



Taking it live: On-line, on-load treatment of insulating oils

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Transformer maintenance presents an interesting and a challenging problem in that the system is highly sensitive to any kind of disturbance of the insulating oil that may stir up contaminants and/or lead to the formation or release of gas bubbles. In addition, great care must be taken to avoid the introduction of external contaminants or air bubbles into the oil while the transformer is energized. These considerations are of particular importance when the purification procedures are to be performed on “live” electrical equipment; consequently, most of the transformer maintenance today is performed on de-energized equipment. However, off-line treatment often fails in removing residual moisture from the paper insulation. To achieve this, a separate procedure that involves high heat and high vacuum conditions as well as hot oil spraying is often required. High costs due to labor and lost revenue—often quite significant with \$100K per day not being out of the ordinary—are associated with these procedures.

Given the above considerations, it became evident that the industry could benefit from improvements in technology and more efficient maintenance practices. For this purpose, Pall Corp. developed the HTP070 fluid conditioning purifier (HTP) specifically to remove impurities from the insulating oil and reduce moisture content in cellulose insulation under on-line, on-load conditions. Consultation with a major electric utility (Electricité de France, EdF) in regard to design parameters and operational issues of the HTP ensured that all safety concerns in regard to operation of the unit on “live” transformers were properly accounted for. Briefly, the fluid is pumped into the HTP’s vacuum chamber through a fine nozzle, creating a thin film cone with a large surface area. Air entering the chamber expands rapidly thus decreasing the relative humidity within the chamber to a fraction of the ambient level. Gases and water vapor are then transferred from the oil into the air stream thereby drying and degassing the fluid through a process of mass transfer. The purified fluid collects at the bottom of the chamber and is returned to the transformer through a high-efficiency Pall Ultipor® III filter element. A second vessel and associated valving are located downstream of the discharge filter for detection and removal of air bubbles from the oil before it

is returned back to the transformer.

The safety of the transformer treatment under on-line, on-load conditions is assured in a three-fold manner: 1) by the presence of isolation valves which isolate the HTP from the transformer whenever any faults and/or leaks are detected; 2) by connections which provide for venting of pipe work connecting the purifier to the transformer; and 3) by special equipment employed for air bubble and oil leak detection. The overall operation of the HTP is controlled via a programmable logic controller (PLC) that continuously monitors for any fault conditions during the operation. Should a fault occur, the PLC automatically shuts off the isolation valves to isolate the purifier from the transformer and sounds an alarm. Under normal operation, the automatic controls allow the treatment to continue unattended for several weeks, if required. The purifier has been also outfitted with a water sensor that monitors the moisture content in transformer oil. The output of the water sensor is also recorded by the PLC.

Florida Power Corp. (FPC) Crystal River Energy Complex in Crystal River, Fla., employs a McGraw Edison (1969) as a step-up transformer. Prior to HTP treatment, the unit exhibited a high rate of gassing, indicative of breakdown of paper insulation. Power was thus curtailed from 520 MW and 233 MVars (570 MVA) to 450 MW and zero MVars. After an initial 12-hour off-line treatment with the HTP, the transformer was brought back on-line. The power load on the transformer was then ramped up gradually to 450 MW over several days to make sure that the treatment was not affecting the performance of the transformer in any adverse way.

The initial phase of the transformer treatment was performed over 14 days, on a nearly continuous basis. The results of the dissolved gas analysis, collected between Jan. 12 and Jan. 24, 2000, showed a reduction in the levels of hydrogen (H₂), ethane (C₂H₆), acetylene (C₂H₂), carbon dioxide (CO₂), methane (CH₄), ethylene (C₂H₄), carbon monoxide (CO) and oxygen (O₂). It should be noted, however, that initially the dissolved gas content was so high that the oil could not be treated directly with the HTP. Prior to being treated with the HTP the oil required a 24-hour pre-treatment with FPC’s degasifying unit. As a result of this treatment, the dissolved gas content (excluding nitrogen [N₂]) was reduced from its Jan. 6, 2000, value of 21,019 ppmv (parts per million by volume) to 6,949 ppmv. Subsequently, a nearly uniform decrease in the dissolved gas content has

been achieved in the course of the treatment. These data show that the treatment is not dependent on the gas type and applies equally well to hydrogen and hydrocarbon gases as well as carbon monoxide, carbon dioxide and oxygen, illustrating the strictly physical nature of gas removal.

The changes in moisture content observed in the course of the treatment were monitored. The data demonstrate the process of moisture transfer from the cellulose insulation into the insulating oil as the power load and the operating temperature increase. Thus, initially, in the “cold” transformer, the oil exhibited water content of 14 ppmw (parts per million by weight) that increased to 26 ppmw as the moisture transferred from the paper into the oil. Subsequently, through the action of the HTP, the moisture content of the insulating oil dropped to 13 ppmw in a nearly uniform fashion. Because the moisture was now permanently removed from the system, no further significant fluctuations in moisture content of the oil were observed. Therefore the treatment was effective in reducing moisture content not only in the insulating oil but also in the cellulose insulation, as intended. The reduction in moisture content in paper insulation was in fact quite significant. For example, in the two months prior to treatment, the water content of paper insulation was estimated at an average value of around 1.6 wt% to 1.9 wt%, depending on equilibrium conditions. The treatment with the FPC degasifying unit was shown to have only a marginal effect on water content of the paper insulation. In particular, based on the oil sample collected just after the treatment (Jan. 9, 2000), the water content in paper insulation was estimated at 1.4 wt%. In contrast, based on the oil sample collected on Jan. 12, 2000, i.e., after treatment with the HTP, the water content in paper insulation was estimated at 0.35 wt%. The overall trend observed for reduction of moisture content showed the effectiveness of the fluid conditioning purifier in reducing moisture content not only in the oil but also in the paper insulation, as intended.

The data presented in this paper demonstrate that transformer service life can be extended and its performance characteristics can be significantly improved by performing the vacuum dehydration / mass transfer treatment while the transformer is on-line and under load. The data show that the treatment is effective in removing dissolved gases and moisture from the insulating oil while simultaneously reducing moisture content in the cellulose insulation. The data presented herein should therefore be of interest to plant and substation operators in that they demonstrate that substantial savings in operating costs can be realized by employing the HTP for transformer maintenance under on-line, on-load conditions as described. **ELP**

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For additional information about the HTP070 Fluid Conditioning Purifier, please contact Pall Power Generation at 1-888-873-7255, or visit us at www.pall.com.



HTP 070 System

The Pall HTP 070 on-line, on- load system allows efficient drying and degassing of the insulating coil and paper while maintaining the transformer in full operating capacity.



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