Case Study - How we solved an Earth-fault (mal)Tripping that was causing tripping of complete plant

Background

Routine Maintenance and Testing of the various equipments in the plant is one of the most important jobs, which is usually entrusted to experts. We are presenting herewith a case which makes such activities meaningful and can save the assets.

We were appointed to carry out the routine maintenance and testing of the Switchgears, Relays, CTs & PTs in one of the Continuous Process Plants in India.

During these activities, one day, the Engineer-in-Charge informed us that there is a long-pending problem in LT PCC Incomer Feeder, and whether we can solve it. The Earth Fault element operated every time the load increased beyond a certain limit (but within TR limit). As it was a continuous process plant, they had turned off the Earth Fault protection and were running the feeder without the Earth Fault protection. They wanted to take this protection in line.

Findings

As per the EIC, the plant operated on low loads and there was no evident fault (i.e., short circuit or considerable leakage).

Upon checking, Earth Fault protection was found to be of Derived type.

- In Derived type Earth Fault protection, current to the relay is fed from the Phase CTs only. From the available Phase currents, relay calculates the residual current which is represented as the Earth Fault current. Hence, inside the relay, vector summation of Phase currents ($\boldsymbol{I_a}$, $\boldsymbol{I_b}$ & $\boldsymbol{I_c}$) is carried out and Earth Fault current ($\boldsymbol{I_n}$) is derived.

$$\overline{I_a} + \overline{I_b} + \overline{I_c} = \overline{I_n}$$

- Above vector sum is always zero in normal condition. Hence, if the Earth Fault element operates, it is understood that this summation is non-zero, there is some unbalancing in three phase currents, which is higher than the adopted settings.

Unbalancing in the three phase currents can be due to unbalance loading condition also.
As the entire loading was 3-Ø and balanced, there was no question of unbalancing.

Image 1 : Actual Relay Measurement

As, it can be seen (*Image 1*) on the relay, Current in the Neutral is around 610 A. Earth Fault Pick-up was set at 400 A in the relay. Hence, relay kept operating when it sensed higher current. Phase CTs were having a ratio of 4000/1 A and the Earth Fault element was set at 400 A, i.e., 10 %.

Root Cause Analysis

- The programming of the relay was found in order. Tripping relays were assigned and operated as per drawings.

- The Relay was tested by secondary injection method and found healthy.

- The wiring to relay from CT and the CT links were found alright. It was decided then to check the CTs for its various characteristics.

Usually, for higher rating CTs, Primary Injection at Site is done at comparatively lower currents, due to size and weight limitations posed by higher current -injection kits. Besides, even if we somehow manage to inject such heavy currents, it does not usually lead to conclusive Ratio Measurement. High currents generate considerable heat in the injection cables (due to I^2t), which in turn results in fluctuation of currents, as the cable resistance keep on changing due to heating. Moreover, measurement of such large primary currents with Clamp-on Meter is also a challenge.

- So, we employed a state-of-the-art CT Testing Instrument, CT Analyzer of Omicron Make, which uses IEC 61869-2 standard and performs model-based testing which is far more accurate and conclusive.

The following are the results of Y Phase CT :

Secondary winding resistance

R-meas (25.0 °C)	2.722 Ω	R-meas (25.0 °C)+Rlead	2.722 Ω
R-ref (75.0 °C)	3.246 Ω	R-ref (75.0 °C)+Rlead	3.246 Ω

Excitation

Ls	Lm 0.009550 H	Results at rated burden (15.00 VA)		Results at operating burden (15.00 VA)	
Kr 100.37 %		ALF	ALFi	ALF	ALFi
Standard IEC 61869-2		εci (@ ALF=10)	> 61.220 %	εci (@ ALF=10)	> 61.220 %
V-kn	I-kn	Ts 0.001 s		Ts 0.001 s	

Ratio

Turns ratio	1194.7109	Results at rated burden (15.00 VA)		Results at operating burden (15.00 VA)	
εt	-70.1322 %	Ratio	4000.0 : 0.5064	Ratio	4000.0 : 0.5064
Polarity	OK	ε -49.3583 %	Δϕ -1574.06 min	ε -49.3583 %	Δϕ -1574.06 min
		εc 58.9874 %		εc 58.9874 %	

Image 2 : Omicron CT Analyzer Test Results for Y Phase CT

- We found that R and B Phase CTs were having minor errors, but Y phase CT had a ratio error of 50 % at rated burden. It means, CT will act as it is having a ratio of 4000/0.5 A instead of 4000/1 A. Phase angle error was also found to be -1574.06 min.

- Due to high errors (Magnitude and Phase angle) of Y Phase CT, relay mal-operated in Earth Fault element.

- The faulty CT was replaced with a new CT after proper testing and wiring, the Transformer was switched on and re-commissioned with loading.

SYSTEM PROTECTION
Electrical Engineers & Consultants
Consulting | Installation | Testing | Maintenance

Conclusion – how advanced technology can help solve such issues more accurately

- At times, routine test equipments, such as Primary Injection Kit, do not provide the conclusive results. It is likely that the fault in the equipment may go unnoticed / unchecked despite carrying out Routine Testing.

- Upgrading ourselves constantly with advanced technology has always been at the forefront for us, and we invest heavily in such technology so that our Customers can keep their protection systems safer and more reliable.

- Transformer is a very important asset, and the loss of production due to mal-operation of its protection system, can run into crores. All our efforts are viewing the problems from customers' point and resolving them in totality.

- The above was in fact the major problem found, we also observed some minor abnormalities and corrected them too. There could be many reasons for mal-operation of Transformer Protection System and can be addressed on case-to-case basis. To know more, you may call/write to us.

  And if you are looking for a dedicated agency that understands the direct link between your assets and your revenue, call/write to us, we will be happy to assist you.

SYSTEM PROTECTION

E-Mail : bdm@systemprotection.in
Web : www.systemprotection.in
Tele : +91-265-2225137
(Servicing & Testing of Circuit Breaker, Relay, CT, PT, Transformer, Other Switchyard Equipment's, Relay Co-ordination Studies, Cable, etc.)