http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 6 (6): 919-923, 2007
ISSN 1812-5638

On-Line Monitoring of Hydropower Plants in Pakistan

Iftikhar Ahmad and Abdur Rashid
Department of Electrical Engineering, COMSATS Institute of Information Technology, Abbottabad, Pakistan

Abstract: In this study, we present a comparison of traditional and modern techniques for monitoring hydropower plants. Traditionally, in Pakistan, the maintenance of hydropower plants is based on periodic-based corrective techniques, which involves shutdowns of plants over specified periods. The method not only restricts the operator to wait for the periodic shutdown for routine maintenance, but also proves to be more costly in case of major defects occurring in the plant. We propose on-line monitoring of the equipment, which involves continuous observation of the system parameters without system or equipment being stopped. The outcome is the early detection of any abnormality/fault and limiting of the severity of any potential damage to the system.

Key words: On-line monitoring, hydropower, turbine, generator, transformer

INTRODUCTION

Electricity is a commodity that is vital to the economy of any country. Like other developing countries, Pakistan is also eyeing on the industrial revolution for its growth and prosperity, which in turn is mostly dependent upon the availability of sustainable, reliable and economical electrical power.

In today's world of partially deregulated utilities and grid systems, the hydropower units need to undergo continuous load changes and partial-load operation. Running a unit at partial loads brings into play considerations like rough load zone and cavitation, along with operation that is far from the unit's peak efficiency. Further, continuous load cycling introduces thermal, mechanical and electrical stresses on the machinery that may not have even been considered in the original design. This scenario has changed the concept of maintenance where normal scheduled maintenance outages are being reduced or eliminated. The need for condition monitoring on hydro units has risen now to ensure reliability, availability, safety and efficiency of the system.

Condition monitoring enables the power providers to transform their maintenance programs from periodic to condition- based leading to more effective and economically optimized maintenance and operation.

Several techniques have already been developed and implemented. Many of todays solutions are not new, advanced control, performance monitoring, condition monitoring, cost of generation monitoring automated decision support and other applications are with us for a while (Roehl and Lloyd, 1995). Techniques for partial discharge on-line monitoring (Chengjun *et al*., 2002), Generator stator end winding and shaft potential monitoring (Michael *et al*., 1988) and on-line vibration condition monitoring system (Wang *et al*., 2002) have already been developed and presented. These methods have been tested and implemented, however the technology is still new for Pakistan.

Having great potential of hydropower generation, the authorities here, have planned to develop several large and small hydropower plants. The advance consideration of modern technologies will help in obtaining such equipment and technologies that are more reliable, efficient and economical. This study is performed to provide an initial guideline to utilize the on-line monitoring techniques in existing as well as future power plants with proven efficiency benefits and economical advantages. The modern technologies have been identified and discussed and a comparison of in-use monitoring techniques and the modern on-line monitoring methods has been provided.

OFF-LINE MAINTENANCE TECHNIQUES

Off-Line maintenance techniques involve corrective or preventive maintenance scheduled on certain regular or irregular periods. This practice restricts utilities to wait for periodic shutdowns or the failure due to any defect or damages. In Pakistan the periodic maintenance programs are scheduled on monthly basis for the routine minor checkups while annual base is utilized for overall maintenance of the power plant. The method has several limitations such as:

Corresponding Author: Iftikhar Ahmad, Department of Electrical Engineering, COMSATS Institute of Information Technology, Abbottabad, Pakistan

- The exact time interval that excludes the possibility of any failure occurrence cannot be established. Unplanned outages result in huge production losses beside the loss of reliability and credibility.
- Maintenance is carried out even when the actual condition of the plant does not warrant it. This is the waste of resources and loss of revenue.
- The preventive maintenance frequency has to be increased with the aging of the machinery that necessitates increased resources to be mobilized. This has proven to be very costly.
- Possibilities of failure being calamitous are also significant and the environmental and safety aspects are compromised.

