External Flashover of Generator Circuit Breaker in Coastal Power Plants having Air Insulated Switchyard

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***Abstract*—The breaker flashover can be either internal or external. External flashover is mainly due to deposition on the external surface of the contact housings. In case of Power Stations in coastal areas, salt deposition takes place because of saline atmospheric pollution. Breaker flashover is an abnormal condition and may result in severe damage to capital equipment like Generator and Generator Transformer. Additionally it may also result in explosion of Circuit Breakers which can damage nearby equipment in Switchyard and put Substation personnel at risk. Numerical relays used for Generator Protection have the feature to detect breaker flashover condition and quickly isolate the equipment. This paper describes such problems at Mundra Thermal Power Plant in western coast of India and also dwells upon the causes, protection philosophy, preventive measures and recommendations.**

***Index Terms*—flashover, an unintended electric arc, creepage distance, shortest path between two conductive parts measured along the surface of the insulation**

I. Introduction

A. Brief Description of the Plant and the Problem

Adani Power Ltd is a Private Power Utility company in India having currently installed capacity of 6600 MW in three geographical locations and another 2640 MW is under installation. Mundra Thermal Power Plant is flagship plant of Adani Group having 4620 MW installed capacity and located in west coast of Gujarat State, India. The Power Station has 5 units of 660 MW and 4 units of 330 MW. Two units of 330 MW are connected to 220 KV and rest all units are connected to 400 KV grid.

The Power Plant is located 0.5 KM (Arial distance) away from sea. Humidity remains 70% in day time and 80% in night. Both 220 KV and 400 KV Switchyard are outdoor Air Insulated Switchyard (AIS) and the bus arrangement is Double main and Transfer and one and half breaker scheme respectively.

The Power Station has been experiencing failures of string and suspension insulators because of salt coating on external surface since 2009. The salt contamination in combination with dust because of proximity to sea lead to decrease in withstand voltage and dry band formation near cap & pin by high density of leakage current. Erosion of porcelain insulators result due to increased leakage current and finally it develops in to overall flashover.

Tracking along the insulator surface and consequent failures prompted the Power Station authorities to replace all the porcelain insulators with Composite long rod insulators and start hot line water washing on regular basis. The ceramic insulators of equipment like CT, PT, CB, Isolators etc. are part of equipment and hence can not be replaced. However these insulators have been coated with Room Temperature Vulcanizing (RTV) Silicone Compound.

B. Incidence

On 30/06/2012, at about 04.22 Hrs, the 330 MW Unit-4 was getting ready for synchronization with the grid after a forced outage. The Turbine Generator (TG) set was at 3000 rpm and the Generator isolator in switchyard was in closed condition. As soon as the voltage was built up to about 24 KV, external flashover took place across the Y-Phase Generator Circuit Breaker contacts with heavy sound and the insulator housing of the contact got broken. The unit got tripped on actuation of Generator Protection.

At the same time Local Breaker Backup (LBB) Protection of 400 KV bus also operated and all the breakers connected with the bus also got tripped.

II. Observations Post Occurence

Photographs of the damage Breaker pole has been placed below as Photograph-1 and Photograph-2.

Photograph-1: Damaged Breaker Pole

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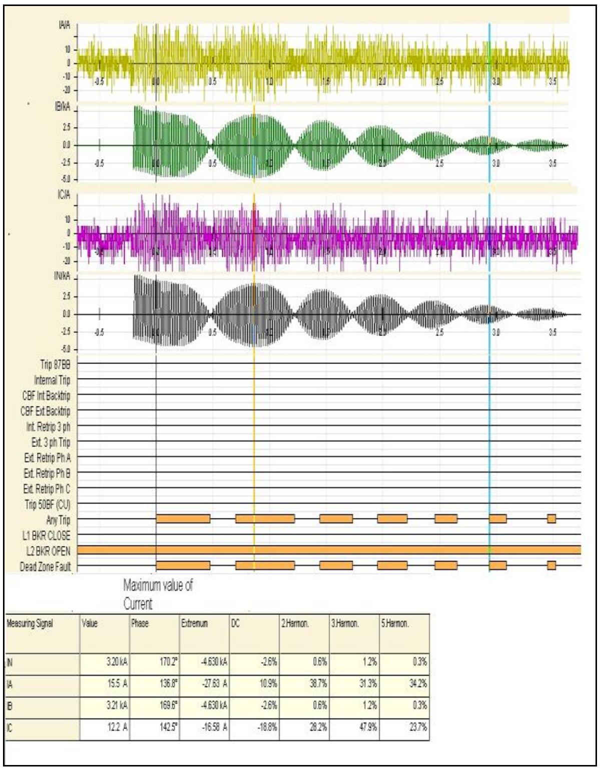
Photograph-2: Damaged Breaker Pole

