Protection Schemes For Generators and Recommended Settings Training

Description

Course Description

Protection of Electrical Power Systems requires an understanding of system faults and their detection, as well as their safe disconnection from the power system. This course presents a comprehensive and systematic description of the concepts and principles of operation and application of protection schemes for power generators. The course begins with an overview of power system faults and the protection scheme requirements for the detection and coordinated clearance of these faults. This course deals with protection systems from a practical perspective, and includes important functional aspects such as testing and coordination of protection systems. It is specially designed for industries and utilities, which depend on proper system protection for operational efficiency and minimizing damage to equipment.

The 5 days course is designed to provide excellent understanding on both a theoretical and practical level to attendees. The workshop starts at a basic level, to ease the engineer and technician into the perhaps forgotten art of studying, and provide a refresher to those who are more familiar with the basic topics covered. The workshop then moves onto more detailed applications. The workshop features an introduction covering the need for protection, fault types and their effects, simple calculations of short circuit currents and Generator neutral grounding configurations. The workshop also includes some Simulation work using ETAP power station for simple fault calculations, & recommended relay settings for generators as per recommended practice and based on setting rules.

Course Objective

The aim of this course is to provide in-depth discussions of the major electrical protection schemes associated with synchronous generators. The principles and criteria presented are applicable to both large and small machines. The discussions include analysis of the damage and damaging mechanisms relating to each protective function. An understanding of these parameters is important not only for the application of protection but also when operability issues arise during or after abnormal operating events.
Recommended settings applied to any protective device represent a balance between adequate

sensitivity to detect a damaging condition and the security required to prevent false tripping during events that do not threaten the protected equipment. The importance of this balance at generation facilities is highlighted by the intense scrutiny given these protection schemes in the wake of large-scale system outages.

Course Outline

Generator Short Circuit Calculations

- Introduction
- Short-Circuit Current Characteristics
- Generator Internal Magnetics
- Generator Magnetic Structures
- Generator Constants
- Fault Current Calculations
- Initial Load
- Fault Calculation Overview
- Determination of Xf and Fault Currents
- Three-Phase Short Circuit
- Phase-to-Phase Short Circuit
- Phase-to-Ground Fault
- Other Fault Conditions
- DC Component of Short-Circuit Current
- RMS Asymmetrical Current
- Voltage Regulator
- Short Circuit Calculation Examples
- Establish Prefault Conditions
- Three-Phase Fault at Generator Terminals
- Effects of the Automatic Voltage Regulator

Generator Differential Relay (87G)

- Introduction
- Ideal Differential Relay
- Practical Considerations
- CT Ratings
- CT Saturation
- CTs and Fault Current Replication
- Percentage Differential Relay
- Relay Characteristics
- Electromechanical Relays
- Solid-State and Microprocessor Relays
- Minimum Operating Current Setting
- Slope Setting
- Requirements for Slope Setting
- Advantage of Low Slope
- Sensitivity and Load Current

- Relay Response to Saturation
- Methods of Choosing Slope Settings
- Manufacturer’s Recommendations
- Qualitative Determination of Slope
- Error Current Calculations for Unsaturated CT
- Mason’s Method
- Example of Mason’s Method
- Fundamental Frequency Analysis
- Sample System Differential Relay
- Sample System Differential Circuit
- Electromechanical Relay
- Specifications for Relay Chosen
- Choosing Slope Static and Microprocessor Relays
- Stabilizing Resistor
- Balancing Burden
- Time Delay
- Frequency Response

