Relion®. The perfect choice for every application.
The widest range of products for power systems protection, control, measurement and supervision. Interoperable and future-proof solutions designed to implement the core values of the IEC 61850 standard. ABB’s leading-edge technology, global application knowledge and experienced support network ensures complete confidence that your system performs reliably - in any situation.
ABB is pleased to provide you with technical information regarding protective relays. The material included is not intended to be a complete presentation of all potential problems and solutions related to this topic. The content is generic and may not be applicable for circumstances or equipment at any specific facility. By participating in ABB’s web-based Protective Relay School, you agree that ABB is providing this information to you on an informational basis only and makes no warranties, representations or guarantees as to the efficacy or commercial utility of the information for any specific application or purpose, and ABB is not responsible for any action taken in reliance on the information contained herein. ABB consultants and service representatives are available to study specific operations and make recommendations on improving safety, efficiency and profitability. Contact an ABB sales representative for further information.
Jack Chang is the regional technical manager for ABB Inc. in the Substation Automation business serving customers in Canada and northern regions. He provides engineering, commissioning and troubleshooting support to customers applying ABB’s high-voltage protective and automation devices. Prior to joining ABB, Jack worked as a substation P&C project engineer in two specialized consulting firms (now ABB and Quanta Services, respectively) and also as an engineering consultant to a public owned utility in their transmission expansion and upgrade projects. Jack is a registered professional engineer in the province of Alberta, Canada.
Learning objectives

- Power Generation fundamentals
- Generator Faults
- Generator Abnormal Conditions
- Modern Generator Protective IED Capabilities
- Typical Generator Protection Functions
Standards

- C37.101: Guide for AC Generator Ground Protection
- C37.102: Guide for AC Generator Protection
- IEEE Tutorial On The Protection of Synchronous Generator (PSRC)
Power station is the most complex part of the power system.

- **HV System**
- **Step Up Transformer**
- **LV Drives**
- **MV Switchgear**
- **Control Systems**
- **Communication**
- **Control Room**

**INSTRUMENTATION**
- Temperature
- Pressure

**ANALYZERS**
- Actuator on-off, controlled

**ACTUATOR**
- LV Switchgear

**MV MOTORS**

**LV MOTORS**

**TURBINE GOVERNOR**

**GENERATOR CIRCUIT BREAKER**

**SYNCHRONIZATION**

**STAR POINT CUBICLE**

**EXCITATION TRANSFORMER**

**UNIT PROTECTION**

**PT's**

**CT's**

**SA's**

**Power Island**

**Power station is the most complex part of the power system.**
Typical Parts of a Power Plant

- Busbar in HV Substation
- HV - Breaker
- Main Transformer
- Generator Breaker
- Turbine valve
- Turbine - Generator
- Earthing System

HV Substation
Power plant
Auxiliary Transformer
Excitation Transformer
Excitation System
Field Circuit Breaker
Different power plants electrical equipment layouts
Damage to the stator core in case of earth-fault

- Practically all unit connected generators are high-impedance earthed
- Only industrial generators may be low-impedance earthed
Stator winding earthing practices

- Resistive Grounded
  - $R \approx 1\, \Omega$

- Grounding Transformer (Neutral)
  - $R \approx 0.5\, \Omega$

- Grounding Transformer (Terminal)
  - $R \approx 3.0\, \Omega$

- Isolated
Possible faults

- Stator Earth Faults
- Rotor Earth Faults
- Stator Short Circuits
- Stator/Rotor Interturn faults
- Unit transformer faults
- External faults
Abnormal operating condition

- overcurrent/overload
- unbalanced load
- overtemperature
- over- and undervoltage
- over- and underexcitation
- over- and underfrequency
- over-fluxing
- asynchronous running
- out of step
- generator motoring
- failures in the machine control system (i.e. AVR or governor failure)
- failures in the machine cooling system
- failures in the primary equipment (i.e. breaker head flashover)
- open phase
Allocation of protection functions

- **32 Reverse power**
- **81O/U Frequency**
- **46 Unbalance**
- **40 Loss of excitation**
- **78 Pole slipping**
- **64R Earth fault rotor**
- **49R Rotor overload**

**Turbine**

- **87G/87O Differential**
- **59 Over-voltage**
- **24V/Hz over-fluxing**
- **49S Stator over-load**
- **21/51V Voltage/over-current**
- **64S Earth fault stator**
- **Inter-turn**
- **50AE Accidental energizing**

