CTs)
- Voltage or potential transformers (PT, VT)
- Introduction to relays
- Solid-state relays
- Electromechanical relays
- Overcurrent relays
- Protection of radial systems
- Protection of mesh networks
- Zones of operation
- Impedance relays
- Directional relays
- Differential relays
- Protection of AC machines
- Protection of buses
- Protection of transformers
- Protection of loads