Using the TESLA 4000 DFR to Detect Transformer Saturation

Due to Geomagnetic Induced Currents (GIC)

Introduction

Power systems on the earth's surface are periodically subjected to the effects of quasi DC ground currents induced by the sun's solar flares. Every eleven years, the sun has this peak activity. Past notable occurrences of peak GIC activity occurred in 1863 and more recently in 1989 (when Hydro Quebec experienced transformer damage as a result).

The year 2012 is a year when peak GIC activity will occur. Because predicting exact GIC effects is a rather complex phenomenon, it is easier to detect its effects instead rather than measuring the event itself. In this way, detecting that a transformer has gone into saturation is more meaningful than simply detecting the presence of GIC. When the DC current from a GIC event occurs and enters a transformer through a neutral to ground connection, this current can cause the iron transformer core to become saturated. The result of this will be a reactive current flow into the transformer, along with the generation of harmonic components in the currents and voltages.

Modeling Transformer Saturation Due To GIC Current

To validate this concept and to determine how much DC current is required to saturate a transformer core, an EMTP model (PSCAD/EMTDC) for a transformer was created and subjected to GIC.

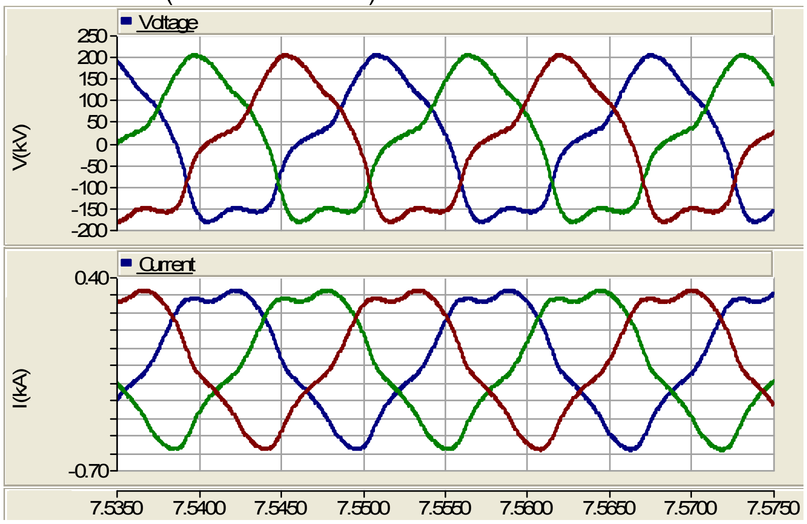

Figure 1: Voltage and current waveforms during GIC.

The waveforms shown in Figure 1, illustrate how the current and voltage waveforms into a transformer are distorted during a GIC occurrence.

The harmonic content of the current waveform of Figure 1 were extracted and are shown in Figure 2.

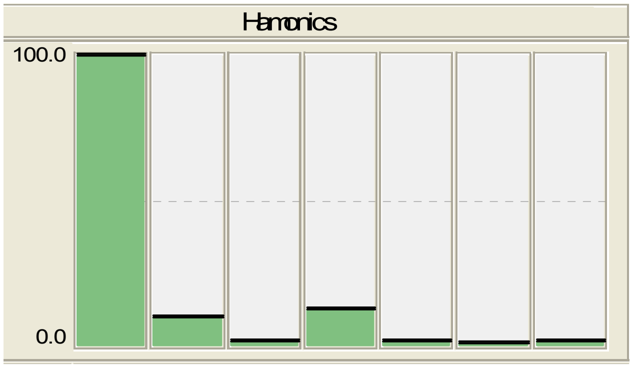

Figure 2: Harmonic components in the current waveform during a GIC storm.

Transformer Differential Relay Status During a GIC Storm

A transformer differential relay determines whether a fault is in a zone by comparing the current entering and leaving a transformer, as defined by the current transformers. This differential protection in many cases also uses 2nd and 5th harmonics in the currents to block the differential relay during energization, and often to block differential relay operation during overfluxing of the transformer (ANSI Device 24).

It can be seen from Figure 2 that harmonics created by the GIC effect could in fact block transformer differential protection during this period. As a result, transformer tripping from GIC possibly may not occur until the operation of a slow gas relay (after the damage has been done). Monitoring the harmonic content THD could enable earlier detection, protecting a transformer subjected to GIC.

Note: Two products, the ERLPhase T-PRO transformer differential relay and the TESLA recorder have the ability for the user to apply THD measurement to currents entering or leaving a transformer.

Providing Transformer Saturation Detection During a GIC Storm

Studies of transformers exposed to GIC storms have shown that there are several effects that occur for a transformer undergoing saturation.

Some methods available using a TESLA recorder are:

1. Monitor the DC current on the transformer's neutral connection. This could be done by measuring the voltage across a suitable shunt or by using some other suitable current monitoring device. The TESLA DC module could help accommodate this. Alternatively, some other type of DC current sensor with connection to the TESLA could be used.
2. Monitor the acoustic sound of the transformer tank. The acoustic sound given out during GIC saturation can be monitored and fed into the TESLA recorder. In this case a suitable acoustic sensor would be required.
3. Monitor the THD on the transformer input currents and voltages. TESLA can do this directly by bringing in the voltages and currents via the AC voltage and current modules, then setting the THD monitor function. A typical setting of THD might be 10%. A time delay of 2 or 3 seconds could be applied to prevent the THD function from operating during faults. The THD output can be a simple ALARM or can be set to close an OUTPUT CONTACT.
4. In addition to the THD, saturation of the transformer iron core will result in MX flow into the transformer from one or all sides. The amount of MX flow will depend upon a number of factors such as DC neutral induced GIC current and transformer tap position. Generally, however, if MX flow into the transformer

exceeds about 25% of the transformer rating, it is a good indication that GIC is present. The transformer manufacturer should be consulted to see what MX flow might be considered as critical.

Providing Transformer Protection from GIC Damage

Monitoring the transformer during a GIC storm can determine whether the transformer is going into saturation. The question is, “What should we do then?”. Depending upon specific conditions, several possible actions can be taken once an indication of transformer saturation is detected.

Possible actions might include:

1. Take the transformer out of service if load can be met by other transformers. This may be difficult as in all likelihood all transformers in the area will most likely be affected at the same time.
2. In lieu of 1, attempt to reduce loading on the affected transformer as much as possible.
3. In order to try to keep differential protection in service, try a setting change that minimizes differential restraint due to 2^{nd} and 5^{th} harmonics. Transformer differential relays like the T-PRO will successfully energize a transformer with secondary load connected (even with a high harmonic restraint setting) because of delta phase supervision.
4. Provide warning to the system control center operators about GIC presence with the possibility of transformer and shunt capacitor bank trips. Some actions may be possible by this control center to minimize some equipment outages.

Conclusions

The operation of a transformer subjected to GIC can be unpredictable because of the various factors in place. A simple warning detection can be done using a TESLA recorder measuring THD of the transformer voltages and currents. These warnings can be provided to control center personnel who may be able to reduce risk of tripping by lowering loads to reduce the heating effect. Presence of THD in the currents may also block differential protection. Gas relay protections will still be in service if a fault takes place within the transformer.