The above limitations as well as the increased demand of reliable power has put a big question mark on the use of traditional maintenance techniques and has forced the authorities to incorporate modern technologies and innovation in the field.

ON- LINE MONITORING TECHNIQUES

In contrast to the periodic based maintenance, the on-line monitoring of the equipment facilitates the transformation of maintenance programs from periodic to real-time condition based maintenance. On-line monitoring involves continuous observation of the system parameters without system or equipment being stopped, resulting in the early detection of any abnormality/fault and limiting the severity of any potential damage to the system. Further benefits of on-line monitoring techniques are:

- Frequency of the outages can considerably be minimized as the shutdowns are carried out only when is indicated by the monitoring system.
- Efficiency and life of the system is improved by adopting preventive techniques.
- Early diagnosis of faults helps preventing major breakdowns and allows the operator to think for the remedies in advance.
- Equipment replacement/refurbishment strategies can be developed on actual system parameters.
- Reduction of personal risks and improvement in system security can be achieved by real-time alarm systems.
- Monitory saving in operation and maintenance.

COST BENEFITS OF PLANT CONDITION MONITORING

The following potential benefits of an on-line condition based monitoring program can be evaluated while preparing an economic justification. The actual value of these benefits will however, depend greatly on the individual circumstances of the plant involved (IEEE Standards):

Table 1: Based on the results of 1988 multi-industry survey (Predictive O and M by Jhon O Connor, Hydro Review/July 1997)

Maintenance cost	Reduced 50 to 80%
Machinery breakdowns	Reduced 50 to 80%
Spare parts inventories	Reduced 20 to 30%
Total machine downtime	Reduced 50 to 80%
Overtime expense	Reduced 20 to 50%
Machine life	Increased 20 to 40%
Overall productivity	Increased 20 to 30%
Profit	Increased 25 to 30%

- Reduced inspection outage frequency
- Reduced maintenance outage frequency
- Reduced maintenance outage repair time
- Reduced forced outage frequency
- Increased generating unit operation efficiency
- Increased generating unit capacity
- Improved equipment safety
- Improved operational and maintenance skills
- Increased plant life expectancy
- Unattended operation.

The Table 1 quantifies the above potential cost benefits in terms of percent increase or decrease:

MAJOR PLANT OUTAGE FACTORS AND THEIR MONITORING

The hydraulic generator, the power transformer and the turbine runner are the three most important and cost intensive electro-mechanical equipment in a hydropower generation plant. The studies of Pakistan's major hydropower contributors have revealed that most of the outages are associated with the above-mentioned major equipment of the plant. The main parameters to be monitored in relation to the main power generating equipment are discussed.

GENERATOR STATOR WINDING INSULATION

The condition of the stator winding insulation determines the occurrence of unplanned system outages and production loss. The insulation of high voltage rotating machines is continuously subjected to mechanical, thermal, electrical and environmental stresses. Studies have shown that 40% of the serious motor and generator problems are due to the deterioration of the stator winding insulation. Rapid deterioration of the stator

end winding can occur due to various reasons resulting in wear of coil insulation and fatigue cracking of conductors. Both conditions can eventually lead to forced outage of the generators. It is therefore, important to monitor the stator winding condition continuously to avoid system outages.

Traditionally condition monitoring of generator stator winding is based on off-line techniques such as Tan delta and partial discharge. These techniques do not provide sufficient information and require the plant to be shutdown. On-line monitoring techniques such as On-line Partial discharge detection and Air gap monitoring are well acclaimed. Technologies have been developed and implemented for on-line monitoring of generator condition utilization of rotor mounted sensors (Ramussen, 1999) and continuous measurement of partial discharge to improve generator availability (Stone and Lloyd, 2001) are the examples of such development.

