COURSE DESCRIPTION - PRESENT AND/OR REMOTE ATTENDING CLASSROOM

CHP188 – Advanced Protection for various Power Networks – System Design

Course goal
The participants acquire advanced in-depth knowledge about the protection concepts and setting calculations based on electrical power system analyzes. In addition, they learn to elaborate protection concepts and are able to perform coordination studies. They have an awareness of protection problems associated with the operation of such systems. They acquire the necessary analytical skills for handling particular problems related to the protection of complex in transmission, distribution and industry networks.

Main learning objectives

Part 1: Refresh Network Analysis (2 days)
— Explain the power system dynamic and stable behavior, including the transitions between the different power system states.
— Describe the components and general behavior of the power system from generation via transmission and distribution to consumption.
— Symmetrical and related components in power systems.
— Analyze the power flow as well as fault calculation for the different power systems.

Part 2: Specification of Instrument Transformer (1 day)
— Specify requirements for protection applications.
— Evaluate behavior of instrument transformers and check performance with respect to the standard specifications.
— Calculate examples for different protection applications.

Part 3: Protection applications for power networks: Transmission, industry & distribution, centralized and distributed generation (5 days)
— Provide an overview of network structures and protection concepts.
— Model and analyze power networks.
— Evaluate network requirements and define the protection concept.
— Define appropriate protection functions.
— Setting calculation examples based on typical applications and modern protection devices.

Participant profile
Design, planning, engineering and application engineers and consultants from the electricity supply industry, technical personnel from ABB companies.

Prerequisites
Engineering degree with experiences in protection application for lines, transformer, busbar and generator/motor is required.
Required is one of the following courses or equivalent experience:
— e.g. CHP132 or CHP134 Protection Application Courses

Course type
This course runs as a face-to-face classroom course, which you can attend present or remote from home/office. Time 9:00AM until 4:30PM CET. Training with maximum 8 participants.

Learning methods and tools
Lectures, demo, practical exercises, videos, self-study.
Laptop is required to have access to the e-documentation. In case of remote attending, to have access to the life training session and a remote connection to the training infrastructure/equipment.
(two screens are recommended)
Topics Part 1 / Refresh Network Analysis

- Fundamental properties of transmission, distribution and industrial power systems
- Overview of abnormal system conditions in the power system and their characteristic time constants
- Network equations for a power system
- Description of the components of a power system from the power plant to the consumer in terms of network equations
- Load flow assessment of:
  - Balance of active power (losses, efficiency and angle between node voltage phasors), balance of reactive power (surplus or lack of reactive power), balance of voltage (length difference between node voltages phasors), overloaded elements, reactive power compensation, changing load distribution by in-line and phase shifting transformers, on-line load flow and contingency analysis for on-line assessment of power system stability (wide area monitoring) i.e. voltage stability (off-line), static and transient stability, risks for blackouts
- Short circuit current calculations:
  - Calculation method according IEC 60909-0
  - Fault types, short circuit impedances of network elements, effectively and non-effectively grounded networks, grounding schemes
- Symmetrical components in power system

Topics Part 2 / Specification of Instrument Transformer

- Introduction
  - General description of instrument transformers, mode of operation and application
- Theory of magnetic circuit and of transformers in general
  - Connection diagrams of CTs, the magnetizing current, burdens, saturation etc.
- The transient behavior
  - Current and voltage-transients, transient performance
- Non-conventional types of instrument transformers
- Exercises
  - Practical calculation examples for different protection types
- Standards
  - IEC, ANSI, IEC 60044-6, practical examples, CT classes

Topics Part 3 / Protection applications for power networks

- Introduction to network structures and protection concepts based on case studies
- Protection conception and planning on basis of short-circuit calculations
- Protection principles and protection concepts:
  - Overcurrent / earth-fault protection, arc flash protection, distance protection, differential protection, back-up protection, voltage protection, frequency protection, ...
- General protection applications for various network elements:
  - Overhead lines, cables, transformers, reactors, centralized / distributed generation, motors, loads, capacitors, ...
- Special protection application:
  - Multi-circuit transmission lines, multi-terminal and tapped lines, series compensated lines, redundancy concepts, power system stability, system split and island operation, transient generator behavior, critical clearing times, load shedding ...
- Consideration of different boundary conditions and requirements
  - Industry & Distribution:
    - Thermal short-circuit capability of equipment, n-1 contingencies, maximum load currents in normal operation, and emergency operation, max. voltage drop during start-up of motor, max. permissible short-circuit duration of generators, arcing faults etc., possibilities of detection of single-phase-to-ground faults, influence of the cable dimensioning on the network protection concept
  - Transmission:
    - Mutual coupling, effect of intermediate in-feed, load compensation, protection using tele-communication, weak-infeed, earth fault protection, power swing, auto-reclosing function, stability issues
  - Distributed generation:
    - Evaluation of in-plant network structure, impact of reactive power compensation, consideration of grid code requirements (fault ride-through capability, active/reactive power infeed at fault duration and after fault clearance …), design criteria for protection of the individual generation unit and the network infeed, compensation equipment and filters
Setting calculation

Industry & distribution:
Calculation of load and fault currents, protection setting calculation, current/time grading, backup protection, selectivity diagrams

Transmission:
Impedance grading, impedance loops calculation, grading charts for zone, load encroachment

---

Duration
8 days

Course Map
Typical course layout (time and sequence might be changed)

<table>
<thead>
<tr>
<th>Subject: Power System</th>
<th>Power System</th>
<th>Instrument Transformers</th>
<th>Transmission Application</th>
<th>Transmission Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course: CHP188</td>
<td>CHP188</td>
<td>CHP188</td>
<td>CHP188</td>
<td>CHP188</td>
</tr>
<tr>
<td>Topics:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Course Introduction</td>
<td>- Short-circuit theory</td>
<td>- IEC Standards</td>
<td>- Distance protection</td>
<td>- Distance protection settings, grading/coordination</td>
</tr>
<tr>
<td>- Fundamental properties of power systems</td>
<td>- Symmetrical components in power system</td>
<td>- Required U_{enf}</td>
<td>- Complex network configurations</td>
<td>- Transformer protection setting</td>
</tr>
<tr>
<td>- Load flow theory</td>
<td>- Short circuit current calculation exercises</td>
<td>- Knee-point voltage</td>
<td>- Simulation of short-circuits and distance protection</td>
<td>- Generator Protection</td>
</tr>
<tr>
<td>- Load flow exercises</td>
<td>- Load flow exercises</td>
<td>- Class P, PR, X, PX</td>
<td>- Transformer Behavior</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td>Day 1</td>
<td>Day 2</td>
<td>Day 3</td>
<td>Day 4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject: Industrial and Distribution Networks</th>
<th>Protection coordination concepts</th>
<th>Case Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course: CHP188</td>
<td>CHP188</td>
<td>CHP188</td>
</tr>
<tr>
<td>Topics:</td>
<td>- Fault currents for protection coordination</td>
<td>- Cables</td>
</tr>
<tr>
<td></td>
<td>- Protection concepts</td>
<td>- Transformers</td>
</tr>
<tr>
<td></td>
<td>- Influence of DER</td>
<td>- Motors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Generators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Selectivity diagrams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Distributed &amp; embedded generation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td>Day 6</td>
<td>Day 7</td>
</tr>
</tbody>
</table>