MODERNIZATION OF TEMPERATURE MEASUREMENT AND VOLTAGE REGULATION

Problems with operation of taps under load and failures in thermometers led to the execution of a pilot project, shown in this article, for modernization of voltage regulation and temperature measurement systems on power transformers. Outcomes included increased operating reliability and reduction of maintenance costs, with the project serving as pilot for modernization of other transformers.

Power transformers are certainly a substation's most expensive and important equipment. For this reason, maintenance of this equipment deserves special attention, since their failure implies in great disturbances and huge losses.

According to reference [1], most failures in national transformers in the country have been caused by taps under load. On the other hand, due to the need to maintain voltage levels at normalized value ranges, deploying these devices on transformers has become vital. Temperature measurement devices are another set of vital devices. Thermometers play a fundamental role in defining transformer load conditions is a safe and reliable manner.

Targeting safer operation of power transformers, linked reduction in maintenance costs, a study was undertaken to modernize voltage regulation and temperature measurement systems for power transformers.

Event History

First, a detailed survey of all maintenance operations performed on devices for voltage regulation and temperature gauging. Based on this survey, it was noticed that a fair amount of work was done on these devices. In addition to costs involved in these maintenance actions, per se, it was also necessary to shut down transformers in order to carry out the repair work.

Most problems found were due to lack of accuracy in figures delivered, in particular by thermometers. Most of the failures detected on thermometers were on capillaries, that due to the action of time (aging) broke and leaked the liquid used in the gauging process. Inaccuracy in thermometers caused a lot of inconvenience, such as false alarms, unnecessary shut downs and others. In addition to this, these devices operating failures and inaccuracy compromised significantly the safe and reliable operation of transformers.

Another finding of this survey was the high number of events involving voltage relays used in the taps under load of transformers. A few abnormalities detected on relays

caused, in certain cases, serious problems in tap changers.
Based on the results of this survey, it was decided to choose a transformer to carry out a pilot project for modernizing these devices.

Definition of Transformer

In the region of the Baixada Santista, in the state of São Paulo, a 60 MVA transformer had its voltage regulation system blocked and temperature measurement devices operating precariously. After specific analysis of the equipment, complaints from clients about level of output voltage were found. There were also complaints from substation operators about the lack of accuracy in the thermometers of this transformer. Due to the bad operating performance of the automatic voltage relay, a substation operator had to be present full time to perform manual regulation as the load varied during the day.

Data Survey

Initially, a detailed analysis was carried out of the transformer's entire electrical wiring diagram for control of voltage regulation and temperature gauging. The transformer chosen is a special equipment, equipped with two taps under load operating in parallel and simultaneously. Using two taps under load in one transformer was an option made by the manufacturer, in order to allow operation at high currents.

As a function of this particularity of the equipment and the importance of the substation, the manufacturer was informed of the intended modernization. After green light was received from the manufacturer, a careful market survey was started foe voltage regulation and temperature measurement equipment for power transformers. The manufacturer of the equipment helped in this by indicating a few companies that manufactured this type of devices.

Basic requirements

Based on survey results, CPFL's maintenance engineering drafted a list of technical specifications with the minimum requirements the equipment had to feature:

- Possibility for ac and dc power input between 80V and 270V, 50/60 Hz;
- Maximum consumption per device of 15W;
- Operating temperature: -10 C to 70 C;
- Oil temperature sensor: Pt 100 ohms or Cu 10 ohms;
- 5A current transformer;
- Output current of 20 mA;
- 1% scale end accuracy; and
- RS 485 or RS 232 serial communication.

Tests required

The devices should also have the following test/assay certification:
- Surges and transients (IEC 266-6);
- Impulse (IEC 255-5);
- Applied voltage (IEC 255-4/6);
- Climate (IEC 68-2-14); and
- Electromagnetic compatibility (IEC 61000-4-2).

In addition to the technical data for the equipment and the test certificates, only vendors with proven application in power utility companies were considered. During the survey, other utility services that already had similar devices installed on their transformers were consulted. Information was obtained about the operation of these devices, problems found and advantages and disadvantages.

After analyzing several vendors, three were selected for a second stage with more depth, based on the particularities of the transformer in case of point. So, since the transformer is equipped with two taps under load operating simultaneously, in addition to voltage regulation relays, ancillary equipment had to be used to check for parallelism supervision of the taps. At the time, only one of the vendors had equipment specific for this purpose, while the other two offered this control by way of auxiliary relays.

Analysis of the solutions presented

Based on the technical analysis of the propositions, the solution chosen was the one that, in addition t being economically advantageous, also offered higher reliability. Technically, the main reason for this choice was the deployment of micro-controllers instead of micro-processors.

Using micro-controllers makes the equipment more reliable and safe for operation in substation environment. Since no micro-processors were used in the equipment, there was no need to acquire special panels to install them on transformers. This detail contributed towards reduction of final cost of modernization, as well as to higher overall reliability.

Another point taken into account in choosing this solution was the low number of components used in modernizing the equipment. With few components on the panels, there is a reduction in the number of defect points, meaning higher overall operational reliability.

Voltage regulation

Because this is a special transformer, equipped with two taps under load operating in parallel and simultaneously, a special configuration was also used. A parallelism supervisor was installed on each tap under load, being used to define the status of master for one tap and slave for the other.

Temperature measurement

As previously mentioned, the transformer's temperature measurement system was operating precariously, jeopardizing the equipment's normal operation. Bearing in mind the importance of thermometers in the equipment's safe and reliable operation, a similar survey was carried out for the purpose of modernizing these devices, too.

