The dielectric failures of three 500 kV Inductive Voltage Transformer (IVT) at a large 3,750 MW hydroelectric power plant in northern Brazil motivated a series of analysis to find the probable cause of the occurrences. The voltage transformers were installed at a SF6 gas insulated substation (GIS) and field inspection detected that the failures had the same dielectric mode, inter-turn short-circuit at the end of the voltage transformer high voltage windings. The root cause and the reason of the repeated damages could not be identified. An interesting information reported by the plant operation staff was regarding the significant number of disconnector switching in the vicinity of the IVTs before the failures.

Although equipment dielectric failures have been reported associated with very fast transient due to switching inside GIS, it was available in the technical literature similar occurrence with IVTs. In view of the singularity of these occurrences, a detailed analysis of the failures was planned involving transient simulations, special IVT high frequency modeling and discussions with the manufacturer to improve the equipment reliability in field operation.

An information of great relevance for the analysis was the measurement provided by the manufacturer of the voltages transferred to various inner layers of the high voltage winding as a function of frequency when voltage was applied to the high voltage terminal. Where the failure occurred, below 20% of the winding close to earth, important resonances were observed in two frequency ranges: from 780 Hz to 1.2 kHz and at 1.7 Mhz and above. The presence of these internal resonances raised the possibility that transient voltages with frequencies in the range of these resonances, such as those generated by internal and/or external switching in the GIS, could have excited internal amplifications above the withstand of the insulation. This type of analysis with focus on the transient interaction between equipment and the power system is not trivial in view of the wide range of phenomena to be evaluated.

Based on manufacturer measurement of frequency response of the failed winding, two sets of simulations of maneuver transients were defined. They considered the two frequency bands where internal resonances were detected near the failure. The first one considered 500 kV line energizations which generate overvoltages with lower frequencies in the order of kHz. The second considered disconnector switching in the GIS, in this case the overvoltages present high frequencies in the MHz range.

The most critical case referred to the maneuver of a disconnector close to one of the VTs, presented in Fig 1, together with its Fast Fourier transform. A special VT black-box model was considered [1] in the simulations. Many resonance peaks can be visualized in the MHz range, confirming the occurrence of VFTO phenomena associated with switching operations in a GIS.

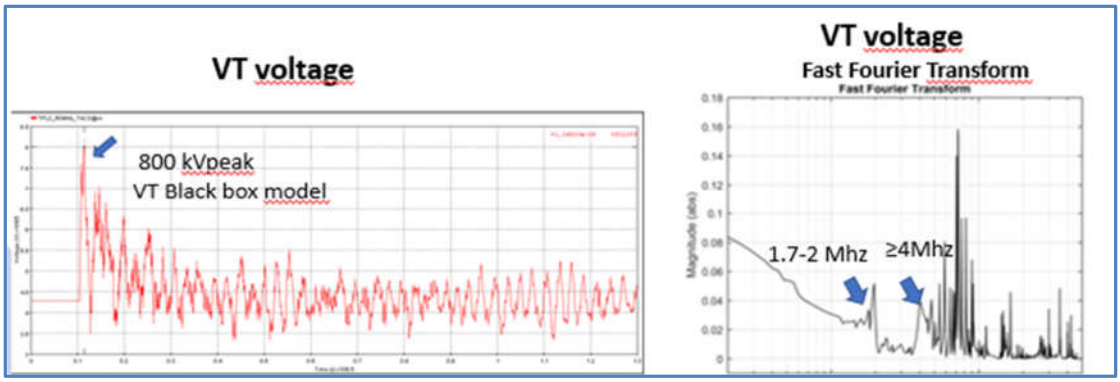

Fig 1 - IVT transient overvoltage due to disconnector switching and FFT – Most critical case

The transferred voltages to the internal points of the IVT winding, in the portion where the failure occurred, were calculated for this case and indicated the presence of high voltage amplifications. At 0.6% of the winding near the earth point, the amplification was 230 % of the voltage expected at nominal 60 Hz frequency.

These results were analyzed by the manufacturer and the conclusion was:

- The insulation was expected to withstand the most severe condition during operation However, cumulative effect of repetitive impulses and the possibility of the occurrence of different critical cases may be the cause the dielectric failures.

Based on this analysis, a series of procedures was taken by the plant operation staff to minimize the impact of these switching on the VTs.

This contribution emphasizes the complexity considering all manufacturers-dependent influences in the analysis of a failure due to unknown causes. It also shows the importance of a good relationship and collaboration between client and manufacturer to improve the equipment reliability in operation.

Reference list:

[1] Gustavo H.C. Oliveira, Lucas P.R.K. Ihlenfeld, Lucas F.M. Rodrigues, Angélica C.O. Rocha, Diogo J.D.E. Santo. Expanding the Measuring Range via S-Parameters in a EHV Voltage Transformer Modelling for Reliable GIS VFT Simulations. Electric Power Systems Research. 2022.