2008년도 한국전기전자재료학회 센서박막재료연구회 및 광주·전남지부 춘계학술대회 논문집 (2008. 04. 17 - 18)

배전반 시스템의 온라인 감시 및 진단

최 용성, 이 경섭
동신대학교 전기공학과

On-line Monitoring and Diagnostics for Distribution Panel System

Yong-Sung Choi, and Kyung-Sup Lee
Department of Electrical Engineering, Dongshin University

Abstract : Continuous on-line temperature monitoring allows corrective measures to be taken to prevent upcoming failure. Continuous temperature monitoring and event recording provides information on the energized equipment's response to normal and emergency conditions. On-line temperature monitoring helps to coordinate equipment specifications and ratings, determine the real limits of the monitored equipment and optimize facility operations. Using wireless technique eliminates any need for special cables and wires with lower installation costs if compared to other types of online condition monitoring equipment. In addition, wireless temperature monitoring works well under difficult conditions in strategically important locations. Wireless technology for on-line condition monitoring of energized equipment is applicable both as standalone system and with an interface with power quality monitoring system.

Key Words : Continuous on-line temperature monitoring, Event recording, Wireless technique

1. Introduction

The ability to continuously monitor the condition of energized equipment (on-line monitoring) enables operation and maintenance personnel with a means to determine the operational status of equipment, to evaluate present condition of equipment, timely detection of abnormal conditions, and initiate actions preventing upcoming possible forced outages [1]. The consequences of such faults are serious enough to justify the efforts to build a temperature monitoring system to protect electric facilities from disaster.

Needless to say, in real life when the same contact is exposed to thousands of amperes of alternating current, it may behave very differently. For example, some of the laboratory tests demonstrated that high contact resistance during the test does not lead to overheating when in service, due to the presence of films on the contact surface with non-linear resistance values [2]. On the other hand, a loose, "hand-tight" connection could easily pass the Contact Resistance Test. Therefore, having the ability to directly measure the temperature of the contacts while in service will provide more information to determine the true condition of the equipment. Corrective actions could be performed only when a degraded condition requires maintenance, thus reducing the time and cost of PM testing.

The paper presents the results of wireless temperature monitoring of distribution equipment at a power plant.

2. On-line Wireless Temperature Monitoring

2.1 Hardware

A. Sensors

- wireless units equipped with unique identification;
- sensing units built from miniature and dielectric components;
- signal transmissions from multiple sensors do not interfere with each other;
- units are installed at the key points on the equipment in limited space;
- sensing units may have one of the following power sources:
  - * power supply such as battery
  - * self-powered by the alternating magnetic field of a bus bar
  - * remotely powered

B. Receiver or interrogator

- installed at a significant distance from the sensors in the central location;
- collects data from all sensors;
- works independently in series with other receivers;
- easily recovers from temporary electro-magnetic interference;
- transfers the data to PC

2.2 *Software*

- Analytical diagnostic software provides tools to not only locate the source of temperature rise, but also to determine what type of change in physical conditions of apparatus led to heat runaway. In other words, the diagnostic software would be able to determine whether there is a surface decay, mechanical deterioration, or lack of sufficient airflow inside a cubicle (or a combination of the causes) resulting in heat runaway.
- Analytical prognostic software provides tools, which will determine what kind of actions should be planned in condition based maintenance (CBM) based on diagnosis and issue recommendations on the actions for the user to undertake in regards of CBM.
- Analytical optimizing software addresses the issues of optimized operation of the system in regards to reconfiguration of the loads due to the various ambient conditions, equipment location and conditions, or modification of the overloading profile (emergency loads for critical applications during the power consumption peaks), providing effective asset management.

Some other benefits in effective Wireless Temperature Monitoring System are:

- Low installation costs
- Easy-to-use product
- High reliability, minimum defects, low maintenance
- Compatibility with existing products
- Long service life

Two versions of a temperature monitoring system may be used. A stand-alone system provides the delivery of data from a receiver to a local PC. The temperature information is then processed for visual representation (graphical or tabular) by software, which also issues audio and video alarms as soon as temperature of a particular point reaches a pre-determined level. This type of system provides reliable continuous monitoring of thermal conditions of electrical units. Another version of a temperature monitoring system having an interface with power monitoring system provides continuous monitoring of both temperature and power quality through a web-based server is presented.

