MEASURMENTS OF GIC IN THE NORWEGIAN HIGH VOLTAGE GRID

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Keywords

Geomagnetic induced currents (GIC), Measurements, Transformers

Abstract

GIC on transformers in the Norwegian power grid has been measured. The measurement setup is presented along with the results. The largest storm that has been measured so far was the 24th of April 2012. The peak value of the current in the transformer neutral was 40 A. This is in accordance with earlier measurements of GIC in Norway. More measurement equipment is to be installed and will be in place through the peak of solar cycle 24.

Introduction

With the sun entering the peak of solar cycle 24 there is a concern in power utilities regarding the vulnerability of the power grids towards geomagnetic induced currents (GIC). A systematic description of the challenges for power system operators can be found in [1]. The Norwegian transmission system operator (TSO) Statnett has initiated a R&D project for examining the impact of GIC on the power system. An important part of the project is to perform measurements if GIC. This is relevant for finding the true response of the grid towards solar weather. The measurements can be used to tune and validate simulation models.

About the Norwegian Power System

Statnett is the owner and the operator of the transmission grid in Norway. The Norwegian Power Grid consists of 420kV and 300kV solid earthed system and a 132kV of resonant earthed neutral system. Transmission lines run both West – East and North – South and the longest lines have a length in the order of magnitude of 120 – 150 km. The 300 kV and 420 kV lines are the most relevant towards GIC as the transformers connected to these lines have solid earth neutrals. The long term goal for Statnett is to have a 420 kV grid covering the whole country. One line that may be particulary interesting in association with GIC is the planned 420 kV line to Hammerfest, a city located at app 70 degrees north.

Transformer Trip due to GIC

Statnett has had one transformer trip that was due to GIC. Maintenance workers were at work in the substation when the incident occurred in the evening the 9th of November 2004. They reported increasing noise from the transformer. It was the buckholtz relay that made the transformer trip. This relay's purpose is to monitor the pressure in the transformer tank. Oil samples were taken from the transformer and it was inspected by the manufacturer. No damages were found, and the transformer was put into operation again. After this incident measurement equipment was installed on the transformer, however no GIC was measured in this substation.

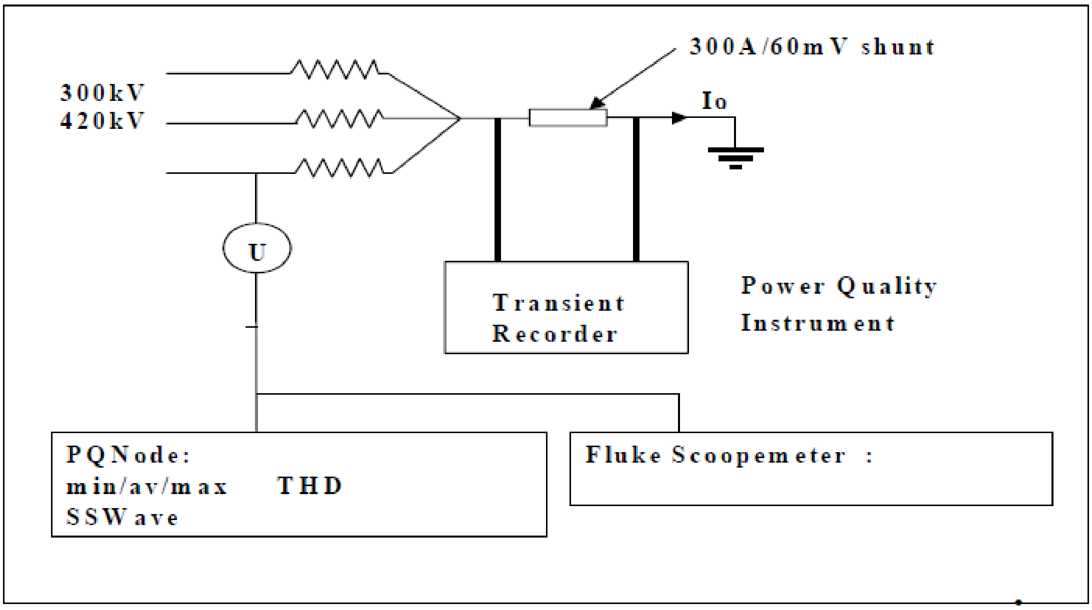
Measurement setup

Statnett has installed measurement equipment on chosen transformer from March 2012. The substations were the measurements have been installed have been chosen based in the following criteria (neither of the substations cover all)

1. Connection to long 300 or 420 kV lines
2. Substations were earlier measurements have been performed
3. Substations located far north
4. Substations located near the ocean

The measurement setup is shown in Figure 1. Both the neutral current and the phase voltages are measured to capture both the GIC current and the resulting increased harmonic distortion and the voltage drop in the station.