POWER TRANSFORMER INSULATION

Power Transformer insulation condition is the basic indicator of the best operation of the transformer. The power transformer insulation is effected by aging, transient voltages and high operating temperatures. Therefore the insulation condition needs to be monitored constantly to avoid any defect. Several on-line insulation monitoring techniques have been developed such as, Hydrogen monitoring, hydran sensor, pressure monitoring and the transformer insulation condition monitoring system (TCIMS). Out of these techniques, TICMS is the most promising as it provides real time on-line continuous monitoring of the insulation condition.

To increase availability and optimize operating management on-line condition monitoring of power transformers is useful and necessary. Throughout the last years on-line monitoring systems have been installed in a large scale at power transformers. To monitor the condition of the active part of a power transformer various measurement and analyzing quantities can be realized. As main parameters, beside others, are to mention temperatures, loading conditions, gas-in oil content, moisture of oil and paper insulation system (Stirl *et al*., 2002).

TURBINE VIBRATION AND EROSION

Both mechanical and electromagnetic forces in a hydro plant induce the vibration of turbine and generator that affects the efficiency and safety of the system and lead to enormous economic losses. The problem of cavitation and abrasive erosion associates excessive vibration, which requires continuous monitoring.

Mechanical vibration information is critical to diagnosing the health of a generator. Vibration monitoring techniques have been developed and utilized for timely detection of damages caused by excessive vibration. Amongst those, the examples are vibration, air gap and magnetic flux measurement utilizing multidimensional techniques (Bajic *et al*., 2000) and on-line monitoring system based on LonWorks control network (Wang *et al*., 2004).

Studies of hydropower plants in Pakistan namely Tarbela and Warsak have shown that the most serious factor that causes unit outage and production loss is the erosion of turbine due to Cavitations or abrasive erosion.

Cavitation is the formation of vapor or bubbles/cavities in a flowing liquid due to the abrupt drop in the pressure. These cavities implode or collapse as they move to higher pressure against the metal surface of the turbine runner. This implosion causes damage to the metal surfaces thus causing efficiency loss in the turbine. The problem is more significant at Tarbela Power station.

The abrasive erosion is the mechanical removal of metal by the action of suspended solids in the water, which act as an abrasive medium for the metal surface. The presence of silt or sand in the water causes wearing of the runner blade surfaces where the velocity of water is higher such as leading edge of turbine blade. This problem has caused serious effects on Warsak Power station.

MAINTENANCE TECHNIQUES-COMPARATIVE STUDY

The traditional off-line maintenance techniques are being employed at the power stations in Pakistan involving periodic shutdowns. Usually on annual basis, to monitor and repair the damages caused to the equipment. The practice not only costs more in terms of repairs, as the damage caused further deteriorates until the annual shutdown is implemented, but often causes unplanned outages and shutdowns.

The in-use maintenance practices based on periodic shutdowns and the available modern on-line monitoring techniques are listed in Table 2 with reference to the major plant outage factors described earlier:

Table 2: Comparison between traditional off-line and proposed on-line monitoring techniques

	Existing methodology		Proposed modern techniques	
Parameters	Periodic shutdown tests	Limitations	On-line monitoring	Potential advantages
Generator stator winding condition	Partial discharge tests, tan delta, etc	• Plant to be taken out of service • Condition cannot be assed during plant operation; possibility of nnplanned outages is always there.	On-line partial discharge detection Air gap monitoring	• Monitoring of the plant in running condition • Early detection of the defect and possibilities of remedies being taken before the damage is significant. • Saves unplanned outages and reduces periodic shutdown time
Transformer winding insulation	Dissolved gas analysis	• Rapid changes in the insulation condition are not detected. • Detection of very low concentration of dissolved gases is difficult. • Precise location of fault cannot be established.	TICMS (Transformer Insulation Condition Monitoring System) Hydrogen monitoring etc.	• Provides real time continuous monitoring of insulation condition. • Provides effective transformer protection
Turbine maintenance	Periodic visual inspections	• The cavitation damages cannot be detected nntil the nnit is stopped, dewatered and inspected visually. • More time and manpower is wasted. • Repair of erosion damages cost more if the damage has increased due to late shutdown.	Vibration Monitoring of the system with permanently installed sensors Vibro-acoustic detection techniques	• Cavitation is associated with abnormal vibration and noise in the system. On-line Vibration* monitoring of the system facilitates the early detection of the abnormal vibration and alarms or shutdown the system accordingly. • Real-time detection of the problem Prevents defect propagation and Avoids system outages