The Disturbance Recorder (DR) chart of Generator placed below as Fig. 1 clearly showed flashover of Y-Phase CB. The current measured was 3.21 kA (RMS) and 4.63 kA (Peak).



Measuring Signal	Value	Phase	Extremum	DC	2.Harmon.	3.Harmon.	5.Harmon.
IN	3.20 kA	170.2°	-4.630 kA	-2.6%	0.6%	1.2%	0.3%
IA	15.5 A	136.8°	-27.63 A	10.9%	38.7%	31.3%	34.2%
IB	3.21 kA	169.6°	-4.630 kA	-2.6%	0.6%	1.2%	0.3%
IC	12.2 A	142.5°	-16.58 A	-18.8%	28.2%	47.9%	23.7%

Figure 1. Generator disturbance recorder chart

From the above observation and seeing the physical condition of the Circuit Breaker, it was concluded that the flashover in Y-Pole was due to external contamination in saline atmosphere. Since the machine was ready for synchronization, one side of the breaker was having grid voltage and other side voltage i.e. machine voltage was varying with respect to the grid voltage. Under such condition, breakdown voltage was reached across the breaker pole and flashover took place externally.

Similar flashover incidence has also been experienced by Mundra Thermal Power Station previously in Unit-3 and Unit-7.

III. Cause of Breaker Flashover

Flashover may occur across Generator Breaker terminals during synchronization while the breaker is open due to:

- External flashover due to contamination
- Internal flashover due to low dielectric pressure
- High level of humidity

Frequently, only one phase of the breaker flashes over during synchronizing procedures. In such case-

- Power system suffers an undesirable out-of-step and single-phase synchronization
- Extensive damage to generators and step-up transformers.

During synchronization process, the out-of-phase voltage angle between contacts changes from 0 to 360 degrees continuously. Voltage across the breaker contacts reaches its maximum instantaneous value when the angle difference between the voltages is 180 degrees as shown in Fig. 2 below-.

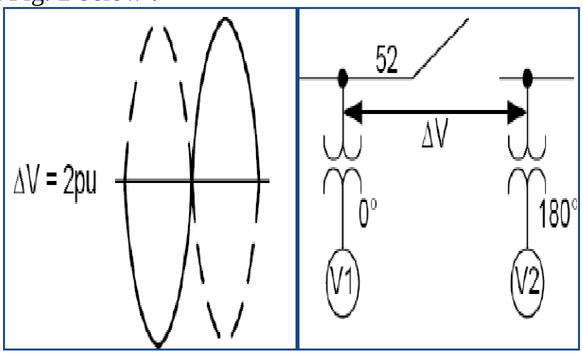


Figure 2. Voltage across breaker contacts

The voltage across breaker contacts before synchronization (considering connection with 400 KV Grid) -

Line voltage = 400 KV

Phase voltage = (400 / √3) = 231 KV

Peak value of Phase voltage = √2 x 231 = 327 KV

During out of phase condition, i.e. (voltage vectors 180 degree apart), net voltage across breaker contacts = 462 KV (RMS) and 654 KV (Peak)

This voltage may cause external or internal flashover depending upon the breaker condition.