Figure 1: Measurement setup



Measurements

According to the magnetometer at Dombås, provided by the University of Tromsø, the most powerful solar storm in the period of measurements took place the 24^{th} of April 2012. Figure 2 shows the output of the magnetometer.

Due to asymmetry in the grid the transformer normally has a small steady state AC-current in the neutral point. This current is shifted during a GIC event. The amplitude of the AC current is also normally increased. The peak value of the current that was registered in the neutral point in one of the transformers in Sylling was 40 A. The DC component of the current during the first 40 s of the storm was 6.9 A. A plot of the RMS current in the neutral point of the transformer is shown in Figure 3.

Figure 2: Magnetometer Dombås, April 2012, [3].

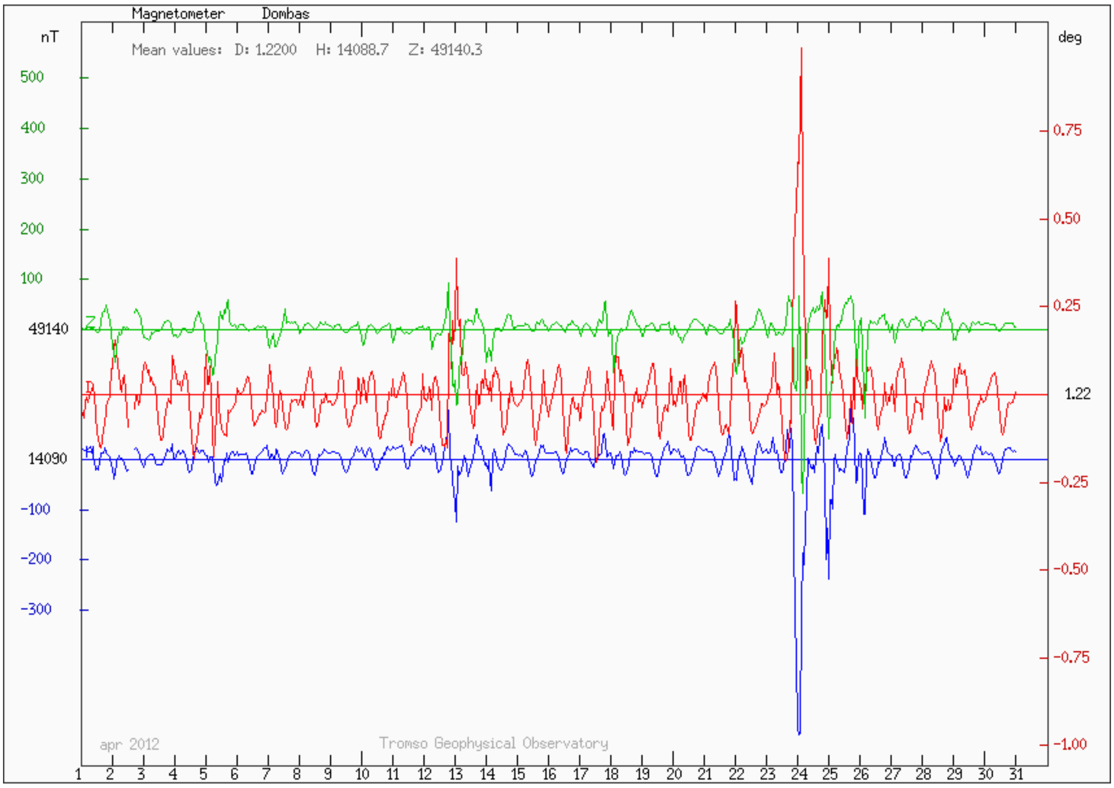
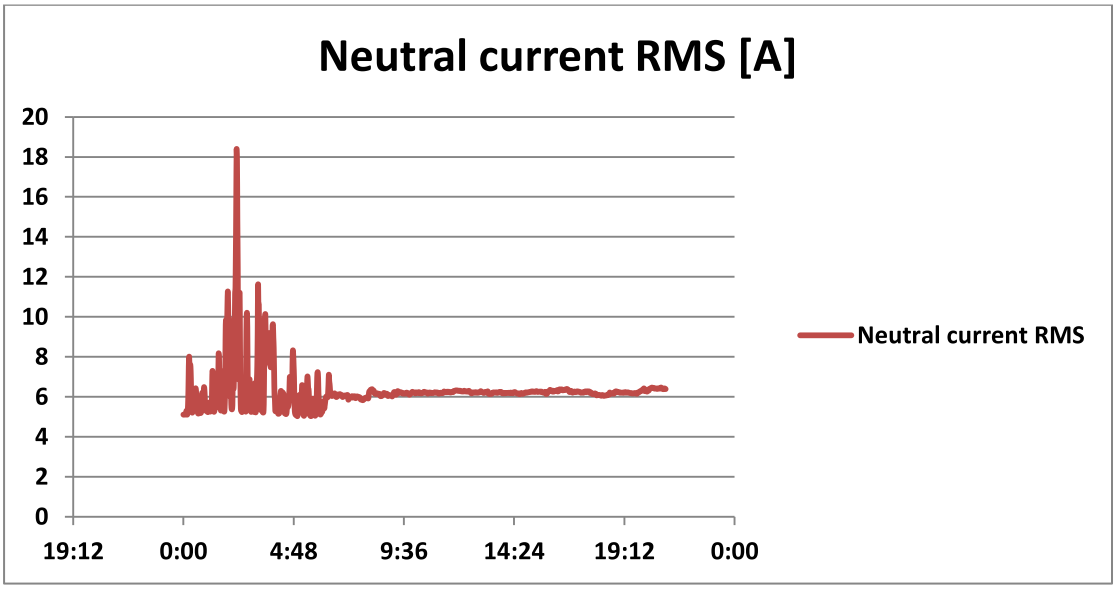


