Monitoring and diagnostic center for generators
NENAD KARTALOVIC, BLAGOJE BABIC, SAVO MARINKOVIC, DRAGAN TESLIC, ALEKSANDAR NIKOLIC
Electrical Engineering Institute Nikola Tesla
University of Belgrade
Koste Glavinića 8a, 11000 Belgrade
SERBIA
nenad.kartal@ieent.org, www.ieent.org

Abstract: Modern control systems in Power plant can not be realized without the modern monitoring system of process parameters or parameters of machines and systems. This paper presents a pilot project of monitoring center for generators in Power plants, company Electric Power Industry of Serbia. It is based on indirect monitoring of other measurement variables which are available via SCADA system. Development of generator's monitoring contributes to the development a diagnostic of generator, implementation of condition based maintenance, contributes to a more reliable estimate of the remaining life expectancy of the generator and so on.

Key-Words: generator, monitoring, diagnostic, partial discharge, insulation

1 Introduction
Before the formation of the pilot project of monitoring center for generators in Power plants, company EPS (Electric Power Industry of Serbia), had implemented comprehensive survey of contemporary practice and professional literature in the world.

Modern control systems in Power plant can not be realized without the modern system of monitoring of process parameters or parameters of machines and systems. Continuous monitoring includes continuous monitoring of machine operation (on line), automatic storage of information and the possibility of automatic or subsequent processing and analysis. It also includes the generation of specific alarms and their submission to the operator and control system, according to a certain procedure [1].

Continuous monitoring is of growing importance for several reasons. Firstly, the process by Power Plant are increasingly automated and the increasingly stringent requirements of exploitation. On the other hand, workers and experts that are working in the plant are reduced. It should be borne in mind that the monitoring of electrical machines is traditionally on relatively low level [2].

This paper presents a pilot project of monitoring center for generators in Power plants, company EPS. It is based on direct monitoring of partial discharge (PD) and on indirect monitoring of other measurement variables which are available via SCADA system. For now, the focus are on monitoring and analysis for diagnosing the condition of the insulation system of hydro and turbo generators. The intention is to develop the center into a global monitoring center at the corporate level.

2 State of Generator’s Insulation System
Generator's insulation system and the entire generator are exposed to various stresses (long or transient). The effects of the above factors are given in Table 1 [3].

Table 1. Factors that reduces the service life of the generator

<table>
<thead>
<tr>
<th>factor of aging</th>
<th>way of influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermal</td>
<td>• the normal aging process</td>
</tr>
<tr>
<td></td>
<td>• accelerated aging due to over-</td>
</tr>
<tr>
<td></td>
<td>heating</td>
</tr>
<tr>
<td>electrical</td>
<td>• transients / surge voltages</td>
</tr>
<tr>
<td></td>
<td>• partial discharges</td>
</tr>
<tr>
<td>mechanical</td>
<td>• mechanical shocks</td>
</tr>
<tr>
<td></td>
<td>• vibration</td>
</tr>
<tr>
<td></td>
<td>• erosion</td>
</tr>
<tr>
<td>environment</td>
<td>• moisture</td>
</tr>
<tr>
<td></td>
<td>• conductive dust</td>
</tr>
<tr>
<td></td>
<td>• chemicals</td>
</tr>
</tbody>
</table>

When stress, normally permanently or transiently attains endurance coils or other parts of the generator and leads to generators collapse, the generator removes from the plant for a long time, Fig. 1. This may lead to increased repair costs and unplanned losses due to electricity production.
The question is "what is service life", Figure 1. It is obvious that the service life is statistical value that depends on many factors. The modern monitoring system enables the monitoring of many measuring values and a good diagnostic of state of generator and the power system. Only their comprehensive knowledge provides an objective and reliable assessment of service life.

3 Test and Diagnostics

Diagnostics of the generator are based on a wide range of data from off-line and on-line testing generators and data analysis. All test data, operating data, data of the machine, are stored in a database for generators. Thus, all test data from any lab, repairs, unexpected events, failures are available for analysis. The data in the database with each successive inspection and testing are updated. The database is very flexible and has the ability to expand for all possible new types of tests, acquisition of photo records of visual inspections, etc. Search and analysis of various data are practically not limited [4].

Some of the basic methods of testing generators are:
- measurement of insulation resistance of the stator winding (and the polarization index);
- measurement dielectric dissipation factor (initial value and increments);
- Measurement of leakage current in HV AC and HV AC;
- measurement of partial discharge activity (off line, on line);
- high pot test;
- ramp-test;
- measurement of resistance coils;
- check the cooling system of the generator;
- measuring the frequency of vibration of the stator winding head;
- testing package sheet nominal and low value of magnetic induction (hot spots);
- bump test of magnetic core.

4 Significance of partial discharge activity

According to a series of studies, reliability and service life of the generator depend largely on the behavior of the stator (especially coils). Also, most of the time is spent to repair just the stator.

Table 2 shows the main types of failures of the generator stator. In order to determine the degree of importance of various failures, and in that way to establish scale of the importance, "qualitative damage index" ("index"), linked to a individual defect.