One of the most important requirements analyzed in choosing the temperature measurement device was accuracy and reliability of the data delivered. Accuracy is very important, since in moments when the equipment must operate under overload, loading is done based on maximum oil and winding temperatures.

In addition to the gauging certificates, another point taken into account was operational reliability and forms of alerts in case thermometers stop operating or loss of communication. This concern being owed in particular, in addition to the equipment's importance in the grid, to being electronic devices operating in aggressive environments.

After a technical and economic analysis of the vendors, the same vendor used for the voltage regulation relay was chosen. This vendor presented the best technical and economical proposition and, in addition to which, their thermometers offered an additional protection feature, in case of a communication failure with the transformer: fans are automatically switched on and a remote alarm is sent to the operation center, pointing out existence of abnormal condition on the device. This way, no reliability is lost for the transformer, since, if fan motors are on, refrigeration is assured until the problem on the thermometer is solved.

Definitions of the systems used

After an exacting analysis of equipment vendors, the same one was chosen for both the voltage regulation and parallelism supervision. The definitions were based on technical, economical and reliability criteria, in addition to proven efficiency in use by utility services.

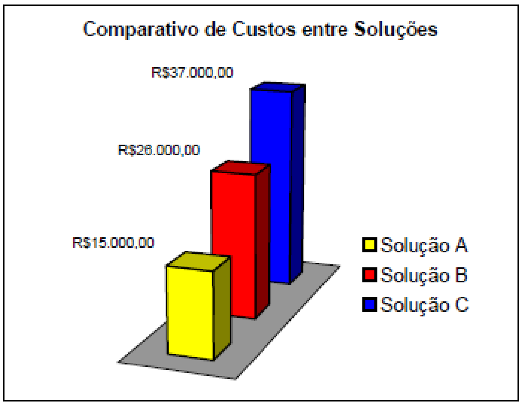

Figure 1 shows a cost comparison between the different systems analyzed.

System installation and adjustment (set up)

Once the vendor was defined, a project request was issued for installing and adjusting the system for analysis and approval. After the project was approved, the logistics required in exchanging the systems was programmed, targeting reducing transformer downtime as much as possible.

Six hours were required to install the new systems, during which the transformer was shut down. During this time, all the old equipment was removed and the new ones, with the required changes, were installed.

Advantages of the New System

The following advantages were obtained from installing the new voltage regulation and temperature measurement systems:

- Increase in transformer operating reliability;
- Reduction of operating costs because of an operator no longer being required at the substation full time to do manual voltage regulation;
- Improvement of voltage levels resulting from better regulation delivered by new system;
- Possibility for remote operation and communication;
- Possibility for real time monitoring; and
- Use of micro-controllers, instead of micro-processors, increasing system reliability.

As another advantage of the modernized system, maintenance interval for the transformer were lengthened, since the main activity of the annual shut down and maintenance was a full overhaul of the temperature measurement systems.

At the same substation there are two identical transformers, one with the original design system and another with the modernized system. Since modernization, follow up of both transformers has been started, using different maintenance criteria for each one, as appropriate.

The transformer with the original design system, had its annual shut down and maintenance activities with check up of temperature measurement systems, among other activities. The modernized transformer only received routine inspections and systems were followed up over a period of four years. During this period, there were no shut downs for maintenance activities. Systems were followed up using parameter comparison such as, for instance, load current and similar loads on other equipment.

During these four years, systems installed did not have any problems and have shown they are reliable. After two years of operation, a simulation was carried out for loss of communication in order to test the thermometers warning and alarm system. In this test, upon loosing communication with the system, the device immediately switched on the two sets fans and sounded the problem alarm.

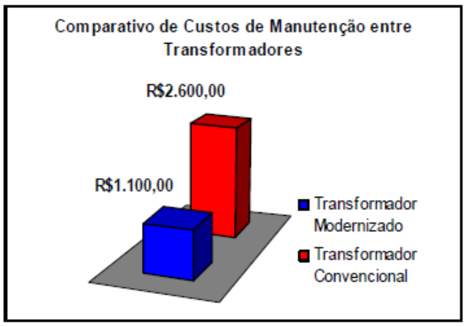

Figure 2 shows maintenance costs involved in the four-year period, for both transformers in the substation. As can be seen on the chart, by modernizing the systems, a cost reduction on the order of 60% in comparison with the conventional system was obtained. Another point to be highlighted are the ambient conditions found on the substation site, with ambient temperatures above 35 C and relative humidity of the air in the 60% to 80% range, most of the time.

Conclusion

The outcome of the modernization is very positive, since, at the end of the process, there was an improvement in the transformer's operating conditions due to its increased reliability, in addition to the reduced maintenance costs.

By proper measurement of temperature, the transformer begins to operate in a more reliable manner since there is no risk of overloading the equipment beyond norm values for oil and winding temperatures. In addition, the temperature measurement system offers a favorable concept for use in substations, since it deploys micro-controllers and not micro-processors.

Another advantage offered by this temperature measurement device in relation to conventional ones is in terms of its maintenance needs. Because this is a totally sealed, electronic device, it does not require preventive interventions as do conventional ones. In terms of safety requirements, all the equipment has proven to be very reliable, since in over two years in operation, in addition to faultlessly in the loss of communication simulation activity. Another positive point of modernization was the reestablishment of voltage regulation, which contributed materially to the improvement in the quality of the energy delivered to clients.

This configuration served as model for transformer automation specifications, in the substation automation process that followed this. Based on this work, maintenance engineering carries out a procedure to increase time intervals between transformer maintenance activities for those that have already had this modernization process.