Web-based PD monitoring of a Generator in Loforsen, Sweden

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Abstract: Electricity is an increasingly precious commodity. Thus, operators want to minimize the costs for maintenance and number and length of outages. Therefore the interest for condition-based maintenance techniques is increasing. To be able to perform condition-based maintenance a suitable method for diagnostics and/or monitoring is required. The recourses and time to gather, interpret and analyse the available is limited. Consequently there is need for an efficient tool to simplify this process. Therefore STRI, LDIC, VB Kraft and VB Elnät have decided to develop an user friendly on-line web-based PD monitoring system to monitor one of the generators installed in a hydropower plant owned by VB Kraft. The aim of this project is to get service experience with such a system for on-line analyzing using state of the art WAN communication. In this paper the complete system including, measuring system, generator, transmission and communication system and website together with the so-far obtained service experiences are presented.
The on-line monitoring system with its built-in pre-set levels establishes a fingerprint to which the on-going monitoring can be compared to see trends of deterioration. This enables the operator to plan for repair, refurbishment or replacement in a timely manner. After a reinvestment the performance of such activity can be monitored during the warranty time and thereafter.

1 INTRODUCTION

Generators represent and important investment and an insulation failure would cause a serious fault and long repair time. The possibility to monitor the condition of the generator and detect any trend that could result in a fault is therefore very valuable.

To be able to perform condition-based maintenance some kind of diagnostics and or monitoring is required. PD measurement is one of the methods to detect deterioration in insulation. STRI, LDIC, VB Kraft and VB Elnät have, in a joint project, developed an on-line web-based PD monitoring system to monitor one of the generators installed in a hydropower plant owned by VB Kraft.

The details of the generator, monitoring system are presented in this paper.

2 GENERATOR

The Loforsen generator is rated 7,7 MVA at 6,6 kV and directly coupled to a vertical Kaplan turbine at 500 rpm. It features a rotating brushless excitation system. The generator windings are cooled by closed-loop water-cooled air. It has been in operation since 1990.

Compared to the sole machine rating the Loforsen hydropower plant is situated underground at a fairly large reservoir. VB Kraft also controls all the upstream reservoirs in the catchment area. The main operating pattern is peak-power production. At periods, 2 – 4 weeks at a time, with ample runoff it operates around the clock at rated power.

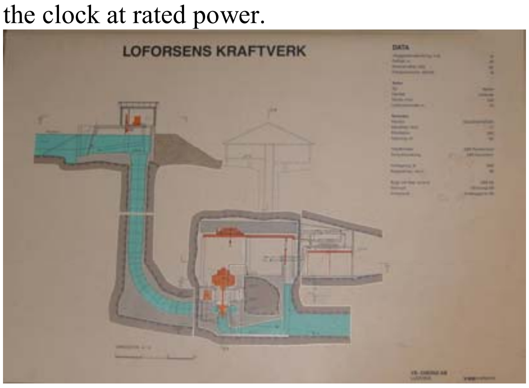

Fig. 1 Placement of the generator

Fig. 2 Part of the generator

3 MONITORING SYSTEM

3.1. Overview

A schematic overview of the monitoring system is presented in Fig. 3. As can be seen from the figure three coupling capacitors are connected to the generator. A more detailed picture is shown in Fig. 4.

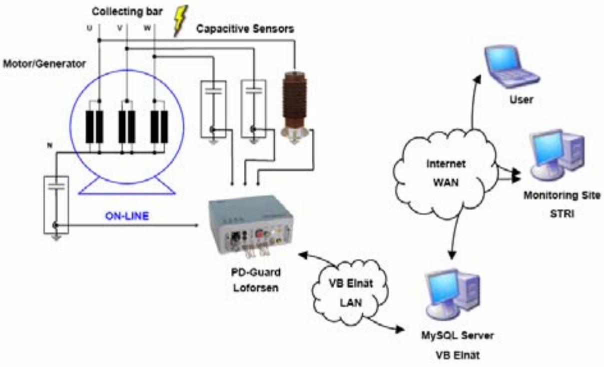

Fig. 3 Schematic overview of the monitoring system.

The coupling capacitors are connected to a acquisition device called PD guard. The PD guard is via an opto fiber connected to a SQL server that is positioned in an office of VB Elnät in Ludvika.

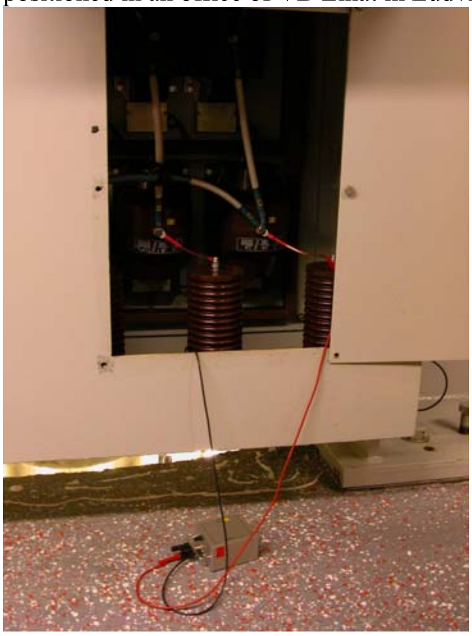

Fig. 4 Capacitors installed on site.

