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Q 3.1 : What are the benefits of digital solutions like IoT-Sensors, machine learning, artificial intelligence etc. for substation life cycle from planning to maintenance ?

Together with the introduction of a new generation of monitoring systems for transformers and tap-changers, the question of using vibroacoustic as a new and innovative technology for the online monitoring of this equipment in substations was also raised. The available sensor modules and the high computing power of modern systems make it possible, even from the existing motor drive, to provide a new quality of data processing directly at the transformer in the substation. For the new, intelligent transformer monitoring systems based on integrated smart modules, one of the goals was to develop self-learning systems.

A first step was therefore to explore possibilities that could potentially guarantee the online monitoring of tap-changer by vibroacoustic methods. The basis for this was the knowledge that had been gained from the worldwide service deployment of vibroacoustic. At the same time and in addition to the evaluation of the switching sequence of the tap changer, further data are recorded which characterize the noise of the transformer.

Particularly for heavily utilized equipment such as heavy loaded transformer, this opens a new level of quality for monitoring and functional analysis. Furthermore, the contribution will show, that – aside from the known standard methods – vibroacoustic analysis offers enough potential to open new ways for the condition analysis of the active part of transformers or reactors.

Over the past six years, following the first demonstration of the procedure based on a wavelet transform, the offline analysis of the operating condition of a tap-changer has established itself as an excellent tool for tap-changer service.

During the operation of the online tap-changers the acoustic signal reflects mechanical events during the switching events. The electrical events cannot be measured directly but are in the relation with the mechanical events. During the further development of the vibroacoustic online method, an essential pragmatic working procedure was developed. With this method, based on the experience gained from the vibroacoustic analyses of tap-changers in the service sector, it was possible to develop online systems for the vibroacoustic monitoring of tap-changer by using suitable data reduction procedures.

For the evaluation of the tap-changer switching operations, the significant part of the data set for generating envelopes is reduced to about one hundred grid points during signal processing. Assuming a Gaussian probability distribution for the signal level, the significant peaks of the recorded curve are subsequently expanded. Through this procedure, the system iteratively learns during switching operations how the acoustic signature of a correctly functioning tap-changer looks like, in order to use the self-created envelope to check that the progression of all subsequent tap-changers. Now the self-learning method can significantly increase the functionality of future monitoring systems for tap-changers in transformers and reactors.

After the envelope has been calculated, the complete raw data set of all acceleration values is also available. In order to determine possible trends about the operating condition of the active part of the reactor, a second series of measurements was evaluated, which contains data sets from more than three years of operation of the shunt reactor. The new approach required a Grey Box Regression Model: Such a Grey Box Model consists of a partial theoretical structure in which unknown parts of the model are estimated from measured data.

During the learning phase (approx. 1 year) of the vibroacoustic monitoring system, the model described in the contribution, was trained with measured vibration values and operating parameters of the transformer is quantitatively determined in the monitoring system. In the two-year operating phase, the vibration is recalculated from the transformer's operating data and compared with the measured values recorded by the online transformer monitoring system. A significant deviation may indicate a fault. A recognizable trend may indicate changes, e.g. a reduction of the clamping force. It is obvious that the condition of the active part can be monitored here. Considering that the results shown, the detection of a deviation of 20 - 30 % should be enough to detect undesirable changes in the active part of a transformer.

In the future, statistical data evaluation directly done on the device will be one of the essential features that make it possible to characterise the operating condition of a transformer. The contribution shows in general a new quality of self-learning, intelligent data analysis for autonomous supervision of substation equipment. Assessing the operating condition of a transformer or reactor is just one example of an application of vibroacoustics to ensure operation and to create a new database for asset management.