FAULT DIAGNOSIS OF ON-LOAD TAP-CHANGER BASED ON VARIATIONAL MODE DECOMPOSITION AND RELEVANCE VECTOR MACHINE

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ABSTRACT

Arcing measurement is proposed in this paper to complement to vibration measurement. Arcing is annoyed when OLTC switching contact closes at a fixed tap position and it can lead to electromagnetic signals flowing through transformer windings and lastly reaches earth. The arcing measurement is achieved by using a High Frequency Current Transducer (HFCT) clamping on the transformer's grounding cable. The joint vibration and arcing dimension can provide an improved means for interpreting events involved in OLTC process and facilitating an enhanced OLTC condition monitoring. Since HFCT measured arcing signals can be attached with noise, a probabilistic wavelet transform is thus working in this paper to extort arcing signals from noise. Field measurements on two dissimilar types of OLTCs are performed using the joint vibration and arcing measurement system to validate the proposed methodology.

KEYWORDS: Arcing; condition monitoring; On-load Tap Changer (OLTC); power transformer; vibration; wavelet transform.

INTRODUCTION

The primary function of an on-load tap changer (OLTC) is to choose another tap position without interrupting the load current. This can be talented in a variety of ways, resulting in a considerable diversity of tap changer designs. An overview of OLTC mature and degradation mechanisms and some examples of diagnosis performed that indicated ageing will be discussed. The role of the on-load tap changer is to convey the load current during switching and they are consequently prepared with an arcing switch. Two dissimilar arcing switch principles are:

1. Diverter switch

2. Selector switch

The major disparity between these designs is that a diverter switch type OLTC uses a tap selector to pre-select taps without switching current, in combination with a diverter switch to switch the load from the selected to the pre-selected tap. A selector switch type OLTC combines the selection of fine tap windings with the switching of the load current. In several countries the tap changer has the highest contribution in the failure statistics of power transformers. This emphasizes the need to recognize tap changer degradation and to be able to achieve perceptive diagnostics to distinguish upcoming problems.

An OLTC has set of contacts that switch different currents at different recovery voltages. For model, the main contacts of the arcing switch are designed to transfer the load current to the transition contacts. The arcing contacts of the arcing switch are designed to break the load current and the circulating current. The contacts of the tap selector and the change-over selector are not calculated to switch current. Therefore these sets of contacts wear differently. Change-over selector contacts (including tap selector contacts) do not carry as hasty as arcing switches contacts that wear due to the switching of load currents. These contacts will not switch important currents, but can show pitting of the contacts and the growth of so call pyrolytic carbon. This contact dilapidation is not due to the arcs cause by switching the current but by a long term overheating process. Furthermore, the associates of the change-over selector are uncommonly used and can be stationary for long periods. These activate the subsequent degradation apparatus of change-over selector contacts: a long-term aging effect on associates under oil.

RELATED WORKS

In [1] Pengju Kang and D. Birtwhistle et al presents the operation of a power transformer On-Load Tap-Changer (OLTC) produces a well-defined series of vibration bursts as its signature. Due to the harmonic and nonstationary nature of the transient vibration signal, traditional frequency and time-frequency techniques are no longer successful for classification of this type of vibration signals, as the localized time area features, such as delays between bursts, the number of bursts, and the strength of bursts, are necessary for the condition assessment of OLTC. A wavelet transform based technique is developed in this paper to characterize the OLTC vibration signals. This technique gives a simplified design for displaying and representing the essential features of the OLTC vibration signatures. Application results from a selector type OLTC demonstrate that the features extract in the wavelet domain can be utilized to offer reliable indications of the actual heath of an OLTC. The OLTC can be considered to be a multifaceted mechanical system with the excitation input being the impulse forces initiated by the fast phone movements and the output being the vibration rejoinder of the equipment tank calculated using an accelerometer.