The Wireless Temperature Monitoring System has been installed at one of the power plants at a large utility, which suffered multiple violent thermal failures on main breakers. The goal was to use the temperature sensors to continuously monitor temperature while the breakers are under load. The stand-alone system is able to provide warning alarms as soon as the temperature of the points where sensors are installed reaches a pre-determined level. Wireless temperature sensors have the following parameters:

- uniquely identified sensing units are built from miniature and dielectric components and operate in direct contact with the surface;
- sensors are calibrated in wide temperature range: from -0 ℃ to 150 ℃ (for outdoor applications sensors are calibrated from -40 ℃ to 85 ℃);
- transmittance intervals are based on the rate of a temperature change: signal is sent every minute at temperature rising for 3oC per minute and once in 3 minutes at stable temperature (battery life saving mode);
- Sensing units use a small coin battery as a power source; minimum battery life 5 years, typical 7-10 years, easily changeable.

Miniature wireless sensors have been installed at all six finger clusters (FC) of four MV circuit breakers, two of which (main breakers) are continuously under load. Two other breakers are used as reserve. Every cell is also equipped with a sensor on the internal wall to measure temperature of the ambient air within the cell. One reading device installed in the control room receives RF signals with information about the location and temperature of each point where the sensors are installed (there are a total of 28 transmitters). This information is continuously transferred from the Reader to the local PC located in the operator room and connected with a reading device via communication cable. The temperature data is continuously collected in the database and analyzed together with load data to determine any abnormalities in temperature behavior.

3. Results and Discussion

The change of finger cluster temperature (Fig. 1, A) follows every increase and decrease of the current (Fig. 1, B) with very short delay (minutes). The shape of the temperature curve is very similar to that of the load, copying even minor changes of the current.

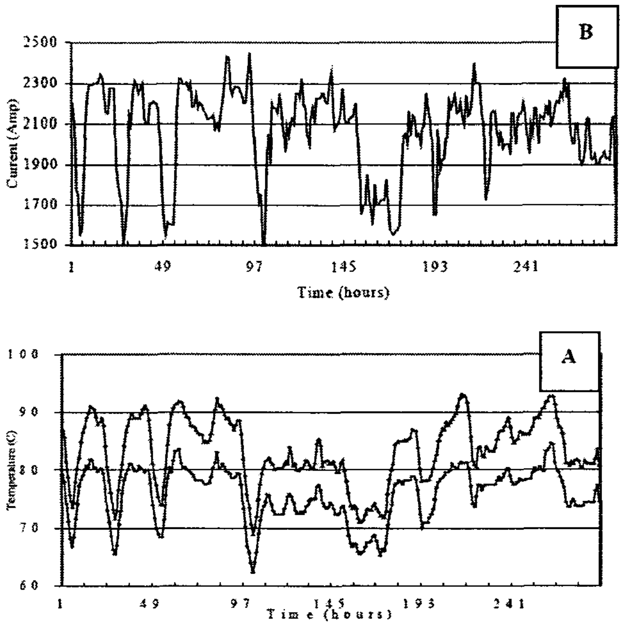

Fig. 1. Temperature (A) on Top FC of Phase A and B and Load (B).

The temperature of the top and bottom FCs on Phase A and C are very close. The difference in temperature between Phase B and Phases A and C is usually in the range 5-10 ℃. After one month of monitoring, the first warning signal was an observation of a very high temperature of the ambient air within the main cells. It was reaching 60 ℃ even though the current was well below the maximum rated current for the breakers. As a result, the temperature on the finger clusters occasionally reached 100 ℃, which is very close to standard maximum for current-carrying parts of MV circuit breakers (105 ℃) (Fig. 2, A). It was determined that the elevated temperature within the cells was caused by a poor ability to evacuate heat build-up. The existing switchgear did not provide louvers on the doors and no forced ventilation within the cells.

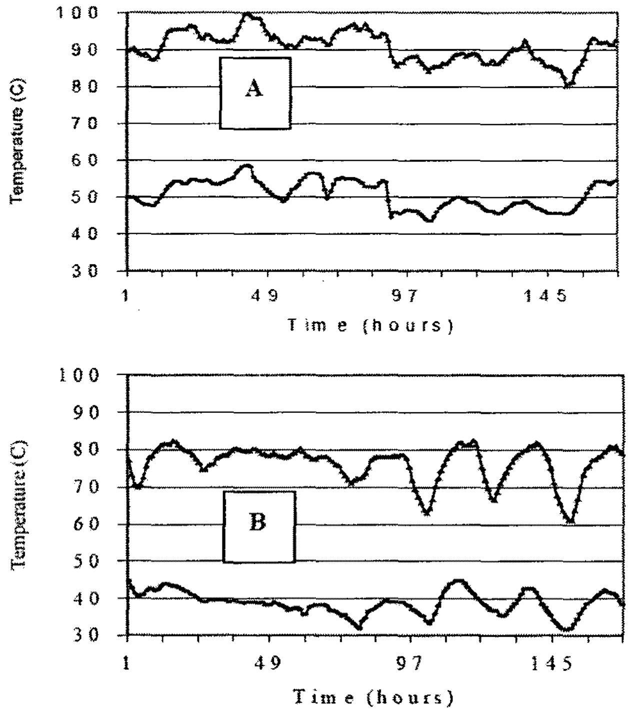

Fig. 2. Ambient temperature (bottom curve) and on B Phase Top FC (top curve) in the same cell without ventilation (A) and with forced ventilation (B).

