DEVELOPMENT OF VIBRATION CONDITION MONITORING SYSTEM APPLYING OPTICAL SENSORS FOR GENERATOR WINDING INTEGRITY OF POWER UTILITIES

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This paper describes the vibration condition monitoring diagnosis system developed for stator and rotor winding integrity assessment of 100MW class gas turbine generator in combined-cycle thermal power plant. High reliability of windings is one of the most essential prerequisite for generators of power utilities. Assessing the condition of stator winding insulation systems requires objective information from condition monitoring system. In-service monitoring is essential if a power plant is following a condition-based maintenance strategy. Generator damages are caused by the high vibration and the power system instability by secondary impacts of an unannounced plant stop and the life of the generator is decreased. The mechanical vibration in generator is induced by both mechanical and magnetic forces. The vibration condition monitoring system is required for the improved savings of operation and maintenance cost in terms of reliability in power plant.

Keywords: Inter-annual Degradation; Generator Winding Integrity; Integrated Condition Monitoring System; Optical Vibration Sensor; PD sensor ; Shorted-turn Sensor.

1. Introduction

Long-term use and efficient operation of equipments in power plants demand the diagnosis techniques to improve reliability and to reduce the operating and maintenance cost urgently requested due to larger in size as well as inter-annual decrepitude due to aging. The device monitoring the status of the equipment is required because of deterioration of the performance of these facilities and a variety of causes and symptoms of abnormal conditions caused by a sudden load change, other than operations. The

efficiency and accuracy for monitoring and diagnosis system has been improved with the development of new technologies. By applying the latest technology, which "condition based maintenance" reducing the period and extending the cycle, it is known that the equipment maintenance cost was reduced approximately 14% and the productivity was improved by 60% [1].

Predictive maintenance; condition-based and proactive maintenance; root cause-based are interest in the emerging core technology for predictive failure diagnosis. The development of vibration monitoring system is essential in order to apply to them. Then, the condition monitoring and diagnosis system may be substituted the aging vibration monitoring systems of power plants in Korea. The maintenance activities affects production cost, productivity, and quality. Thus, the maintenance technique which may minimizes loss of the facility by preventing the untimely stop is going to evolve into preventive maintenance or condition based maintenance. In particular, the recent trend, which departs from simply monitoring of real-time state, is proceeding to develop the correlation integration system considering the information of operation and the variety analysis in abnormal conditions of the equipment.

This paper describes the vibration condition monitoring diagnosis system developed for stator and rotor winding integrity assessment of 100MW class gas turbine generator in combined-cycle thermal power plant. High voltage rotating machines including generators in 230 units in Korea are expected to increase during operation failure due to driving conditions of most inter annual as over 15 years. Failure and maintenance history of the survey was obtained that breakdown in as the stator windings is 32 units and damage in the rotor 10 units, which the ratio of more than 10 years is 81%, 7-8 years is 17%, and 4-6 years 2%, were analyzed[1].

2. Necessity of Integrated Condition Monitoring for Generator

Breakdown, damage of generator, the secondary impacts accidents, and unannounced stops of power plants make unstable power system and degrade the life of the generator. Especially, the vibration of stator windings abrades the insulation at blocking and bracing points in the winding, as well as the slot. The mechanical vibrations in stator slot sections and winding are induced by both mechanical and magnetic forces [2]. The vibration condition monitoring system is required for the improved savings of operation and maintenance cost in terms of reliability in power plant. Generator damages are caused by the high vibration and the power system instability by secondary impacts of an unannounced plant stop and the life of the generator is decreased. In particular, if a fault occurs in the generator stator winding, it takes a lot of maintenance cost by more than at least 15 days period to get recovery. In particular, the future, the plant's planned preventive maintenance cycle will be followed long by more than 10 years from four or five years. It is important to develop the condition monitoring system using the vibration signals with PD and shorted-turn signals for the improvement of operation reliability and the saving of maintenance cost for electrical generator. On-line condition monitoring technology on high vibration appearing as the sign of failure is ensure the soundness of

the generator, and is enable to predictive diagnostic. It is essential to manage the facility with competitiveness of improved equipment operating efficiency and through improved productivity by timely plant outages and maintenance. Thermal-bending by various kinds of mechanical causes and damages of the rotor winding are known as the sources of the rotor vibration during operation. Condition monitoring system and diagnosis technology for generator rotor and stator during operation of the plant are the major factors for operational reliability in terms of promoting preventive diagnosis and prevention of secondary failure. Thus, it is important to develop the integrated monitoring diagnostic techniques that prevent the causes of the catastrophic outages in a large amount of high-voltage equipments.

