GIC Immune Transformers

An Evaluation of Their GIC Elimination and Fault Behavior

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The electrical power grid is vital to just about every function in today's society. Everything from household electronics to traffic lights to hospital appliances requires it to work. The effects of Geomagnetically Induced Currents (GICs) and unsymmetrical faults jeopardize this and must therefore be minimized. For the first time ever, the performance under these circumstances have been tested on the recently invented GIC immune transformer, for multiple transformer types, and the implementations behavior during unsymmetrical faults has been investigated in the referenced thesis.

In an ordinary, balanced, power system the currents in the three lines add up to zero, since they have a phase offset, see Figure 1. This means that no current actually flows through the neutral point to ground. Some times errors occur in the system, so called faults, which cause the sum of the three currents to deviate from zero and this current, a so called zero-sequence current, has to travel from neutral point to ground. The most common of these faults are the single-line-to-ground faults, e.g. lightning strikes. The neutral point impedance (Z_N) is used to handle these currents. The current can be compared with the water flow through a hose, in which the Z_N is a bottleneck on the hose, see Figure 2. If there is no Z_N the water flows freely but as Z_N increases it gets harder for the current to pass and the flow is decreased. At the same time the voltage, or pressure, before the Z_N increases and this affects the voltages in the un-faulted, sound, lines. It is important that both these voltages and the current is kept from increasing too much and this is done by choosing the right Z_N. What value should be used to obtain the same current and voltage levels when using the GIC immune transformer implementation as when using a regular transformer?

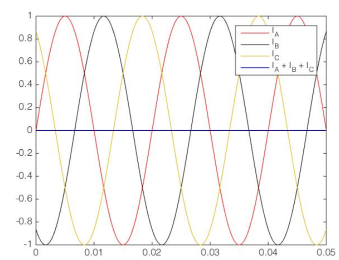

Figure 1: The three line currents, I_A, I_B and I_C, and the sum of their instantaneous values, which is zero.

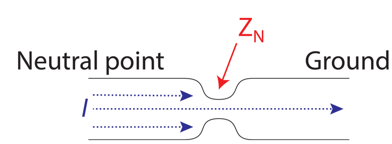

Figure 2: The Z_N acting as a bottleneck on the current flowing from the transformers neutral point to ground.

The simulations performed during the thesis show that as the compensation windings in the GIC immune transformer cancels out the transformers zero-sequence reactance, it is necessary to have a Z_N which makes up for this. This means that the Z_N used with the GIC immune implementation must have a larger reactance than the one used with the regular transformer. Transformers that use a certain connection configuration, have a low zero-sequence reactance and therefore only need a small additional Z_N, or none at all, when using the GIC immune implementation.

Geomagnetically Induced Currents (GICs) are currents with very low frequencies, near Direct Current (DC), that occur in the power grid when space weather, caused by violent changes in the Sun, make the Earth's magnetic field shift. These DC-like currents are the same in all three lines, thus their sum is not zero, and so they cause a zero-sequence-like current to flow through the transformer. GICs generate DC-offsets of the voltages causing the transformer to be saturated in the positive (or negative) half period, half-cycle saturation, which leads to the deformation of the current wave, i.e. the peak seen in Figure 3. This is harmful to the transformer and can cause malfunctions and lead to regional blackouts, which is not only costly but also a vast risk to society. In the year 2003 GICs caused a blackout in southern Sweden, leaving 50 000 customers without electricity for an hour.

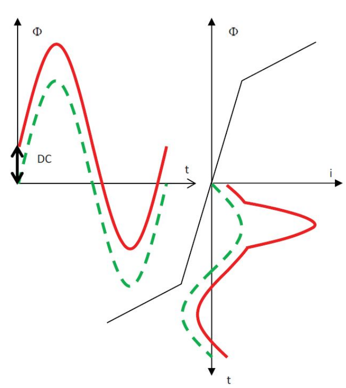

Figure 3: Half-cycle saturation of a transformer.

Public utilities are looking to find ways of securing their systems against the effects of GICs. Among the many possible methods of reducing the impact of GICs we find the GIC immune transformer invented at LTH and the relatively high resistance neutral point impedance (Z_N) used in e.g. Finland. Though it is not the primary function of Z_N, using an impedance which has a high resistive value will suppress the GICs. The GIC immune transformer is designed to cancel out all effects of GICs. In the thesis, different transformer types have been tested in this respect. How does the GIC immune transformer live up to its name? Is there any difference between the transformer types?

The experiments and simulations performed have shown that the GIC immune transformer completely eliminates the two effects of GICs, studied in the thesis, regardless of transformer type. This implementation is found to be much more efficient than the usage of Z_N, which only suppresses the effects. The experiments also show the significance of transformer type, in the regular transformer setups, since not all transformers are equally sensitive to GICs, and that utilizing the certain connection configuration, mentioned above, has a positive effect for them.

Resistance - A type of electrical opposition which is not dependent on the signals frequency.

Reactance - A type of electrical opposition which is dependent on the signals frequency.

Impedance - An electrical opposition which can be either resistive, reactive or a combination.