Case Study on On EHV Circuit Breaker Flashover
AUTHORS:

- B. K. SINGH (AGM-ELECT)
- S.C. SINGH (SUPDT-ELECT)
- MANOJ SHARMA (Dy SUPDT-ELECT)
- ANAND PANDEY (ENGR-ELECT)
There has been a rising trend in the number of breaker-flashover failures worldwide.

Existing protection schemes either fail to detect breaker-flashover conditions or operate too late to prevent extensive damage.

Breakers can explode, damaging neighbouring equipment or placing substation personnel at risk.

Dedicated protection is required to prevent damage resulting from breaker flashover.
Introduction

Flashover may occur during synchronization across breaker terminals while the breaker is open due to -

• Internal or external contamination
• Low dielectric pressure
• Humidity

Probability is higher on breakers used to synchronize two isolated power systems or on generator breakers.
Frequently, only one phase of the breaker flashes over during synchronizing procedures.

Power system suffers an undesirable out-of-step and single-phase synchronization.

Extensive damage to generators and step-up transformers.

No dedicated breaker flashover protection exists in our plant.

SSTPS also experienced one such incidence during synchronization on 15.09.2010 in 400 KV SF6 Breaker of Unit#5.
Incidence at SSTPS

- Following protection operated during the incidence resulting in BUS-II and Unit#3 trip

- GT back up earth fault (51NGT)

<table>
<thead>
<tr>
<th>Type</th>
<th>CDG11</th>
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<tbody>
<tr>
<td>PMS</td>
<td>0.2</td>
</tr>
<tr>
<td>TMS</td>
<td>0.45</td>
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- Pole slip (98G) relay Type- ZTO11

*During pole flashover Generator voltage sinks & Current shoots considerably in oscillatory manner leading to operation of pole slip relay*
Current flow in Generator winding in case of Single Pole flashover
Incidence at SSTPS

Power Flow as recorded in DAS system
Analysis of incidence

In order to analyze simultaneous operation of B/U Earth fault of transformer and Generator pole slip protection during synchronization following components were checked:

- Generator Transformer
- 400 KV side CTs
- GT LAs
- Generator Breaker for any internal failure

GT, 400 KV CTs & LAs were tested thoroughly and found OK.
Analysis of incidence

- IR of breaker across the contacts of Y-phase under open condition taken and found zero.
- Breaker was closed and CR was found to be 1800 micro ohm against a value of 100 micro ohm.
- It is concluded some internal problem has occurred inside breaker.
- The failure of breaker lead to operation of above relays.
- SF6 gas sample of failed pole was found to be contaminated thereby confirming an internal flashover.

The unit was synchronized on TBC.

Breaker was later on dismantled for investigation.
Generator circuit breaker flashover

Fig.01 Image of internal components of failed breaker at SSTPS

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Generator circuit breaker flashover

Fig.02 Image of internal components of failed breaker at SSTPS
Generator circuit breaker flashover

Fig.03  Image of internal components of failed breaker at SSTPS

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Generator circuit breaker flashover

Fig. 04 Image of internal components of failed breaker at SSTPS

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Generator circuit breaker flashover

Fig. 05 Image of internal components of failed breaker at SSTPS

Ballast cylinder

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Why do breaker flashover occur?

- During synchronization, the out-of-phase voltage angle between contacts changes from 0 to 360 degrees continuously.
- Voltage between breaker contacts reaches its maximum instantaneous value when the angle difference between the voltages is 180 degrees.

For 400 KV system $\Delta V_{\text{max}}$ may be 654 KV (aprox).
Voltage across breaker contacts before synchronization

Line voltage = 400 KV
Phase voltage = \((400 / \sqrt{3})\) = 231 KV
Peak value of phase voltage = \(\sqrt{2} \times 231\) = 327 KV
Similarly voltage also appearing on Bus side of breaker contact.

During out of phase condition (180 deg)
Net voltage across breaker contacts =
\[327 \angle 0^\circ - (327 \angle 180^\circ) = 327 - (-327) = 654\] KV
Why Traditional Protection is not effective

- Flashover is a series fault and lead to power oscillation
- Residual current much lower than phase-to-ground fault
- Generator protection are not effective or effective with delay in this situation
- LBB Scheme is not effective at detecting flashover failure
- Relying on an external trip prolongs the failure until line, generator, or transformer protection trips
Due to oscillatory & pulsating voltage & currents relay fail to detect the flashover condition.
Current & Voltage signals for Protection relays
Methods for Flashover Protection

- Following parameters can be used as inputs for breaker flashover protection scheme
  - Phase currents
  - Residual current
  - Voltages from one or both sides of the breaker,
  - Breaker position auxiliary contacts (52a or 52b)
  - Close-signal monitoring or timers

- Once the flashover is detected, all the breakers in the bus must be tripped, as in a conventional breaker-failure scheme.

- Security considerations are very important to avoid mal-operations.
Method-1

Based on residual-current measurement and a breaker auxiliary contact (52a (NO) or 52b (NC)) supervision

Flashover is detected and the bus cleared if there is residual current and the breaker is open

Require timer to eliminate mismatching in time of simultaneous closing of three phases

Limitation:

- The scheme may mal-operate in case breaker closed status is lost and there is any external fault.
Residual Overcurrent and Breaker Auxiliary Contact

Flashover Protection Scheme With Multifunction Generator Relay
Method- 2

Time Limits and Close-Signal Monitoring to Detect Flashover

In order to operate, this logic requires

- Phase current greater than the setting value, without no current five cycles before the start of the scheme
- Breaker auxiliary contact open (for 52a)
- No closing signals to breaker at least six cycles before the start
Method- 2 Continued...

- Allows scheme operation only if latch conditions occur in the first five cycles after current flows in the breaker.
- No Mal-operation where a breaker auxiliary signal is lost during normal operation with the breaker closed and residual or phase currents present.
- Method I would trip for this condition in case of external fault
- Timer is used to confirm the flashover condition
- The timer resets once current falls set value or close signal appears or 52a indicates a closed indication
Preventive measures to avoid flashover

- Probability of breaker flashover is highest in SF6 type of breaker
- Measurement of Dew point of SF6 gas in breakers (should be nearly -50 deg C)
- Overhauling of breakers at definite intervals
- Site test of breaker during overhauling of Units
- Line isolators should be closed just prior to voltage build-up and when machine is ready for synchronization
Pole Slip relay may be used for two phases for conventional protection schemes
**CONCLUSIONS**

- A dedicated breaker-flashover scheme is a must for breakers used to synchronize systems or generators.
- There are several methods for implementing breaker-flashover protection.
- Residual current and breaker auxiliary position method (Method-I) has lower dependability and security than other methods.
- Method II, based on phase currents, close monitoring, and coincidence timers, has a very good dependability and security.
- Present technology allows us to use multifunction intelligent electronic devices as well as separate breaker flashover protection relays.
Thank-you