Figure 3: RMS current of the neutral current, 1 s average values.



In Figure 4 the total harmonic distortion (THD) of the voltage in phase A on the 420 kV side of the transformer is plotted. The neutral current is relatively small and the increase of THD due to half cycle saturation is small.

In addition to increased DC-component and maximum value of the neutral current during a solar storm, the harmonic content of the neutral current is also changed. This is shown in Figure 5, where the 5th and the 7th harmonic current are plotted. The 5th harmonic current is significantly increased.

Figure 4: THD voltage phase A

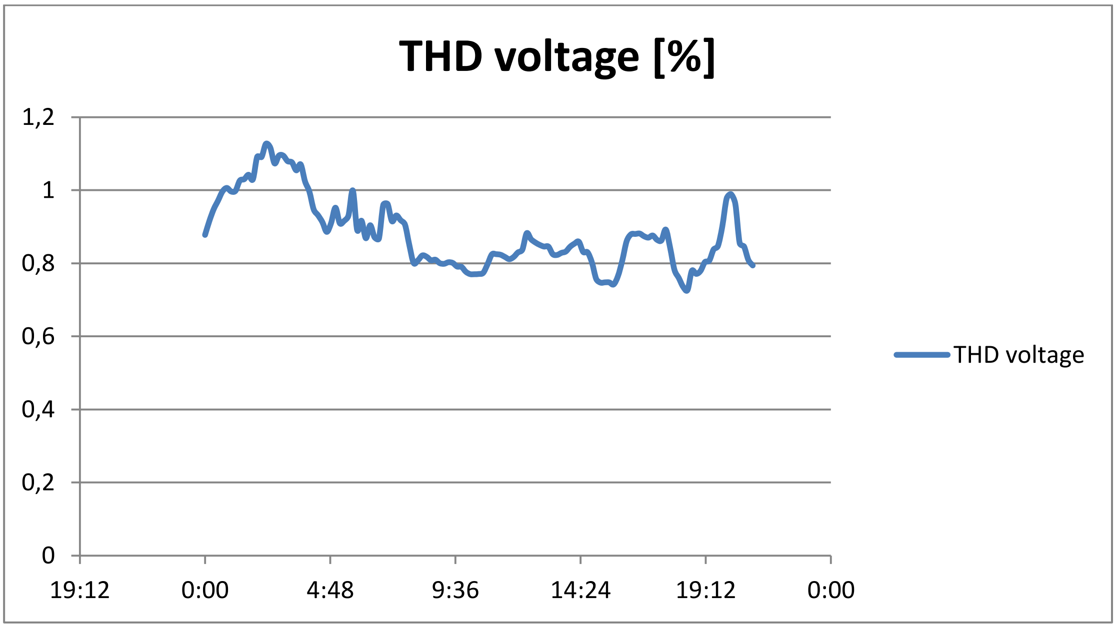
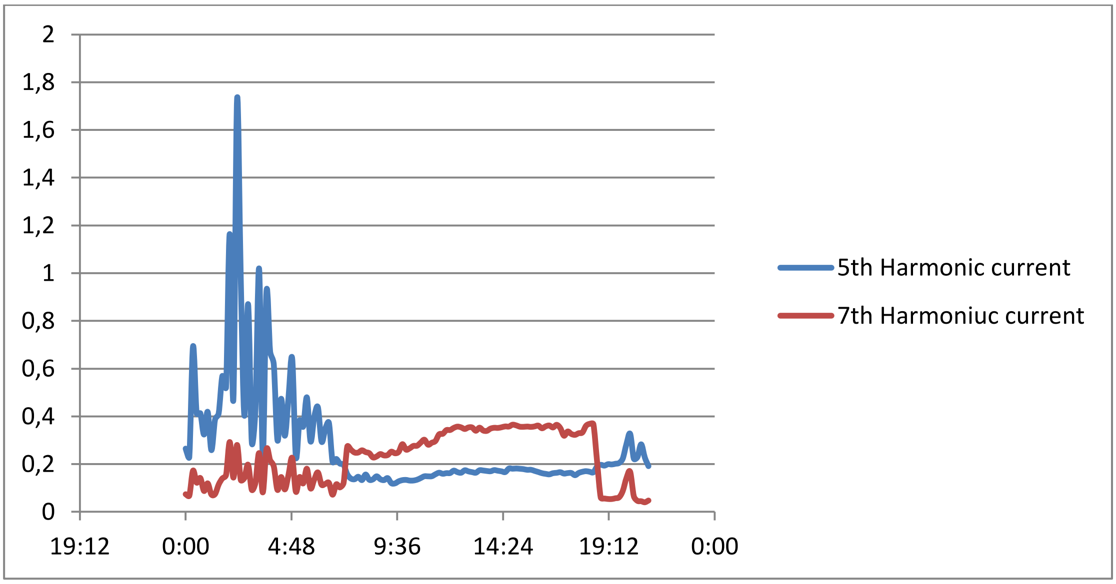


