Analytical Methods for Voltage Control and Reactive Power Planning

Training Course

Industry Need
Voltage problems now constrain transfers and cause more blackouts than first-swing instability, poor damping, and thermal overloads combined. Today, heavily utilized transmission systems may require three Mvar of compensation for each MW of new load to survive single contingencies without voltage collapse. Up to half of this reactive power may need to be provided by generators, synchronous condensers, static var compensators, or under-voltage controlled switched shunt capacitor banks. The task of planning and operating a reactive power compensation system is a complex one. Planners of such systems need an understanding of the ‘slow dynamics’ of voltage instability and collapse in order to achieve a secure system at the lowest cost.

The industry need goes beyond reactive power planning. Utilities are discovering those double ‘voltage’ contingencies, unlike double contingencies associated with thermal limits and angular stability, pose very high risks. Indeed, in many systems seemingly routine coincident equipment outages can cause voltage collapse or greatly increase the risk of collapse. Under-voltage load shedding has emerged as a cost-effective solution to these less frequent but still troublesome events. These and many other aspects and issues of voltage and reactive planning are addressed in this course.

Objectives
The course provides a thorough coverage of today’s voltage and reactive power planning issues, and of the tools and procedures that are most effective in studying them. It presents everything Siemens PTI has learned about developing cost-effective solutions to voltage problems since Siemens PTI engineers first revealed the nature of the voltage collapse problem in 1973.

Prerequisites
Course participants must have at least a year of experience in power system design, planning, or operation. Power flow analysis experience is recommended but not essential.

Course Structure
The course duration is four and one-half days, presented in three-hour morning and afternoon sessions. The last day concludes at noon. The format combines hands-on case studies with the lecture and discussion sessions, providing a more in-depth view at voltage phenomena.

Documentation
Each participant will receive a bound set of course notes that complement the lectures. The lectures closely follow the notes to minimize the need for note-taking during the class. Electronic copies of the case study files will be provided to each participant.

Instructors
The course will be taught by Siemens staff member who has extensive knowledge in transmission system planning and the identification and solution of voltage problems.

Location
The course is conducted on a regular basis at Siemens PTI offices in Schenectady, NY and at other major cities throughout the United States. It is also available for presentation at a client’s location by special arrangement.

Continuing Education Units
2.7 Continuing Education Units (CEU’s) will be awarded for successful completion of this short course. The CEU is the nationally recognized unit for recording participation in noncredit educational programs. One CEU is equal to ten classroom hours.
Course Outline
Overview
• Terminology
• Slow Dynamics
• Fast Dynamics
• Local Collapse
• Cascading Outages
• Three Real-World Examples

Equipment Voltage Characteristics
• Overhead Transmission Lines
• Cables
• Shunt Capacitors
• Generators
• Synchronous Condensers
• Independent Power Producers
• Static VAR Systems and Other FACTS (Flexible AC Transmission Systems) Devices
• Series Capacitors
• Load Tap-Changing Transformers
• DC Converters
  – Exercise 1: Line Characteristics

Analytical Tools
• Power Flow
• Non-Divergent Algorithm
• Optimal Power Flow, Automatic Contingency Analysis
• Dynamic Simulation

Analytical Methods
• QV Curves
• PV Curves
• Contingency Enumeration
• AC-Based Transfer Limit Analysis
• Extended-Term Dynamic Simulation
  – Exercise 2: Calculation and Application of QV Curves
  – Exercise 3: Calculation and Application of PV Curves
  – Exercise 4: Setup, Performance and Results Assessment of Contingency Analysis
  – Exercise 5: Dynamic Simulation

Voltage Characteristics
• Changing Nature of Loads
• Modern Load-Voltage Characteristics
• Dynamic Characteristics Of Load
• Air Conditioner Modeling
  – Exercise 6: Motor Starting

Bulk System Voltage Characteristics
• Steady-State Conditions
• Dynamic Characteristics
• Classifying Voltage Problems
• Root Causes Of Voltage Collapse
  – Exercise 7: Large-Scale Network Voltage Stability Simulation

Reactive Power Planning
• Voltage Criteria
• Shunt Capacitor Allocation
• SVC Application
• Series Capacitor Planning
• SVC versus Series Compensation
• Planning Supply To Large Customer Installations
  – Exercise 8: Reactive Power Planning (one of the following: SVC selection, capacitor allocation, Reactive reserve assessment, series compensation)

Review and Closing Discussion