EXPERIENCE WITH ON-LINE PARTIAL DISCHARGE MONITORING OF GENERATORS AND MOTORS

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INTRODUCTION

On-line partial discharge (PD) monitoring has become the most widely applied method to determine the condition of the electrical insulation in stator windings. Presently over 12,000 large motors and generators around the world are equipped with the required sensors. Over 55 years of experience with on-line PD testing shows that it will detect most (but not all) of the common manufacturing and operations-related problems, including:

- Loose coils in the slot (slot discharge)
- Overheating (long-term thermal deterioration)
- Winding contamination by moisture, oil, dirt, etc.
- Load cycling problems
- Poor resin impregnation during manufacture
- Inadequate electric stress control coatings in the slot or endwinding
- Insufficient spacing between coils in the endwinding area.

PERIODIC ON-LINE PD MEASUREMENT TECHNOLOGY

A particular challenge with PD measurements is encountered when the motor or generator is operating normally. Since the machine is connected to the power system, electrical interference (noise) is often present. Noise sources include corona from the power system or electrostatic precipitators, slip ring or commutator sparking, sparking from poor electrical connections, and/or power tool operation. This electrical noise obscures the PD pulses, and may cause the technician to conclude that a stator winding has high levels of PD, when it is actually the noise. The consequence is that a good winding is incorrectly assessed as being defective, meaning that a false alarm is given suggesting that the winding is bad, when it is not. Such false alarms reduce the credibility of on-line PD tests, and even today, many feel that on-line PD testing is very subjective and best left to specialists.

Twenty-five years ago, the North American utility industry (via the Canadian Electrical Association) sponsored research to develop an objective on-line PD test for machines that could be performed and interpreted by plant staff, rather than experts form machine manufacturers. The type of PD test emphasized separating PD pulses from electrical noise pulses. For motors, hydro generators and small turbo generators, 80 pF capacitors detect the PD, while blocking the high AC voltage. In these machines noise separation methods depend on digitally comparing the time of pulse arrival between a pair of 80 pF capacitive couplers on each phase and/or analyzing the shape of the individual pulses. To maximize the signal-to-noise ratio, and thus also to reduce the risk of false indications, the sensors detect the PD at frequencies of 40 MHz and higher. For larger turbo generators (greater than about 200 MVA), it was found that some sorts of noise from with the generator – for example poor electrical contacts at the gas seal bushing, could be misinterpreted by the capacitive sensors as stator PD – leading to false indications. This led to the development of the SSC sensor which is installed within the stator slot, and seems to be very immune to false indications.

Globally, well over 12,000 machines have the required PD sensors. Interpretation of the PD results is done by analyzing each test result and trending the stator PD over time. The false indication rate using the appropriate sensors and noise suppression methods is less than about 1.5% of “high” readings. Experience shows if the PD magnitude doubles, under the same operating conditions in 6 months or so, the rate of insulation deterioration is increasing significantly. More recently, based on a statistical analysis of data from >140,000 tests, tables of what constitutes a high reading as a function of machine rating and PD detection system have been published (e.g. Table 1).

Table 1: High On-Line PD Levels measured using 80 pF capacitive couplers at motor terminals, operating from a conventional 60 Hz power supply

Voltage Class	High PD Magnitude (mV)
2-4 kV	274
6-8 kV	276
10-12 kV	401
13-15 kV	461

CONTINUOUS ON-LINE PD MONITORING SYSTEMS

Stator winding insulation deterioration is a relatively slow process in which the time between when significant PD can be detected and when winding failure may occur, is usually two or more years in air-cooled machines, and even longer in hydrogen-cooled machines. Thus, periodic measurements done once every six months or so are often adequate for detecting stator winding problems with sufficient warning to conveniently implement corrective action. However, in highly automated or remote plants, continuous monitoring may be advantageous.

For the above reasons, first generation continuous PD monitoring systems were developed for hydro generators, and after some teething pains, were successfully deployed in 1994. However, these early systems had a relatively high installation cost and did not enable generator operating data to be extracted from the plant computer. Under a joint development project between the USA-based Electric Power Research Institute and the New York Power Authority, next-generation continuous monitors were developed. This technology was then extended to the more difficult situation (from a noise point of view) of turbo generators and motors. Today, more than 1500 machines have been equipped with continuous PD monitoring systems.

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