**Rotor**

**Stator**

© ABB Group
August 18, 2014 | Slide 14

© ABB Group
Generator protection

Other functions available from the function library:

- 25 SES RSYN
- 50 PH PIOC
- 51/27 CV GAPC
- 32N 3I
- 64S RIE
- 52PD PD
- 51/67 CV GAPC
- 12d1/1 CCS RDF
- 64R RRE

Function alternatives for 87G/GEN PDIF:

- 87T 3I
- 87 3I
- 12d1/1 HZ PDIF
Generator protection with 87T (87O)
Function allocations with older generation relays

- Older type of design:
  - M1 and M2 with different function allocations

### Table 3: Example on relay functions divided into two function groups

<table>
<thead>
<tr>
<th>Type of fault</th>
<th>ANSI</th>
<th>Protection function</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator stator</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Short circuit</td>
<td>87G</td>
<td>Generator differential</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Minimum impedance or alternatively</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>51/27</td>
<td>Overcurrent/undervoltage for thyristor magnetisation</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>Overcurrent</td>
<td>X</td>
</tr>
<tr>
<td>Dissymmetry</td>
<td>46</td>
<td>Negative sequence overcurrent</td>
<td>X</td>
</tr>
<tr>
<td>Stator overload</td>
<td>49</td>
<td>Thermal overload</td>
<td>X</td>
</tr>
<tr>
<td>Stator earth fault</td>
<td>59</td>
<td>95% stator earth fault</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Loss of excitation</td>
<td>40</td>
<td>Reactive current and phase angle</td>
<td>X</td>
</tr>
<tr>
<td>Motoring</td>
<td>32</td>
<td>Reverse power Redundant protection used for large generators</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Overspeed</td>
<td>81</td>
<td>Max. frequency</td>
<td>X</td>
</tr>
<tr>
<td>Turbine blade fatigue</td>
<td>81</td>
<td>Min. frequency</td>
<td>X</td>
</tr>
<tr>
<td>Intermittent fault</td>
<td>56 or 51N</td>
<td></td>
<td>(X)</td>
</tr>
<tr>
<td>Overvoltage</td>
<td>59</td>
<td>Overvoltage</td>
<td>X</td>
</tr>
<tr>
<td>Over magnetization</td>
<td>24</td>
<td>V/Hz</td>
<td>X</td>
</tr>
<tr>
<td>Low voltage</td>
<td>27</td>
<td>Undervoltage</td>
<td>X</td>
</tr>
<tr>
<td>Inadvertent breaker closing</td>
<td>50/27</td>
<td>Overcurrent with low voltage</td>
<td>X</td>
</tr>
<tr>
<td>(Dead-machine protection)</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Shaft current</td>
<td>-</td>
<td>Overcurrent, fixed time</td>
<td>X</td>
</tr>
<tr>
<td>Generator rotor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotor overload</td>
<td>49</td>
<td>Thermal overload</td>
<td>X</td>
</tr>
<tr>
<td>Rotor earth fault</td>
<td>64R</td>
<td>Injected AC</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Injected DC</td>
<td>X</td>
</tr>
<tr>
<td>Step-up (Block) transformer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short circuit/earth fault</td>
<td>87T</td>
<td>Differential protection</td>
<td>X</td>
</tr>
<tr>
<td>Overcurrent</td>
<td>50/51</td>
<td>Time overcurrent with instantaneous function</td>
<td>X</td>
</tr>
<tr>
<td>Breaker failure protection</td>
<td>50BFR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth fault differential prot.</td>
<td>87D</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Over magnetization prot.</td>
<td>24</td>
<td>V/Hz</td>
<td>X</td>
</tr>
</tbody>
</table>
Complete Protection Scheme

- Generator M1 & M2 protection
  - Two identical IEDs with 87G (low/high impedance based)

- Complete Unit Protection for Smaller Machines
  - One with 87G
  - One with 87T or 87O
Generator protection & optional transformer protection

Other functions available from the function library

- 25 50 31> 51/27 U</> 64S RSE< 87T 3kd/I
- SES RSYN PH PIOC CV GAPC STTI PHIZ T2W PDIF
- 52PD PD 87CT 12d/1 51V I>/U 64R RRE< 32N P0->
- CC RPLD CCS RDIF CV GAPC ROTI PHIZ SDE PSDE
Complete generator-transformer unit protection
Generator terminal short circuit