It was strongly recommended to improve ventilation within the cells, which was done with minimum expense. An opening was made in the door of the cell with two small vents installed to increase airflow inside the cell. The result was very promising: temperature of the air within the cells dropped an average 10 oC for the same current accompanied with the corresponding drop of the temperature on all six finger clusters (Fig. 2, B). This drop in temperature provided a large and safe temperature margin for the load on the main circuit breakers. After one year of data collection and data analyzing, a very unusual abnormality has been detected on one of the phases. The temperature has suddenly risen 10-15 oC on Phase A's finger clusters and they become as hot (or hotter) as the FCs on Phase B. The temperature rise usually happened when the load rose (Fig. 3).

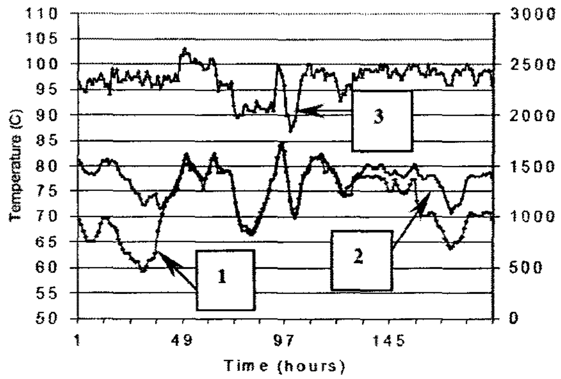

Fig. 3. Temperature growth on Phase A (1) compared with that on Phase B (2) and current (3).

This thermal event on one of the phases affected heat distribution within the cell, leading to significant deviations from normal thermal behavior. The temperature rise on Phase A is accompanied with temperature change on Phase C (Fig. 4), so the top FC becomes warmer than the bottom FC, which is opposite to normal temperature distribution within the cell. The cause of these temperature abnormalities is not yet determined. Plant personnel have been warned about these events and asked to perform inspection of the unit at the earliest convenience.

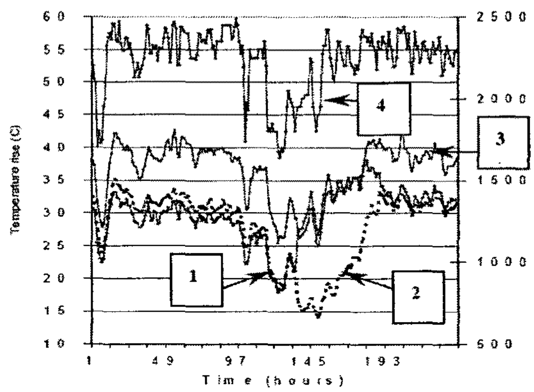

Fig. 4. Thermal abnormality on Phase A effects heat distribution within the cell: temperature rise for Top FCs on Phases A (1), B (2) and C (3), and load (4).

4. Conclusions

Continuous temperature monitoring of energized equipment provides true information about the condition of the equipment while in service. The benefits of wireless online temperature monitoring are:

1. Ease of System Application. Wireless Temperature Monitoring System can be easily applied to existing power equipment. The wireless technology allows installation of the Temperature Monitoring System on existing equipment with short interruption in service. The monitoring system provides accurate measurements and consumes as little power as possible to ensure long operating life.
2. Equipment Integrity. Wireless Sensors do not disturb the thermal, dielectric and mechanical integrity of the power equipment. This requirement is the most important in the real application of the online monitoring system. The sensors and transmission means should not change the properties of the electrical equipment. Such approach allows implementing the system into any electrical equipment without regard for the manufacture, age, maintenance techniques or condition of the equipment in the field.

[Acknowledgement]

This work was finally supported by MOCIE program (R-2007-2-234-01).

[References]

[1] Jeffrey H. Nelson. "Electric Utility Consideration for Circuit Breaker Monitoring", Proceedings of the 2001 IEEE/PES Transmission and Distribution Conference and Exposition, Oct 28-Nov 2, 2002, Atlanta, Georgia, p. 1094-1097

[2] Denis Koch, Ruben Garson. "Square D Type FB4 SF6 Circuit Breaker Contact Resistance", Minutes of the Sixty-First Annual International Conference of Doble Clients, 1994, p. 5-6.1-5-6.1