In [2] Edwin Rivas, Juan Carlos Burgos, and Juan Carlos Garcia-Prada et al presents the suitable condition of an on load tap changer (OLTC) is essential for the operation of a power transformer. It is enormously desirable to have some indicators to charge the OLTC condition, especially if these indicators are capable of being used in an online monitoring system that does not affect the normal operation of the transformer. This paper describes a methodology by using wrapping analysis based on the Hilbert transform and orthogonal decomposition of the wavelet to decide the main diagnostic parameters for power transformer OLTC condition assessment by means of vibration measurements during the tap changer operation. The number and vibration burst amplitudes depend on the manufacturer, OLTC type, and power transformer load, while the time delay between bursts is connected to the number of OLTC operations though in a little type of OLTCs, there is only a minute modify in time delay between bursts

In [3] Edwin Rivas, Juan Carlos Burgos, and Juan Carlos García-Prada et al presents an on load tap changer (OLTC) in fitting conditions is essential for the operation of a power transformer. It is extremely attractive to have indicators that help assess the conditions of the OLTC, particularly if these indicators can be used in an on-line monitoring scheme that does not affect the standard process of the transformer. This paper describes a technique for detect faults in the tap selector by means of vibration measurements during tap changer operation, using covering analysis based on Hilbert transform and wavelet disintegration. Different failure at the tap selector can be notable in the vibration signature as they are reflected in diverse parts of that signature. The diagnosis parameters allow the most selective failure classification is found. However, interpreting the data is often complicated even for experienced technicians and the technique is restricted by the restricted availability of the signature from a faulty OLTC, casing a wide variety of operating organization conditions.

In [4] Junhyuck Seo, Hui Ma and Tapan Saha et al presents Partial discharge (PD) measurement provides a means for online monitoring and diagnosis of transformers. However, extensive interferences and noise can significantly jeopardize the measured PD signals and cause ambiguity in PD measurement interpretation. Necessary PD signal de-noising technique requires to be adopted and wavelet transform is one of such techniques. Mother wavelet selection, decomposition level determination and thresholding are important processes for effective PD extraction using wavelet transform. Various methods have been proposed in the journalism to improve the above processes of wavelet transform. In these methods a single threshold is normally adopted at each decomposition level and a binary decision is made to indicate whether an extracted signal is PD signal or noise. However, in online PD measurements it is tricky to discover a threshold, which can be used for extract only PD signals without counting any noise. As such, the signals resolute by a lone threshold cannot be guaranteed as PD signals with certainty. To address the limitations caused by the single thresholding method in wavelet transform for PD signals extraction, this paper proposes quantile based multi-scale thresholding method at each decomposition level, which can thus provide probability indexes for the extracted signals evaluating the likelihood of these signals to be PD signals

In [5] Alfredo Contin and Stefano Pastore et al presents A K-Means Clustering classification algorithm for the separation of Partial Discharge (PD) signals and pulsating noise due to numerous sources occurring in practical objects. It is based on the judgment of the Auto-Correlation Function (ACF) of the record signals assuming that the similar source can generate signals having similar ACF while ACF differ when signals with dissimilar shapes are compared. The ACF has been selected for its capability of well recapitulate both time- and frequency-dependent features of the signals. A correlation index that presents the best compromise between strong and weak discrimination among pulses, has been selected out of different distance measurements. The final result of the algorithm is a set of classes containing signals having comparable shape which can be processed sequentially for signal source identification. Meaningful applications of the proposed algorithm are also reported. Improvements in separation effectiveness can enhance the plainness of the PD patterns and, as a result, the quality of the imperfection identification

PROPOSED SYSTEM

An arcing measurement system is residential and integrated with the vibration measurement organization. Arcing signals measured by HFCT can be compromise by extensive noise during field measurements. To successfully extract arcing signals and afterward identify time instances of events in OLTC operation, a probabilistic wavelet transform was adopted. This paper is aimed at representative the applicability of the above joint vibration and arcing measurement technique for interpreting OLTC operation and facilitate OLTC condition monitoring.