- \( X_d'' \) - Subtransient Reactance
- \( X_d' \) - Transient Reactance
- \( X_d \) - Synchronous Reactance

- The fault current from the generator change during fault sequence
  - Change of generator reactance \( X_d'' \rightarrow X_d' \rightarrow X_d \)
  - Dependent of the excitation system
Stator short circuit

- Consequence of stator short circuit
  - Insulation, windings and stator core can be damaged
  - Large forces, caused by large fault currents, can give damage to other components in the plant
  - Risk of explosion and fire
  - Mechanical stress on generator- and turbine shafts
Detection of stator short circuits

- Protection functions
  - Generator differential protection
  - Block (unit) differential protection
  - Directional negative sequence overcurrent protection
  - Under impedance protection
  - Phase overcurrent protection (sometimes not effective)
  - Voltage dependent phase overcurrent protection
  - Under voltage protection
  - Phase overcurrent protection of the block transformer
Generator differential protection

- Unstabilized differential protection level
- Stabilized differential protection level
  - Harmonic blocking
- Negative sequence unrestrained
  - Combination: bias differential and negative sequence internal/external discriminator; increases speed and security
- Negative sequence sensitive differential protection
Differential protection characteristics

The restrained characteristic is defined by the settings:
1. IdMin
2. EndSection1
3. EndSection2
4. SlopeSection2
5. SlopeSection3

operate current
(gen. rated curr.)

\[ \text{slope} = \frac{D_{\text{operate}}}{D_{\text{restrain}}} \times 100\% \]

The restrained characteristic is unconditionally operated.

The unrestrained limit is indicated by the horizontal line.

Section 1

Section 2

Section 3

SlopeSection2

SlopeSection3

EndSection1

EndSection2

August 18, 2014

© ABB Group
Generator unit (overall) differential protection

- Identical to transformer differential protection
  - Zero sequence current elimination
  - Vector group compensation
  - Transformer ratio compensation
  - Unstabilized differential protection
  - Stabilized differential protection
    - Harmonic blocking
    - Waveform blocking
- Negative sequence unrestrained
  - Combination: bias differential and negative sequence internal/external discriminator
- Negative sequence sensitive differential protection
Phase to phase fault in the stator winding

- Endangering condition
  - Overcurrent
- Protected object
  - Stator winding
- Consequences
  - Heating
  - Forces
  - Smelted stator core

Main Protection Function

Reserve Protection Function
Phase to phase fault in the XFMR, and bus work

- Endangering condition
  - Overcurrent
- Protected object
  - XFMR, bus work
- Consequences
  - Heating
  - Forces
  - Smelted trafo core

Main Protection Function
- Reserve Protection Function

© ABB Group
August 18, 2014 | Slide 28
Under-impedance protection

- Backup protection for internal short circuits in the generator or the unit transformer
- Backup or main protection for fault at the busbar where the plant is connected to the power system
- Backup protection for line-faults at lines out from the power plant
- Up to 3-zones with offset mho characteristic
Phase overcurrent protection

- Backup protection for internal short circuits in the generator or the unit transformer
- Backup or main protection for fault at the busbar where the plant is connected to the power system
- Backup protection for line-faults at lines out from the power plant
External short circuit

- Before Fault
- First period of Fault
- After 0.4 s
- Before Fault

Diagram showing the DC1 Stage Pickup Level with points indicating the periods before, during, and after the fault. The graph includes labels for StartCurr_OC1, VDepFact_OC1 * StartCurr_OC1, and the selected voltage magnitude. The diagram also includes a waveform representation of the current changes during the fault.
Voltage controlled phase overcurrent protection

![Diagram showing OC1 Stage Pickup Level, StartCurr_OC1, VDepFact_OC1 * StartCurr_OC1, UHighLimit_OC1, and Selected Voltage Magnitude.]

© ABB Group
External faults

- Endangering condition
  - Overcurrent
- Protected object
  - External power system parts.
- Consequences
  - Heating
  - Forces
  - Mechanical damages

Main Protection Function

Reserve Protection Function
Stator earth fault

- Damages on the stator iron
- Increased voltage on “healthy phases”
- Small fault currents
- Sensitivity requirements on fault clearance
- The fault resistance is normally low at stator earth fault
- The residual voltage and earth fault current is highly dependent on fault location in the generator
Voltage based 95 % stator earth fault protection

Neutral point voltage transformer used to measure $U_o$ voltage

Voltage $U_o$ has the following primary value for the solid Ph-Gnd fault at generator HV terminals

$$U_o = \frac{U_{Gen\_Ph-Ph}}{\sqrt{3}}$$
Current based 95% stator earth fault protection

Neutral point current measurement

Generator Step-up transformer

10/1A
Why 95% and 100% stator ground fault protection?