Backup Fault Protection

- Purpose and Implementation
- Standard Overcurrent Relays
- Voltage-Dependent Relays
- Electromechanical vs. Electronic Relays
- Voltage Supervised Overcurrent Relays
- Voltage-Controlled and Voltage-Restrained Relays
- Application Options and Fault Sensitivity
- Scheme Sensitivity vs. Potential Transformer (PT) and Current Transformer (CT) Connection
- Sensitivity Related to Relay Type
- Delta Relay Currents
- Settings Considerations
- Basic Requirement
- Automatic Voltage Regulator in Service
- 51 V Transmission System Backup Limitations
- Effects of Wye-Delta Transformer
- Self-Excitation Generators
- Relay Response to Transient Current
- Equipment Protection
- Setting Criteria
- Relay Current and Voltage Calculations
- Relay Current and Voltage Equations
- Sequence Currents and Voltages Calculations
- Sample System 51 V Relay Settings
- Fault Calculations
- Choosing the Undervoltage Setting
- Choosing Overcurrent Setting
- Choosing Time Delay Setting

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- Auxiliary PTs to Correct for Wye-Delta Phase Shift
- Distance Relays
- Distance Relay Characteristics
- Z Measured by Phase Distance Relay
- Mho Distance Relay
- System Impedance vs. Relay Characteristic
- Setting Considerations
- Load Limits
- Apparent Impedance
- Influence of an Interposing Wye-Delta Transformer
- Auxiliary PTs to Correct for Wye-Delta Phase Shift
- Other Distance Relay Applications

Generator Ground Fault Protection

- Introduction
- Generator Grounding Considerations
- Ground Fault Current Limitation
- Overvoltage Concerns
- Core Damage Cause by Ground Fault
- Methods of Grounding
- Ungrounded System
- Solidly Grounded/Effectively Grounded
- High-Impedance Grounding
- Distribution Transformer Grounding
- High-Resistance Grounding on Sample System
- Ground Fault Neutralizers
- Low-Impedance Grounding
- Low-Resistance Grounding
- Low-Reactance Grounding
- Grounding Transformers
- Ground Fault Protection
- Alarm vs. Tripping for High-Impedance Grounded System
- Electromechanical and Electronic Relays
- High-Impedance Ground Protection
- Neutral Overvoltage Scheme
- Application of 59GN on Sample System
- Broken Delta Overvoltage Scheme
- Overcurrent Scheme
- Low-Impedance Ground Protection
- Ground Differential
- 100% Stator Protection Schemes
- Third-Harmonic Schemes
- Third-Harmonic Undervoltage Scheme Settings for Sample System 27H Scheme
- Third-Harmonic Overvoltage Scheme
- Third-Harmonic Voltage Ratio Scheme
- Neutral Injection Scheme

Unbalanced Current Protection

- Introduction
- What Is Negative-Sequence Current?
- Effects of Negative-Sequence Current
- Rotor Heating
- Cylindrical Rotor Generators
- Salient Pole Generators
- Pulsating Torque
- Generator Negative-Sequence Capability
- Continuous Unbalanced Capabilities
- Short Time Unbalanced Currents
- Sources of Negative Sequence Current

- Unbalanced Faults
- Open Phases
- In-Service I22t Duty vs. Standards
- Calculation of I22t Duty
- Isolated Generator
- The Interconnected Generator
- The’venin’s Equivalent Circuit
- Unbalanced Duty on Sample System
- Unbalanced Current Protection
- Negative-Sequence Relay Settings
- Calculation of Open-Circuit Current
- Negative Sequence Relay Setting

Motoring Protection

- Introduction
- Effects of Motoring
- Consequences for a Steam Turbine
- Consequences for Other Prime Movers
- Protection
- Mechanical Protection: Steam Turbines
- Electrical Protection
- Sequential Trip Logic
- Backup Protection
- Setting Device (32)
- Applying Reversed Power Relay on the Sample System
- Field Winding Protection
- Field Ground Protection
- Field Ground Hazard
- Field Ground Protection
- Field Ground Detection
- Field Ground Relay Selection and Settings
- Field Overcurrent Protection
- Field Overcurrent Transients
- Overcurrent Protection Schemes
- Application of AC Relays to Protect the Field Winding
- Basic Rectifier Operation
- Relay Quantities
- Settings For Field Overcurrent/Overvoltage Relays
- Full Load Values
- Maximum Field Current
- Maximum Field Current from a Bridge Rectifier
- Applying Field OC Protection on the Sample System
- Rated Field Voltage
- Maximum Available Field Current
- Pickup Setting