OLTC TOPOLOGIES

Tap-changers are categorize into two major groups– ‘Off-circuit or no-load tap-changers’ and ‘On-load or under load tap-changers’. Off circuit tap changers are those that can modify their tap position only when they are disconnected from the load and there is no current through the taps at moment of tap change. On the other hand on-load tap changers (OLTC) can change their taps even when they are supplying the load. Thus the integrity of uninterrupted power supply is maintained. This makes on-load tap changer more attractive for implementation in the grid but at the equivalent time they are more luxurious and multifaceted in their structure

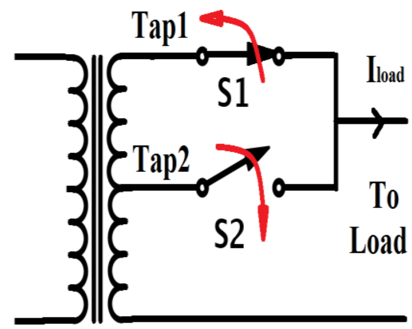


Fig 1 Tap changing in on-load tap changer

BLOCK DIAGRAM

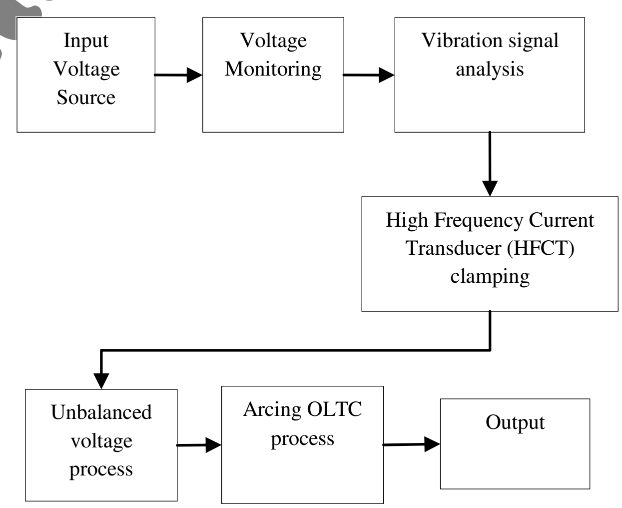


Fig 2 Block diagram

NO LOAD SWITCHES

A no-load switch (NL) is a automatic switch that opens or closes under no-load. In other words, it is operate in such a way that it doesn’t have to generate or break a current and hence has no arcing problems! Such an operation is realized by insertion an electronic switch in series with the no-load switch as shown in Fig. The current creation or interruption process is done in two steps using the electronic as stated in Table. In simple words, change of state of the no-load switch must always be done with the series electronic switch in OFF state. During turn ON, the no-load switch is first tune ON and then the electronic switch. Also during turn OFF, the electronic switch is first turned OFF and then the no-load switch. As can be seen in the table, the two step process cleverly ensures that the present formation or interruption is only done by the electronic switch (BS) and hence protect the automatic switch from interrupt a current and experience an arc.

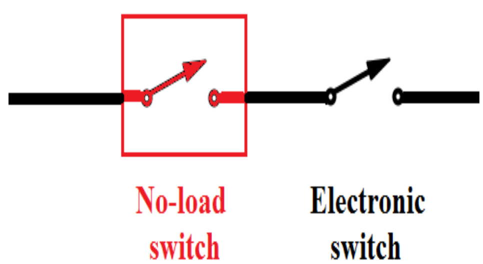


Fig 3 no load switches

The major benefit in using no-load switches for a tap changer is their low cost resulting from simple operation under no-load and low steady state losses (neglecting the cost and losses in the electronic switch). In the afterward section it shall be revealed on how a number of no-load switches can be elegantly coupled to a tap changer and use just two electronic switches to understand their operation.

AUTOTRANSFORMER

A more compacted and cost effective solution to offer a variable secondary voltage is through the use of an autotransformer. In this the case the two windings of a predictable transformer HV and LV as describe earlier, are electrically associated to each other in a series fashion as shown. HV winding is considered as the primary/shunt winding and the LV is measured as the secondary/series winding. By varying the connection of the source and the load across the two windings, the two dissimilar modes of process can be obtained – buck mode and boost mode.

It is significant to understand that for autotransformer the power at the terminals of the transformers S (Through put) is much higher than the power transformed S (Transformed) through the windings by magnetic action. This is because of the presence of an electrical connection between the primary and secondary because of which majority of the power is straight transmitted. The capacity multiplication factor Fc is defined as the ratio of power transmits through the terminals of the autotransformer to power the power that is magnetically transformed through the windings and transformer core.