- Protected zone is approximately 95%
- Last 5% is NOT protected

Over voltage function
95% stator ground fault 59GN
U = 0.05 Un
t = 0.5 s

© ABB Group
August 18, 2014 | Slide 37
Possible 100 % stator earth fault protection solutions

- Measurement of the "natural" third harmonic voltage induced in the generator can be used to protect against EF close to the generator neutral point (i.e. 3rd harmonic based principle; 59THD)

- Neutral point voltage injection where the injected voltage has non-harmonic frequency (i.e. injection principle; 64S)
3rd harmonic 100% stator ground fault

- Simplest approach:
  - 3rd harmonic under-voltage in the neutral (i.e. $U_{3N} <$)
  - 3rd harmonic over-voltage at generator terminals (i.e. $U_{3T} >$)
- Possible problems:
  - Generator start-up
  - Generator shut-down
  - Different generator loading
- $3^{rd}$ harmonic differential principle
  $$|U_{N3} + U_{T3}| \geq Beta \cdot |U_{N3}|$$
3rd harmonic based 100% stator earth-fault

Samples of the neutral voltage from which the fundamental- and 3rd harmonic voltages are filtered out.

Neutral point fundamental frequency over-voltage protection 10 – 100 %

3rd Diff. 0 – 30 %

CB 1 may not exist

step-up unit transformer
Stator injection

REG670 (Injection Unit) ALWAYS required

REX062 (Shunt Resistor Unit) SOMETIMES required

Generator Protection Cubicle

© ABB Group
August 18, 2014 | Slide 41
Earth fault in the stator winding

- **Endangering condition**
  - Overvoltage in two healthy phases
  - Voltage in the star point
  - Relatively small earth fault current

- **Protected object**
  - Stator winding

- **Consequences**
  - Damage to the stator core
  - Risk of second earth fault

**Main Protection Function**

**Reserve Protection Function**
Earth fault in transformer HV winding

- Endangering condition
  - Overcurrent
- Protected object
  - Transformer windings
- Consequences
  - Heating
  - Forces
  - Smelted trafo core

Main Protection Function
Reserve Protection Function
Earth fault in transformer LV winding

- Endangering condition
  - Overvoltage in two healthy phases
  - Voltage in the star point
  - Relatively small earth fault current

- Protected object
  - Transformer winding

- Consequences
  - Small possibility to damage trafo core
  - Risk of second earth fault

Main Protection Function
Reserve Protection Function
Turn to turn fault in the stator winding

- Endangering condition
  - Circulating currents
  - Asymmetrical phase currents
- Protected object
  - Stator winding
- Consequences
  - Damage to the stator core
  - Risk of evolving into earth fault

* 59N will detect this fault when develops into an earth fault

Main Protection Function 🟥

Reserve Protection Function 🟥
Rotor earth fault

- The field circuit of the generator is normally isolated from earth
- With a single earth fault in the rotor circuit it is possible to have continuous operation without generator damages
- There however creates an increased risk of a second rotor earth fault. In such a case there will be large current and risk of severe damages.
- Major damages ensue following a second ground fault
- The requirement of fast fault clearance is moderate
Rotor injection

**Generator Protection Cubicle**

- PCM600 2.3
- ICT
- REG670

**REX060** (Injection Unit) ALWAYS required

**REX061** (Coupling Capacitor Unit) ALWAYS required

**Generator**

---

August 18, 2014 | Slide 47

© ABB Group
Earth fault in the rotor winding

- **Endangering condition**
  - None
- **Protected object**
  - Rotor winding
- **Consequences**
  - Risk of evolving into double earth fault

**Main Protection Function**

**Reserve Protection Function**

© ABB Group
August 18, 2014 | Slide 48

Performance of synchronous machine

- Synchronous machine operating in a parallel with a large power system can:
  - supply active power to the system (operates as generator)
  - receive active power from the system (operates as motor)
  - supply reactive power to the system
    (overexcited machine; operates as shunt capacitor)
  - receive reactive power from the system
    (underexcited machine; operates as shunt reactor)
- Note: machine shall have fixed rotating speed at all times
Different protection operating planes

