Improvements in Generator Breaker Failure Protection During Low-Current Conditions

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Breaker failure schemes

50BF AND 52a

If circuit breaker is stuck, 52a still indicates circuit breaker is open

Scheme is less dependable but more secure

NERC report identified issues with 52a contact
Breaker failure schemes
50BF OR 52a

IEEE C37.119 recommends scheme

Scheme is more dependable but less secure

Incorrect 52a can issue breaker failure trip

![Breaker failure trip diagram]

Breaker failure scheme in digital relays

Use open-phase detection to secure breaker failure scheme against dc subsidence
**Schemes with GCB located on HV side of GSU**
Use breaker currents for 50BF schemes

**Schemes with GCB located on LV side of GSU**
Use breaker currents for 50BF schemes
87 trips do not always engage 50BF scheme

- A-B-phase fault close to generator neutral side
- 50BF schemes fail because of low breaker currents
- Generator absorbs Q

Sequential shutdown increases turbine life

- Works on reverse power
- Can also use low forward power
- Uses 52b to supervise excitation trip (optional path)
Examining generator de-excitation

\[ V_F = 1.35 \cdot V_{ac} \cdot \cos \alpha \]
where \( V_{ac} \) is the excitation transformer-rated secondary voltage

GCB failure to open caused motoring of steam-driven turbo generator
Breaker failure schemes in generator protective relays have benefits

Avoid issues caused by BFI spurious initiations or dc circuit issues

**Set 50BFP to sensitive limit**

**Breaker-status logic**

Uses 52a, 52b, and OPH for better breaker-status logic

**Synchronization-check-based scheme**

Uses voltage measurements of both sides of breaker

**Power-based scheme**

Uses both active and reactive power measured at generator terminals

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Open-phase detection improves breaker status

52CL is more dependable and less secure than 52a

OPH deasserts when ac current peak is more than 0.05 pu

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![Breaker status discrepancy alarm](image)

Breaker status discrepancy alarm

Breaker closed (52CL)
Voltage-based scheme checks for synchronism

Requires synchronism-check function in relay

Setting of 15 to 60 cycles is recommended

One-and-a-half breaker scheme

50BF scheme uses CT-U and CT-Y
New power-based logic improves dependability

- $50BF_P$ for $CT-U = 0.05$ pu on $I_{NOM}$
- $50BF_P$ for $CT-Y = 0.05$ pu
- Total $50BFP = 0.1$ pu
- $CT-T$ current = $0.19$ pu
- Generator MVA corresponds to $50BFP = 181$ MVA
- $50BF$ scheme cannot determine if GCB is open or closed if load $<181$ MVA

RTDS simulation of a simultaneous trip
New logic uses generator power to supervise breaker opening during simultaneous trip

Low forward power checks for breaker failure condition
$I_2$ checks for phase-to-phase faults
DC check identifies three-phase faults

$I_2 < 0.5 \cdot I_1$
$P > LFP_{TH}$

New logic uses generator power to supervise breaker opening during simultaneous trip

50BF uses breaker currents (CT-U and CT-Y)
GENBFP is for simultaneous trip
32RQ can see based on Q loading prior to trip

Low current-based breaker failure scheme

New breaker failure scheme uses reactive power to supervise breaker opening under sequential shutdown

Selecting breakers for one-and-a-half breaker scheme
Examining generator equivalent circuit with capacitances

![Equivalent Circuit Diagram]

\[ C_X = 0.09 \mu F \]
\[ C_G = 0.297 \mu F \]

Analyzing an RTDS simulation of single-pole stuck condition on GSU LV breaker

![Time Response Diagram]

- System voltages, kV
- Generator voltages, kV
- Positive-sequence voltage, pu

Time (s)
**3V0 at LV bus can detect single-pole stuck**

![Graph showing 3V0s (pu), 3V0G (pu), and VN (pu) over time](image)

**Ground fault isolation logic for two generators sharing common GSU has benefits**

Torque control can supervise scheme operation for system faults and LOP conditions

- **Torque control**
  - $3V_0S >$ pickup
  - Trip HV side CBs, LV side GCB-1, and LV side GCB-2

- **GCB-1-52b AND GCB-2-52b**
  - 2 s
  - Trip HV side CBs
Conclusions

50BF scheme cannot cover most faults if $50BF_P$ is not sensitive

Breaker failure schemes should be more biased toward security

Schemes implemented inside generator protective relay are immune to unwanted BFI assertions

Conclusions

Use one of the following schemes to improve breaker failure protection

Improved auxiliary contact scheme

Synchronism-check-based scheme – uses PT on both sides of GCB

New power-based breaker failure scheme that uses generator terminal measurements to make scheme more secure and dependable

GSU LV-side pole stuck can be identified as traditional iso-phase bus ground fault protection
Questions?