Comparison of Offline VLF PD Measurements and Online PD Measurements on a 50-year-old Hydrogenerator stator in Norway

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***Abstract*— Stator winding insulation is the part of the hydrogenerator experiencing the highest number and the most damaging failures. Partial discharge (PD) measurement, both offline and online, are commonly used for condition assessment and monitoring of electrical machines. The main concern of using very low frequency (VLF) methods is the changed electrical field distributions compared to that at power frequency. Hence, PD measurements performed at VLF should be carefully assessed and compared to PD measurements at power frequencies. In this work, offline PD measurement at VLF are presented and compared to power frequency online measurements of a 50-year-old hydrogenerator in Norway, using statistical analysis of phase resolved PD recordings. It is found that both offline VLF and online assessment can identify unnormal PD activity in a specific phase, although the phase resolved PD patterns are not similar for VLF offline and online assessment.**

Keywords — Hydrogenerator, stator insulation, condition assessment, partial discharges, very low frequency (VLF)

I. Introduction

The total installed capacity of larger hydrogenerators in Norway is more than 32 000 MVA. Most of the hydrogenerators was installed from 1955 to 1995. Generally, the technical lifetime of such generators is expected to be more than 50 years dependent on type of loading and operation. A significant percentage of the population has therefore likely reached its expected lifetime. It is determined that stator insulation damages are the significantly most frequent failures and those that produce the greatest extent of damage [1]. There is therefore a need for reliable diagnostic methods to detect degradation of the insulation system of the stator bars. The development and use of reliable diagnostic techniques will likely reduce assessment uncertainty and make the condition estimate more accurate.

On-line partial discharge (PD) monitoring and testing has been performed for many decades. Recently it has also been proposed to use variable voltage frequency PD techniques to improve the on-site degradation assessment of hydrogenator stator insulation systems [2]. Very low frequency (VLF) techniques are mainly based on using 0.1 Hz, but also other frequencies can be applied in the same range (0.001-1 Hz). The technique is very attractive as only a relatively small-sized voltage source is needed to energize the complete generator during the off-line PD measurements. However, it is important to keep in mind that the voltage distribution is different at off-line measurements as the stator bars in each phase are energized at the same voltage level simultaneously, and that also the voltage distributions can be different at endwinding sections, but also close to defects where the partial discharge occurs.

The main purpose of this paper is to compare online and offline VLF PD measurements on a hydrogenerator stator winding in Norway being more than 50 years in service. The measured data at 0.1 Hz and 50 Hz are compared using statistical shape analysis of resulting phase resolved PD (PRPD) patterns. Such analysis can be useful to determine the type of PD source [3].

II. Methodology

A. Test object

In this work a $U_N = 13$ kV line voltage ($U_0 = 7.5$ kV phase to ground), 95 MVA hydrogenerator installed in 1965 have been assessed. The stator bar high voltage insulation system is *Micadur*, which is a mica paper tape with glass-fibre backing [4].

B. Offline condition assessment

Offline PD measurements were performed in compliance with standards IEC 60034-27-1 and 60270 [5, 6]. A 0.1 Hz VLF source, connected in series with a lowpass filter, was used to generate the 0.1 Hz sine wave. The VLF source was connected to the LV terminal at the neutral point side, whereas PD data was recorded using a 5 nF coupling capacitor and PD monitoring system connected to the HV terminal. The pulse amplitude was normalized applying a 500 pC pulse at the HV terminal. The amplitude-spectrum was integrated with centre frequency f_c = 250 kHz and bandwidth δf = 300 kHz. The

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