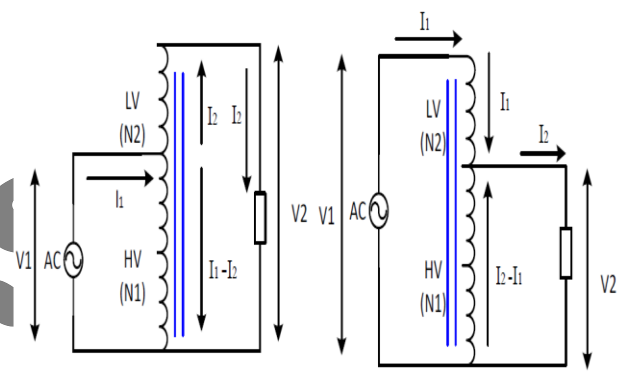


Fig 4 Autotransformer is boost (left) and buck (right) operation

Fc is a function of the ratio of the output voltage to the input voltage of the autotransformer given by r

$$F_c=r/(r-1) \quad \text{(Boost mode)}$$

$$F_c=r/(1-r) \quad \text{(Buck mode)}$$

$$r=V_2/V_1 \quad \text{(Buck \& Boost mode)}$$

PROTECTION AND CONTROL OF SERIES COMPENSATOR

The single phase OLTC autotransformers will be directly connected to the grid. They will be subjected to severe grid conditions specifically those of high over current due to short circuit faults and large overvoltage owing to switching and lightning surges. Further during the startup of the transformer, there will be an in-rush current flowing through the transformer windings that can be numerous times the nominal current, with a DC component. The series compensator must have the capability to withstand such conditions. Besides these external grid conditions, there can be organization generate faults from within the OLTC transformer that can affect both the reliability of its operation and in the worst case, even the dependability of the grid. The first part of this chapter will hence be paying attention on the fault conditions and protection aspects of the series compensator.

The second fraction of the chapter will be dedicated to the development of a low-level control mechanism for the OLTC. The operation of the series compensator as described in previous chapters will be monitored by a centralized controller. The controller depends on information about the grid which is obtained through voltage and current measurements for the load and source. The organization of several aspects of the compensator organization like processing of voltage and current measurements, generate pulses for firing circuits of the hybrid and no-load switches and protection will be under the eyes of the controller. Further if several OLTC are present, it would beneficial to have announcement between these units for a synchronized framework for voltage control in the allocation network.

MEASUREMENT BLOCK

The measurement block obtains parameters from the voltage and current measurement strategy on the succession compensator namely grid/input voltage, load/output voltage and load current. The grid voltage polarity will directly reflect on voltage polarity between the transformer taps and hence will be used in the 4-step commutation of electronic switches. The load voltage and current measurements will be used in estimating the voltage drop along the line and for setting the voltage reference for the controller in the voltage reference block. The measurement will also be used for detecting a fault condition in the protection block and to initiate necessary corrective action in the compensator. Additionally, the voltage across the snubber capacitor in the hybrid switch will be calculated for performing a tap change through the control block. Voltage across the IGBT/MOSFET switches and the emotionless switch can also be measured and included to the controller to present information of the transmission state of the switches.

OLTC CONDITION MONITORING

VIBRATION SIGNAL MEASUREMENT

A series of events can be generating in OLTC operations. The most important events occur when (1) OLTC motor drive starts and stops; (2) Geneva gear is activated or inactivated; and (3) Switching contacts operate. Vibration measurement is employed to measure acoustic waves induced by these events. The existing methods for vibration signal analysis compare the amplitudes and event times of bursts in vibration signals obtained from recent measurement and previous measurement ("before-and-after" approach). The time interval between these bursts is extremely prejudiced by the condition of OLTC components including spring, switching contacts, and Geneva gears. For example, weakened springs can cause a switching contact leaving a current tap position premature and reaching a new tap position late. Accordingly, the transition time of switching contact during OLTC procedure is amplified. Similarly, wornness and misalignment of switching contact can also be evaluate by the "before-and-after" approach