- **U-I Plane**
  - Motor
  - Generator
  - Underexcited
  - Overexcited

- **P-Q Plane**
  - Motor
  - Generator
  - Overexcited
  - Underexcited

- **R-X Plane**
  - Motor
  - Generator
  - Overload Area
  - Fault Area

**Key Points:****
- AB: Field current limit
- BC: Stator current limit
- CD: End region heating limit of stator, due to leakage flux
- BH: Possible active power limit due to turbine output power limitation
- EF: Steady-state limit without AVR
- $X_s$: Source impedance of connected power system

© ABB Group
August 18, 2014 | Slide 50
Loss of/under excitation 40

Causes

- open field circuit
- field short circuit
- accidental tripping of the field breaker
- AVR failure
- loss of field at the main exciter

Consequence

- Asynchronous running of a synchronous machine without excitation – induction generator
- Start drawing reactive power - voltage collapse
- Stator end-core heating
- Induced rotor currents

© ABB Group
August 18, 2014 | Slide 51

© ABB Group
August 18, 2014 | Slide 51

© ABB Group
August 18, 2014 | Slide 51

© ABB Group
August 18, 2014 | Slide 51
Generator apparent power $S$ during loss of excitation

Loss of/under excitation 40

August 18, 2014
Loss of/under excitation 40

- Loss of/under excitation is based on under-impedance measurement (offset Mho)

- Main features:
  - Two zones Z1 and Z2, with independent block and trip
  - Directional element for additional zone restriction (eg. under-exiting operation)
Loss of Excitation Protection

\[ X_{d}'/2 \]

\[ 1.1 \times X_d \]

Diagram showing various settings and limits including:
- Area of Normal Operation
- Directional Unit When Used
- Capability Curves
- Steady-State Stability Limit
- Minimum Excitation Limiter

ABB logo
Loss of/Under excitation 40

- Endangering condition
  - Stator reactive current component
- Protected object
  - Rotor and stator winding
- Consequences
  - Thermal damage of rotor and stator end regions
  - Asynchronous machine operation
  - Voltage and current variations

Main Protection Function

Reserve Protection Function
Generator shall produce active power (i.e. $P>0$)

When it starts to receive the active power it acts as a motor (i.e. $P<0$)

Not dangerous operating condition for machine but it may be dangerous for the turbine
Generator motoring protection 32/37

- **Causes**
  - loss of prime-mover
  - low water flow (hydro)
  - load variations / problems

- **Effects**
  - steam units $\rightarrow$ overheating of turbine and turbine blades
  - hydro units $\rightarrow$ cavitation of the blades

- **Demands**
  - accurate active power measurement (i.e. $P\sim 0$ & $Q=30-60\%$)
Reverse power protection

- Set desired pickup (0.5 to 3%)
- Set time delay 5-30 s
- Sequential tripping logic
Low forward power protection

- Set desired pickup (1 to 10%)
- Set time delay 5-30 s
- Sequential tripping logic
- Blocked by external signal when generator is not loaded
Reverse Power Protection (32R)

- Endangering condition
  - Motor operation
- Protected object
  - Turbine
- Consequences
  - Excessive heating of turbine blades (steam units)
  - Mechanical damages to thrust bearing (Francis turbines)
  - Explosion risk for diesel units

Main Protection Function

Reserve Protection Function
Negative sequence overcurrent (46)

From asymmetric currents, a negative sequence current component \( I_2 \), is filtered out.

Negative sequence stator currents rotate in a opposite direction from the rotor and consequently induce a 120Hz current component into the rotor. As a consequence rotor ends can over-heat.

\[ I_2^2 \times t = k \]
Negative phase sequence (46)

Causes
- unbalanced loads
- untransposed transmission circuits
- unbalanced system faults
- series faults
- CB pole discrepancy
- open circuits

Features
- Characteristic adjustable to $I_2^2 t = k$
Broken stator winding

- Endangering condition
  - Unsymmetrical currents
- Protected object
  - Stator windings
  - Rotor
- Consequences
  - Rotor overheating
  - Vibrations

Main Protection Function
Reserve Protection Function

© ABB Group
August 18, 2014
Pole slip / out of step protection (78)