Table 2. The main types of hydro generator stator failures.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of failure</th>
<th>A</th>
<th>B</th>
<th>Index</th>
<th>PD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>weakening of coil's bracing</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>+</td>
</tr>
<tr>
<td>2.</td>
<td>weakening of the core tightness</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Vibrations of coil's head</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td>4.</td>
<td>Insulation damage due to PD</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>+</td>
</tr>
<tr>
<td>5.</td>
<td>Insulation damage due to core damage</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>+</td>
</tr>
<tr>
<td>6.</td>
<td>Interphase short circuit</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>+</td>
</tr>
<tr>
<td>7.</td>
<td>Local preheating of sheets</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>weakening of the elements for radial fixing of the cores</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>weakening of the elements for axial fixing of the cores</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>breaking of the winding head</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>+</td>
</tr>
</tbody>
</table>

Note:
- **type of failure**: Basic types of machine failure during operation
  - **A**: The frequency of failure: 4 = often, 3 = less often, 2 = rarely, 1 = very rarely
  - **B**: The cost of repairing the fault (1000USD): 1 ≤ 7.5; 2 < 15; 3 < 25; 4 < 50; 5 < 100; 6 > 100
From Table 2 we can note that the PD measurement can point to six of the ten types of failure represented for the stator. The cumulative damage index value is 41 (out of possible 59), which is more than two-thirds of the possible total value of damage index.

**Figure 2.** Statistical distribution function of PD charge [2].

As stated above, the majority of failures in the insulation of the stator winding were monitored by some kind of partial discharge activity. What type of PD activity is done is determined by statistical analysis, Figure 2. Increased activity of partial discharge in off-line or on-line measurement indicates the need for additional testing and inspection of the insulation.

Off line testing is performed during regular big overhaul conditions that are not realistic. For that reason, is preferred on-line monitoring PD. It can detect potential problems at the very inception and provide timely prediction of major failures.

The study of the correlation between the activity of partial discharges and other operating variables (active and reactive power, temperature ...) can significantly contribute to the diagnosis of the state of the generator.

### 5 Pilot Diagnostic and Monitoring Center

Diagnostic Center for evaluation of generators has a complex hierarchical structure to the extent of their activities and in their work organization. Diagnostics in power systems is a multidisciplinary point of view of the phenomena and processes, and a variety of speaking with foreign objects of interest.

Phenomena that are of interest for the diagnosis and monitoring in the event of a generator are:

- Partial discharge (PD)
- vibration
- temperature
- magnetic flux
- gases (ozone, ...)
- refrigerants
- parameters of the process and so on.

Of importance for the diagnosis and monitoring, in addition to the generator are:

- power and instrumental transformers
- large motors
- bus, switches, reclosers, insulators.

Facts (above mentioned) indicate the structure of the diagnostic center. The block diagram is shown in Figure 3. Within the structure of the diagnostic center a demonstration center for PD monitoring on generators (company EPS) is implemented.

Diagnostic center for power plant includes centers for the diagnosis of generators, transformers, motors, equipment, etc. Figure 3. Within the diagnostic the generator, there is a part of the insulation system diagnostics. Within the monitoring center, Figure 3, there is a monitoring center for partial discharge.

Monitoring Center is distributed and consists of several parts placed in a diagnostic center and power plant. There are measurement data acquisition systems in power plants (for partial discharge, vibration, magnetic flux, temperature, etc.) and monitoring of operating variables via SCADA system, Figure 3. The diagnostic center has personal terminals and server. Whole system is integrated with the communication system and various application software.
Figure 3. The structure of the diagnostic center; monitoring center for PD is within the monitoring center as a structural part of the diagnostic center.

6 Development of the monitoring center

The initial core of the diagnostic center is the existing traditional diagnostics of insulation systems of generators that develops towards the use of new knowledge and technologies.

Development activity of center can be classified into three main categories: daily, periodic and strategic activities. They can be characterized as:

- **Daily activities** include archiving and analysis of data obtained from the monitoring system. Daily communication should be maintained with clients of center (exchange of information, suggesting activities, etc...).

- **Periodic activities** are primarily related to the generation of quarterly and annual analysis and reporting. Permanently work on developing analysis and diagnostics is necessary.

- **Strategic activities** are long-term activities in the work and development center (plans and development strategies). Projects and studies, implementation of monitoring partial discharges and other sizes on specific generators.

Figure 4. Part of the monitoring center located at the Institute of Nikola Tesla.

Diagnostic center should develop scientific research and diagnostic activities through various scientific research projects and participation in professional and scientific meetings. The Centre should organize appropriate technical and promotional / educational meetings for service users and the wider scientific community, which would be strategically important on the development of human resources in the Institute and users.

References:

[1] Pablo Mendivil Ruas, Tomás Alvarez Tejedor, Rafael Sandrea, Jose I. Garcia, IBERDROLA’s Center for Monitoring, Diagnostic and Simulation (CMDS) of Combined-Cycle Power Plants


[4] Claude Hudon and Mario Belec, Partial Discharge Signal Interpretation for Generator Diagnostics, IEEE Transactions on Dielectrics and Electrical Insulation Vol. 12, No. 2; April 2005