Overexcitation

- Introduction
- Causes of Overexcitation
- Damage
- V/Hz Limits
- Protection
- Field Monitoring Relays
- V/Hz Limiter
- V/Hz Relay Applications
- Settings
- Generator V/Hz Settings
- Transformer Settings
- Generator/Transformer Settings
- Setting Limitations
- Time Delay Settings
- Differential Relay Response to Overexcitation
- Application of V/Hz Protection on the Sample System

Abnormal Frequency Protection

- Introduction
- Effect on Generator
- Steam Turbines
- Combustion Turbines
- Hydro Generators
- Excitation System
- Protection and Settings
- Primary Protection
- Backup Protection
- Combustion Turbine Generators Protection

Minimum Excitation Limiter (MEL)

- Overview of the Minimum Excitation Limiter Application
- Operation in the Leading Mode
- Limits on Leading Var Operation
- Setting Criteria Background
- Setting Criteria
- Generator Leading Var Capability
- Stator End-Core Heating in the Round Rotor Generator
- Leading Var Capability of a Salient Pole Machine
- Coordination with the LOF Relay
- System Stability Limits
- Classical View of Steady-State Stability
- Manual Regulator Steady-State Stability Limit
- Automatic Regulator Stability Limits

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- MEL Protective Characteristic
- Straight Line Characteristic
- Multisegment Straight Line
- Circular Characteristic
- MEL Dynamic Performance
- Problems with MEL Stability
- Interaction with V/HZ
- Isolated on Capacitive Load
- MEL Application on the Sample System

Loss of Synchronism

- Introduction
- Turbine Generator Damage
- Transient Stability
- Out-of-Step Protection
- Classical Swing Impedance Characteristic
- Dynamic Swing Representation
- Setting Consideration
- Recoverable Swings
- Current Limitation
- Out-of-Phase Switching Rating for Breakers
- Swing Velocity
- Out-of-Step Relay: Device (78)
- Simple Mho Scheme
- Single Blinder Scheme
- Double Blinder
- Double Lens and Concentric Circle Schemes
- Detection Problems
- Setting Out-of-Step on Sample System

Loss of Field (LOF) Protection

- General
- Other Factors Affecting Loss of Field Severity
- System Impact
- Generator Damage
- Stator Winding Overload
- Rotor Damage
- Stator End-Core Damage
- Torque Pulsations
- Loss of Field Protection: Device (40)
- Distance Relay Schemes
- Distance Scheme 1: Unqualified Trip Scheme
- Coordination for Stable Swings
- Coordination with Minimum Excitation Limiter and Generator Capability Curve
- Modified Scheme: Two Impedance Elements

- Distance Scheme 2: Qualified Trip Scheme
- Trip Delay Considerations
- Criteria for Setting Mho Characteristic
- Undervoltage Element
- Modified Scheme
- Special Consideration for Bussed Generators
- Other Causes for LOF Relay Operations
- Operator Error on Startup
- Frequency-Sensitive Excitation Systems
- LOF Relays During System Disturbances
- Special Considerations for Hydro Units
- Application of the LOF on the Sample System
- Application of Scheme 1 on the Sample System Generator
- Setting Review against Dynamic data
- Application of Scheme 2 on the Sample System Generator
- Setting Review against Dynamic Data

Protection Elements & Main Settings Criteria

- Differential Protection
- Undervoltage protection
- Overvoltage protection
- Reverse Power protection
- Loss of Excitation
- Time Overcurrent with voltage control
- Unbalalnce protection
- Third harmonic neutral unvervoltage
- Stator ground fault/Restricted Ground Fault
- Neutral Overvoltage
- Under frequency protection
- Over frequency protection
- Overfluxing protection