3. Development of Integrated Condition Monitoring System

3.1. Hardware Configuration

Fig. 1 shows the condition monitoring system's configuration in combination of the stator vibration signal, the PD(Partial Discharge) signals, the rotor vibration signal, and shorted-turn signal to do the monitoring of the generator's mechanical and electrical states.

Fig.1. Overall diagram of condition monitoring system with correlation integration PD, stator vibration and rotor vibration by shorted-turn for electrical generator

Local Unit (Data Acquisition Modules) shown in Fig. 2 consists of analog board, A / D (Analog/ Digital) board, DSP (Digital Signal Processor) board, and data storage unit, etc. To enable real-time condition monitoring, DSP board is a dedicated board. DPU (Data Processing Unit) for integrated condition monitoring system receives the output of the signal delivered from Local Unit.

Fig.2. Photograph of local unit for integrated condition monitoring system

Fig. 3 shows that the optical type vibration sensors at the radial directions and tangential directions of winding section at both sides of stator and PD sensors at phase windings of core-end section of exciter side of stator are installed for integrated condition monitoring for the stator winding of 100MW class generator and the sensor developed which can measure the flux of shorted-turn winding rotor of generator is installed at core side. Vibration sensors used for stator winding are the Bragg-grating type optical fiber accelerometers which are suitable to the strong magnetic field of high voltage and current. When vibration occurs, the sensors detect the change of wavelength of the light created to pass a grid of fiber optics. Fig. 4 shows the optical sensors installed at winding of generator.

Fig. 3. View of positions of optical type vibration sensors and PD sensors installed at stator winding of exciter side

Fig. 4. View installed of optical type vibration sensors on stator winding

3.2. Software of integrated condition monitoring and diagnosis system

The configuration of software design for integrated HMI (Human Machine Interface) was based on .NET Framework 3.5 developed by Microsoft. Stator vibration's HMI, rotor vibration's HMI, and shorted-turn's HMI are linked and integrated by Loopback UDP (User Datagram Protocol) communication. SQL DB is used during everyday operation and file DB is used for predictive analysis of transient condition. Fig. 5 shows that the right side of monitor window is the mechanical condition monitoring part and the left side indicates the electrical condition monitoring part. The upper portion of the right part shows monitoring local part of the generator rotor vibration and the bottom is vibration monitoring local part for the stator winding. Upper portion of the left is PD monitoring local part of the stator windings and the bottom is rotor shorted-turn monitoring screen. Vibration characteristics in generator stator winding are used for the learning patterns on the mechanical soundness prediction through error back-propagation algorithm. When the health of the stator winding is diagnosed, the vibration waves from the radial and tangential optical sensors are monitored to represent the behavior of the stator. Then, Learning patterns are created through extracting the variations of each phase on 60Hz responses of rotor rotation and 120Hz responses due to electromagnetic force. The possibility of a resonance phenomenon can be diagnosed by learning these lessons from the patterns of generators in operation by error back-propagation.

Fig. 5. Screen view of integrated condition monitoring and diagnosis system for electrical generator

4. Site Acceptance Test

Integrated condition monitoring and diagnostic system's program includes stator vibration signal analysis, rotor vibration signal analysis, PD signal analysis, and shorted-turn signal analysis. In order to verify the functioning performance of the generator condition monitoring and diagnosis system, a site acceptance test has been carried out for 100MW

class gas turbine-generator shown in Fig. 2 at combined-cycle thermal power plant in Korea. The site acceptance test [3] includes the in-place functional testing of system hardware components such as local unit, DPU, and web-based modules, optical sensors, PD sensors, shorted-turn sensors, etc. The capability of the developed integrated condition monitoring program such as optical sensor data display, stator vibration trends and spectrums, stator predictive failure diagnosis display, PD's signal plots and trends shorted-turn wave pattern display, rotor vibration plots, web-based display and data management capability of SQL database program have fully tested. The reliability of condition monitoring system is confirmed by compared the results of the measurement with precise equipments.

5. Conclusion

Advanced technology for on-line condition monitoring system in large rotating equipment such as power plant generators is avoided transferring from leading companies because of high value-added nature and the monopoly. The integrated condition monitoring system has been developed for the reliable operation of generator winding system of power plant. In order to verify the functioning performance of the generator integrated condition monitoring and diagnosis system, a site acceptance test has been carried out at a 100MW class gas turbine generator in combined-cycle thermal power plant selected as the pilot plant. The output data of integrated condition monitoring system are compared with the analysis results of input signals of local unit through precise equipments and confirmed the reliability. The integrated system includes PD diagnostic subsystem, shorted-turn diagnostic subsystem and vibration condition monitoring and diagnosis subsystems for stator and rotor. In addition, Learning-patterns management option is added for predictive failure diagnosis of stator winding by using each stator side's optical sensor signals.

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