At a web server that is positioned at STRI a web interface is built based on the SOLA concept, which is described in paragraph 3.3.

The user can visit the website http://stri.se/loforsen and look at all project or device related documentation.

Information such as the latest measured PD values, PD trends can be seen and simple custom graphs can be made.

The analysis that need to be performed manually are performed by STRI. The result of these analysis are presented on the website, so the user has easily access to these. It is the idea that measurement results are interpreted and recommendations are made in case actions like maintenance or repair work are required.

The system is able to send alarms in case certain parameters exceed a certain limit.

3.2. PD Measurement Equipment

The measuring equipment comprises a PD guard, see Fig. 5 and 3 coupling capacitors. The present setup of the System in Loforsen is configured to take measurements every four hours.

Fig. 5 PD guard

The PD Guard monitors the PD signals decoupled with the capacitive coupler. With its 4 input channels it is able to acquire the signals of 3 phases and, if required, the neutral winding end. Basically, the operation of the PD Guard is the digital data acquisition and processing and the availability of a distributed Database Link into an Ethernet-based network. Principally, it is an IP device for real-time signal acquisition.

With a FPGA based signal processing, programmable digital filters can be configured according to the particular noise situation on-site. To suppress intermittent interferences a gating input is available. The embedded Linux-based microprocessor processes the acquired data into a real-time SQL Database and with the TCP/IP Interface the PD Guard is directly linked into an external SQL Host database. Each PD Guard device has an IP-identifier for communicating with the Server. The evaluation and analysis of PD data is processed at the database host and also the database management and administration.

The System can continuously measure, record and store PD data into an RAW data format. Phase resolved PD pattern recognition, trending and pulse sequence analysis can permanently be applied and used for failure recognition.

Danger/alarming signals can be released from a built-in alarm-processing unit. With a logical combination of predefined alarm levels like PD magnitude, repetition rate or time of appearance a combination of threshold levels and time can be adjusted individually. Alarm settings can be configured for each measuring device and each measuring channel separately.

The Monitoring devices are scalable to link multiple PD guards into one database and evaluation server. This can be used to monitoring several devices connected to different generators or transformers in parallel and to enter the data into one single database and evaluation server via internet. With the newest version of the PD guard PD signals, decoupled with UHF probes e.g. in GIS, can also be processed into the same database system.

3.3. STRI OnLine Analyzer (SOLA)

STRI already had comprehensive experience with surveillance systems [1][2], and noticed that at the same time where the need for surveillance and monitoring systems is increasing the time available for service personnel is decreasing. They simply do not have time to monitor, interpret and analyse the results. Further many of the systems currently used are owned by universities and manufacturers of HV equipment, implying that service experience is at best fractional.

Therefore STRI wanted to develop a system that gives the user information at the time the user wants, where historical information can be viewed, trends can be watched, gives alarms in case it is needed, and presents the information in an understandable way for large HV equipment such a generators and transformers. In the end the user needs to know if maintenance is needed and if so, what type of maintenance. It should always start with investigated which parameters need to be measured of which PD is one.

The platform chosen for the system is almost identical to the one used for surveillance as described in [1], [2] and is called SOLA.

A sceendump of the website is presented in Fig. 6.

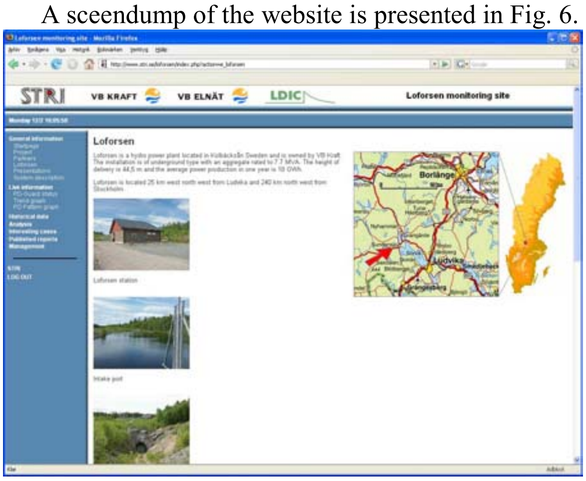

Fig. 6 Screendump of one of the pages of the monitoring site: www.stri.se/loforsen.

Further, as STRI in an independent service and consultant company and has expertise and access to expertise in the area of HV applications, information and experience with different HV equipment can be collected.

4 MEASUREMENT RESULTS

Some typical obtained measurement results are presented in Fig. 8 and Fig. 7.