IV. Methods for Flashover Protection

From the power system point of view, a flashover is a fault which is not a ground or a phase-to-phase fault, but a condition that resembles one phase of a breaker closed, with a residual current much lower than a phase-to-ground fault. A flashover can lead to a power oscillation. Multifunction Numerical Generator Protection relays have the function to detect both inadvertent energisation and also breaker flashover condition. However standard breaker-failure protections effective at detecting flashover failure require an external trip signal from another protection device to initiate the breaker failure. Relying on an external trip prolongs the failure until line, generator, or transformer protection trips.

The current flow during single phase CB flashover has been shown below in Fig. 3.

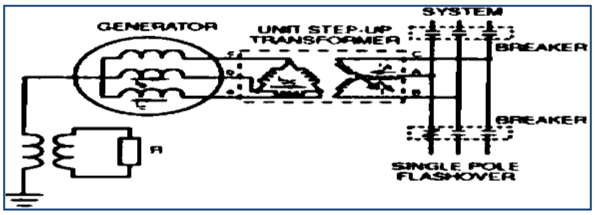


Figure 3. Current in case of single phase CB flashover

Following parameters can be used as inputs for detecting breaker flashover and design protection scheme for the same-

- Phase currents
- Residual current
- Voltages from one or both sides of the breaker,
- Breaker status 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.

A. Method-1

Based on residual-current measurement and a breaker auxiliary contact [52a- Normally open (NO) or 52b- Normally closed (NC)] supervision. Logic for triggering Breaker Failure scheme is shown in Fig. 4 below.

- Flashover is detected and the bus is cleared if there is residual current and the breaker is open.
- Require timer to eliminate mismatching in time of simultaneous closing of three phases.

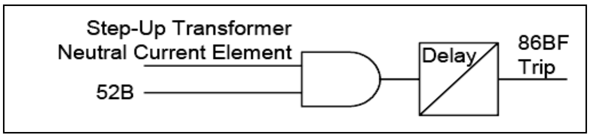


Figure 4. Logic for initiating breaker failure scheme

B. Method- 2

Time Limits and Close-Signal Monitoring to Detect Flashover is shown in Fig. 5 below.

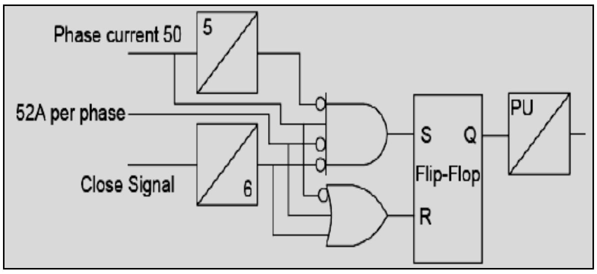


Figure 5. Logic for Detection of Breaker Flashover

In order to operate this logic requires-

- Phase current greater than set value and no current five cycles before the start of the scheme.
- Breaker auxiliary contact open.
- No closing signal to breaker at least six cycles before the start.

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.

Unbalanced currents associated with breaker head flashover will generally cause the generator negative-sequence relay to operate. This will initiate tripping of the generator breaker(s), shutting down the generator and providing the Breaker Failure Initiation (BFI) signal. The Breaker Failure Logic will be initiated only if the breaker failure current detectors are set with sufficient sensitivity to detect the flashover current.

In case the current detectors are set higher than the flashover current and breaker failure is not initiated, the result may be catastrophic failure of the generator. The key consideration for setting the breaker failure current detector is to set it below the level of the current expected for breaker-pole flashovers.

One approach used to speed the detection of a breaker flashover is to modify the breaker failure scheme as shown in Fig-6. An instantaneous overcurrent relay (50N) is connected in the neutral of the generator step-up transformer and is set to respond to an Extra High Voltage (EHV) breaker pole flashover current. The relay output is supervised by the generator breaker "52B" NC contact providing an additional start to the breaker failure scheme. When the generator breaker is open and one or two poles of the breaker flash over, the resulting transformer neutral current is detected by the 50N relay without the delay that would be associated with a negative sequence relay. The current detectors (CD) associated with the generator breaker scheme must be set with sufficient sensitivity to detect this flashover condition.