Figure 5: 5th and 7th harmonic current in transformer neutral (RMS), in Amps.



Earlier measurements

Statnett also performed measurements from February 1999 to June 2002. This was during solar cycle 23. The measurements are reported in [2]. A typic GIC that was measured had a duration of 4-7minutes, a DC component of 15 A and peak values up to 35 A. Different harmonics where present in the GIC, with 5. Harmonic as the most significant.
The phase voltages of the transformers were also monitored at the same time as the neutral current. The measurements show an increase in the total harmonic distortion (THD) of the voltage, and the RMS value of the voltage decreased. In one substation the THD typically increases from a steady state value of 1.3 % to a level of 2.4 % during a solar storm. The RMS value of the voltage can decrease 1-2 kV. The behavior is in accordance with what can be expected.

Conclusion and further work

Incidents when GIC enter transformer neutrals are not unusual in the Norwegian power system. However, the currents are small and cause little problems for the assets or for the system stability. The largest currents measured in 2012 had a peak value of 40 A. Earlier measurements show values in the same range. The equipment is planned to be in place during the peak of solar cycle 24.

References

[1] NERC/US Department of Energy, “High Impact, Low Frequency Event Risk to the Bulk Power System of North America,” June 2010 http://www.nerc.com/files/hilf.pdf

[2] Statnett SF, "Measurement of geomagnetically induced Currents , GICs, in the Norwegian Power Grid," Evald Sætre, Trond M. Ohnstad

[3] Univercity of Tromsø, Magnetometers, http://geo.phys.uit.no

Biographies

Øyvind Rui graduated from the Norwegian University of Science and Technology in Trondheim in 2009. He is now working with R&D in Statnett. His main interests are high voltage DC, transient simulations, insulation coordination and measurements.

Evald Sæthre graduated from the Norwegian Institute of Technology (NTH) in 1976 (M. Sc. – Electrical Engineering). Later he has completed several special courses on power system planning, insulation co-ordination, surge protection and power electronics and HVDC. His employment experieences include Norwegian Water Resources and Energy Administration (NVE) (1978-1986), the Norwegian Power Grid Company (Statnett) and the Norwegian Power Grid Company (Statnett). His special fields of interest are power quality measurements and calculations.

Trond M. Ohnstad graduated from the Oslo College, faculty of electrical engineering, in 1981. Subsequently he has completed several special courses on power system planning, insulation co-ordination, surge protection, power electronics, and HVDC. His employment experience includes the Norwegian State Power Board, the Norwegian State Power Company and the Norwegian power grid company Statnett. His special fields of interest are power transformers, insulation co-ordination and surge protection, power quality, and power system transients.