*Ghazi Barotha Hydro Power Plant (1450 MW) is one of the modern and state of the art hydropower projects in the world. The project is designed and constructed under modern techniques and has got modern plant monitoring techniques, including Air Gap and Vibration Monitoring system. The system enables the operators to continuously monitor the rotor-stator Air Gap, as well as the vibrations in turbine, bearings and other associated equipment. Thus facilitating the early detection of abnormalities by carefully programmed indication and alarm system and helping in taking the suitable remedies accordingly

CONCLUSION

It has been established that modern technologies and innovative methods to maintain power plants can reduce cost, increase plant reliability and minimize prolonged outages. The result is supported by presentation of IEEE quantitative analysis.

The turbine runner, generator and power transformers are the most important and capital-intensive equipment in hydro power plant. Their reliability is determined by the parameters such as, corrosion and erosion, stator winding insulation and transformer winding insulation respectively. Some of the modern technologies and innovative methods of on-line monitoring of theses parameters were discussed. It was also determined that on-line vibration monitoring, continuous air gap measurement, on-line partial discharge measurements and Transformer Insulation Condition Monitoring System are the most promising techniques in the field.

A comparison of traditional maintenance techniques and on-line monitoring techniques is presented highlighting the potential benefits of on-line condition monitoring.

It can be concluded that significant savings in maintenance costs and improvement of profitability and reliability of hydropower plant operation can be materialized if operation and maintenance are optimized based on actual characteristics of the turbine, generator and other major equipment of the plant. Realistic information about these plant characteristics can only be obtained by permanent monitoring of the essential parts of the plant.

REFERENCES

Bajic, B., J. Sabolek, D.J. Dvekar and D. Magic, 2000. Vibration, air gap and magnetic flux investigation in the HPP Dubrava bulb unit 1. 4th Symposium on Power System Management, Cavtat, Croatia, also 1st International Symposium Hydroelectric Power Plants HEPP 2001, Sibenik, Croatia, June 2001.

Chengjun, H., W. Yu and W. Wei, 2002. Development of PD On-line monitoring system for large turbine generator. IEEE International Symposium on Electrical Insulation, Boston, MA USA, April 7-10, 2002.

IEEE Std., 492-1999. IEEE Guide for Operation and Maintenance for Hydro Generators.

John, M., 1997. Reliability Centered Maintenance. 2nd Edn., Industrial Press Inc., New York.

Michael, T. *et al*., 1998. Two recent developments in monitors for large turbine generators. IEEE Trans. Energy Convers., pp: 3.

Ramussen, J.R. and D.W. Thompson, 1999. On-line Generator Condition Assessment using rotor-mounted sensor technology. Int. Conference on Electrical Machines and Drivers, IEMD.

Roehl, A. and B. Lloyd, 1995. A developing standard for integrating hydroelectric monitoring systems. EPRI Motor and Generator Conference, Orlando.

Stirl, T. *et al*., 2002. Technical possibilities and practical operational experiences with on-line monitoring systems for power transformers. ETG Technical Seminar, Berlin.

Stone, G.C., B.A. Lloyd, M. Krikorian, R. Siola and G. Griffith, 2001. Florida Power and Light, Continuous partial discharge measurement to improve generator availability. EPRI Generator Conference, New Orleans.

Wang, Y., F. Sun and T. Huang, 2004. Development of on-line vibration condition monitoring system of hydro generators. Proceedings of the 3rd International Conference on Machine Learning and Cybernetics, Shanghai, 26-29 August 2004.