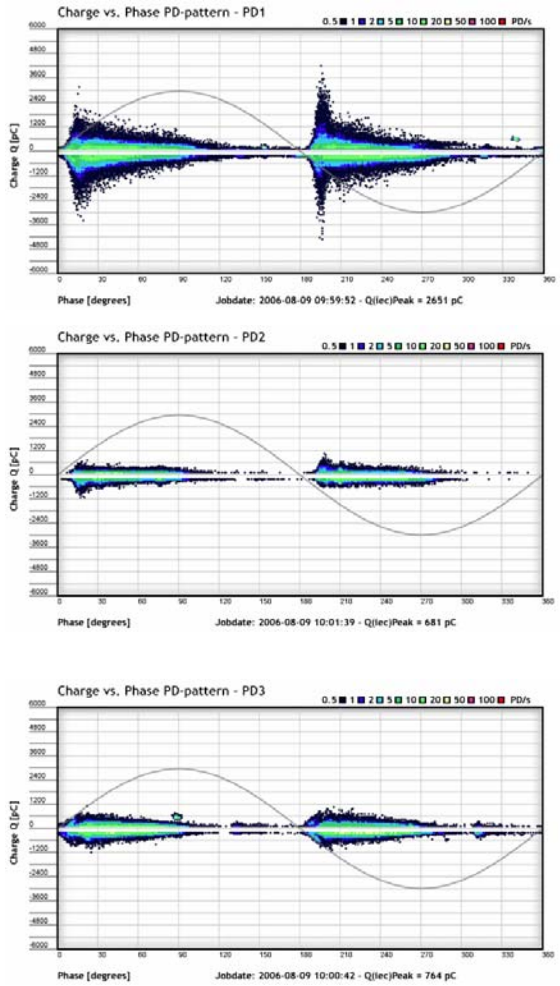

Fig. 7 A phase PD pattern of all three phases (measurement taken at almost the same time)

One can see from the results presented in Fig. 7 that there is a difference in the PD level of phase L1 (PD1) compared to the PD levels of phases L2 and L3. The reason for this difference is not known yet, but most likely due to temperature differences in the three phases. This needs to be investigated in more detail even though the overall PD level is not alarming.

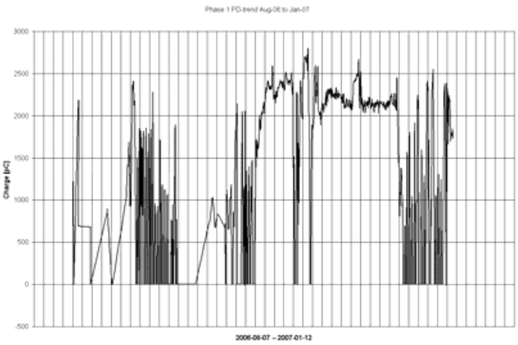

Fig. 8 A trend graph of the measured PD for one of the phases.

The peak-power operating pattern can easily be noticed in Fig. 8.

5 EXPERIENCES

The obtained experience has been very positive. No outages in the data acquisition system has been reported since the installation of the monitoring system.

The PD patterns and trend graphs are easy to retrieve from the system. Users from the system do however want some more information about the information one can see in the PD patterns and want some recommendations about acceptable PD levels.

6 ADVANTAGES OF CONDITION BASED MAINTENANCE

Unplanned outages caused by damaged windings are very costly due to the long downtime before the generator is repaired and the often high cost for buying replacement power. Monitoring of partial discharges and analysis of the measured values offer a way to catch deteriorating windings well before they go to failure. That enables the operator to schedule an outage for repair, refurbishment or replacement. A scheduled outage before failure costs much less than an unplanned one.

A lot of the hydropower and thermal plant generators in operation are 50 years or older. They were almost entirely designed for continuous base-load production. Many of them are now in peak-power production with inherent frequent starts and stops. This causes thermal and mechanical stresses to winding insulation, which it was not designed for. Thus on-line monitoring and analysis of PD is a valuable tool to determine when to make repair, refurbishment or replacement and also in which order such activities should be performed among the operator's generators. The lead times for windings and other generator components are often in the range of about one year or more.

After repair, refurbishment and replacement has taken place the on-line monitoring and analysis of PD enables the operator to determine the performance of any said activity. Initially the PD level can be checked for compliance with contract criteria and to establish a footprint. Subsequently the performance may be compared to it throughout the warranty time and from then on.

7 FUTURE WORK

It is planned to also monitor the temperatures of the windings and the power of the generator.

Interpretation rules need to be developed to know when to trigger an alarm and to know what type of failure one actually sees from the PD patterns. This will be the scope of a project that will start in March 2007.

VB Kraft also indicated that some kind of localisation system will be needed to localise the failures in case a failure is detected. This needs to be done, since with a monitoring system failures will hopefully be discovered earlier and then when opening the generator it might not be so easy to see the location of the failure, especially since the generator is very large (some meter) and the failure very small (some mm).

8 CONCLUSIONS

It was possible to develop an on-line web-based PD monitoring and diagnostic system to monitor one of the generators installed in a hydropower plant owned by VB Kraft. The obtained service experience with the system was very positive.

The system easy to use and gives the user the information about the measured PD, in a way that is understandable for them at times that they choose themselves.

The interpretation and localisation of the measured PD patterns and trend graphs is a subject of a study that will start in March 2007.

9 ACKNOWLEDGMENT

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10 REFERENCES

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