- Asynchronous running of a synchronous machine with the rest of the system but **with excitation intact (opposed to loss of Field)**
- Characterized by power \((P & Q)\) oscillation
- Manifests as impedance movement in R & X plane
- Big mechanical impact on turbine and shaft
- Pole Slip typically caused by:
  - Long fault clearance time (especially close by 3Ph faults are critical)
  - Inadvertent tripping of a transmission line (increase of transmission impedance between generator and load)
  - Loss of large generator unit
Pole slip / out of step protection (78)
Pole slip / out of step protection (78)

- **Endangering condition**
  - High stator current
  - Possible system blackout

- **Protected object**
  - Rotor shaft and stator winding

- **Consequences**
  - Mechanical damages to shaft
  - Asynchronous machine operation (with field intact)
  - Voltage and current variations

**Main Protection Function**

**Reserve Protection Function**
Frequency protection (81U/O)

- **Over-frequency 81O**: protects in case of turbine over-speed
- **Under-frequency 81U**: protection of the steam turbine at the "critical speed"
Low network frequency (81U)

- Endangering condition
  - Under-frequency
- Protected object
  - Transformer
  - Steam turbine
- Consequences
  - Over-excitation
  - Steam turbine vibrations

Main Protection Function

Reserve Protection Function

© ABB Group
August 18, 2014 | Slide 68
High Network Frequency (81O)

- Endangering condition
  - Over-frequency
- Protected object
  - Turbine
  - Rotor
- Consequences
  - Mechanical stresses
  - Turbine vibrations

Main Protection Function

Reserve Protection Function

© ABB Group
August 18, 2014
Slide 69
With faulty AVR overvoltage can cause over excitation of the generator-transformer block

V can sharply increase after load rejection followed by machine runaway
Over-voltage protection (59)

- Endangering condition
  - Over-voltage
  - Improper voltage regulation
- Protected object
  - Electrical circuits
- Consequences
  - Increased risk for earth-faults
  - Over-excitation

Main Protection Function
Reserve Protection Function
Over-fluxing protects generator and transformer magnetic core against overheating.

- Specially critical during start-up and shut-down.
- Wide frequency operation of the relay important for generator protection.

\[ \Phi = const \cdot \frac{E}{f} \approx const \cdot \frac{U}{f} \]
Incorrect turbine control (24, 81O/U)

- Endangering condition
  - Under-frequency
- Protected object
  - Transformer
- Consequences
  - Over-excitation

Main Protection Function

Reserve Protection Function
Accidental energizing, 50AE

- Operates when generator is energized while offline
- Behaved a induction motor
- Significant damages to rotor
- Operating errors, CB flash-over
- Voltage controlled OC most commonly used
Accidental energizing (50AE)

- Endangering condition
  - Stator overcurrent or unsymmetrical currents
- Protected object
  - Bearings
  - Rotor
- Consequences
  - Bearing damages due to low oil pressure
  - Rotor overheating
  - Stator overheating

Main Protection Function

Reserve Protection Function

*3Z< is a delayed reserve protection*
Breaker-failure protection (50BF)

- Issues a back-up trip of adjacent breaker in case of failure of the circuit breaker of the protected object to open (i.e. to interrupt the primary circuit)
- Its operation in most cases trips only local breakers
- Commonly uses the bus bar protection disconnector replica logic to route its tripping command to adjacent breakers
- Re-trip (t1), Backup trip / bus-strip (t2), Second back-up trip timer (t3)
- Short reset time (15ms)
- Known CB faulty (bypass t2)
- Operating mode
  - Current / Contact / Current & Contact
**Breaker fails to open the circuit (50BF)**

- **Endangering condition**
  - Stator overcurrent or unsymmetrical currents

- **Protected object**
  - Electrical circuits
  - Rotor

- **Consequences**
  - Rotor overheating
  - Stator overheating
  - Prolonged damages caused by the fault current

---

**Main Protection Function**

**Reserve Protection Function**
Conclusion

- Stator earth faults
- Rotor earth faults
- Stator short circuits
- Stator/rotor interturn faults
- External faults
- Abnormal operation
Thank you for your participation

Shortly, you will receive a link to an archive of this presentation. To view a schedule of remaining webinars in this series, or for more information on ABB’s protection and control solutions, visit:

www.abb.com/relion
We combine innovative, flexible and open products with engineering and project services to help our customers address their challenges.
Power and productivity for a better world™