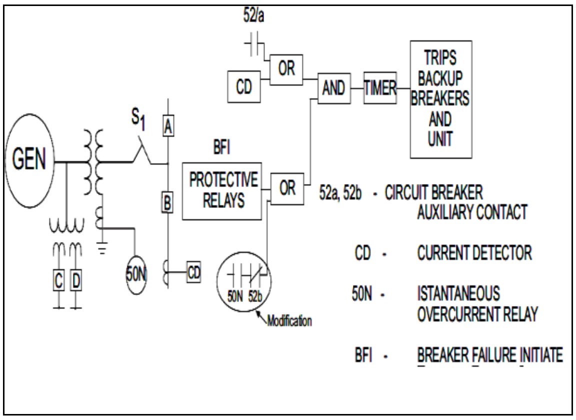


Figure 6. Speedy detection of Breaker Flashover

V. Protection Provided in Mundra Units for Breaker Flashover

A. Phase 1&2 Units

In Phase-1&2 the relay used for Generator Protection is P344 of AREVA make. In this relay, detection of Breaker flashover condition is by a neutral current measuring element. The relay standby earth fault protection element has been connected to measure the transformer HV earth fault current and provide the breaker flashover protection, via suitable scheme logic.

B. Phase 3&4 Units

In Phase-3 & 4, the Generator Protection Relay used is RCS 985B of Nanjing NARI Relays, China make. In this relay single phase and two phases flashover has been considered but three-phase flashover is ignored.

Criterion of circuit breaker flashover:

- Position contacts of three phases of circuit breaker are open
- Negative sequence current is higher than setting
- Excitation has been applied to generator, and generator voltage is higher than setting.

Operation of this protection will shut off excitation and activate BFI Protection.

VI. Preventive Measures to Avoid Flashover

The saline pollution environment is prevalent in all Coastal Power Stations. The degree of pollution may be different at different places.

Probability of breaker internal flashover is highest in SF6 type of breaker. However since external flashover is due to contamination, it can take place in any type of breaker. Following preventive measures need to be taken to avoid external flashover:

- Line isolators should be closed just prior to voltage build-up and when machine is ready for synchronization.
- Generator Breakers used in coastal areas should be designed with higher creepage distance (about 35 mm/ KV) or else use creep extenders.
- Regular cleaning of the insulator (Hot line washing with DM water) to avoid salt deposition.
- Avoid synchronization when humidity is high.

In Mundra TPP, the activity listed in 1 & 4 of above list is being done regularly. Additionally, HVCE (High Voltage Creepage Extenders) are being procured for use.

High Voltage Wraparound Creepage Extenders are designed for use in highly contaminated environments. The wrap around type cold applied variant is retained in place on the collar of the existing porcelain disc with the help of pressure sensitive mastic. Typically application of one extends nominal creepage distance of the existing insulator by 100 mm. It is also quite imperative to note that once 20% of the creepage is added with the help of extender, pollution withstand ability of the original insulator without creating electrical flashover enhances by more than double. The extenders are designed to be resistant to conventional spray washing techniques and will withstand most normal handling, abuse, and extreme weather conditions. Photograph-3 below shows a typical bushing fitted with Wraparound Creepage extender.

Photograph-3: HV Wraparound Creepage Extender

VII. Conclusion

Generator tripping on account of Breaker Flashover can be very disruptive and costly to the Power Utility. Determining the cause of the tripping and assessing equipment damage can take lot of time and consequent delay in returning to normal operations.

Following are the recommendations:

- Presently the cost of Gas Insulated Switchgear (GIS) has come down and indoor GIS can be considered. The author's strongly recommended to go for GIS in place of AIS in Coastal Power Stations. The capital cost of Switchyard shall be about 50% high, but the operating cost shall very less and payback period is about 5 years.
- It is critical to have good sequence-of-events and oscillographic data to review protective relay performance, assess fault levels and clear the machine of any damage. Instead of relying on fault recording feature of Numerical relays, dedicated DR should be installed in all large capacity Generators.
- A dedicated breaker-flashover scheme is a must for breakers used to synchronize Generators.

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