However, the characteristics of bursts in vibration signals such as amplitude, event time, and number are significantly exaggerated by OLTC types and models. Especially, time intervals between events are also decided by properties of switching contacts and OLTC mechanism. The above "before-and-after" advance cannot readily correlate a burst in vibration signal to an event of OLTC function

ARCING SIGNAL MEASUREMENT

Arcing is also generated during the route of switching contact moving from one tap position to another tap position. The arcing occurs when the switching contact closes at a tap position. This is due to the voltage difference between switching contact and tap position. Signals flow through main coil and are then induce to the secondary side coil and lastly to the ground through transformer's grounding cable. Such electromagnetic signals due to arcing can be detected by a HFCT clamp on transformer's grounding rope. The configuration of arcing measurement system is the same as that of inductive partial discharge (PD) measurement classification for transformer. Separating arcing signals (due to OLTC operation) from PD signals. The HFCT measured arcing signal is a type of electromagnetic signal having shorter decay time compared to the measured vibration signal. It propagates through electrical path (transformer winding) in transformer. Moreover, it exhibits consistent individuality over environmental conditions such as temperature and structure of OLTC. On the contrary, vibration signal is vulnerable to propagation average (air or oil), temperature and arrangement of OLTC. As such, measured arcing signals are more appropriate in identify event time of OLTC operation.

$$V_{1\,at\,tap\,(n)} = \frac{N_{1\,at\,tap\,(n)}}{N_2} V_2$$

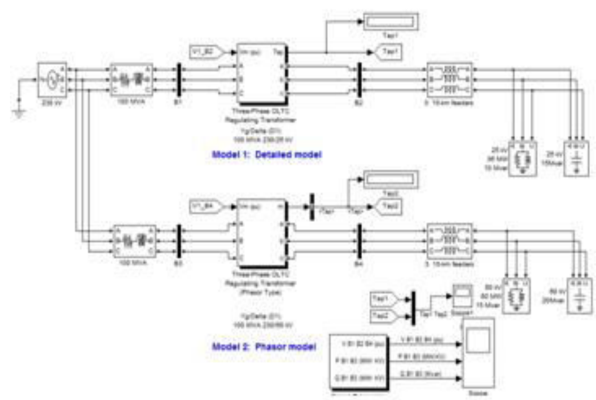
$$N_{1\,at\,tap\,(n+1)} = N_{1\,at\,tap\,(n)} \pm \Delta N_{per\,tap}$$

$$V_{1\,at\,tap\,(n+1)} = \frac{N_{1\,at\,tap\,(n+1)}}{N_2} V_2$$

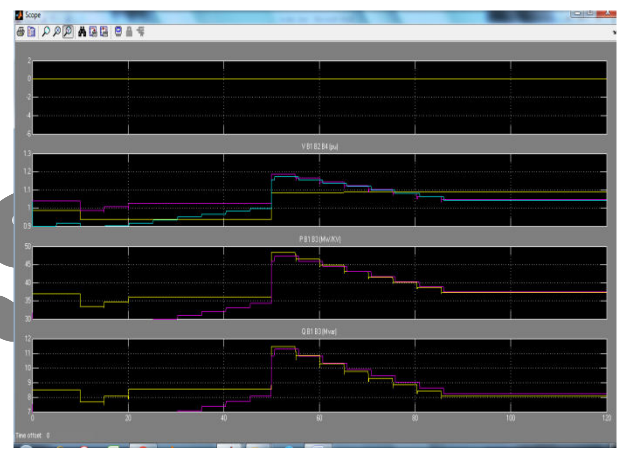
$$\Delta U = \left| V_{1\,at\,tap\,(n)} - V_{1\,at\,tap\,(n+1)} \right|$$

Vibration and arcing signals measured simultaneously when a three phase OLTC is in operation. It can be experiential that the measured arcing signal is 300 µsec in advanced than the measured vibration signal. This is because propagation times of these two types of signals are dissimilar as discussed above. Moreover, the difference in operational time of three phases of OLTC can be identified from the calculated arcing signals which cannot be talented by using the measured vibration signals. The time difference found amongst the arcing signals of three phases may be mainly due to the dissimilarity in signal propagation path on each phase. It may be also caused by little mechanical synchronous error among three phases.

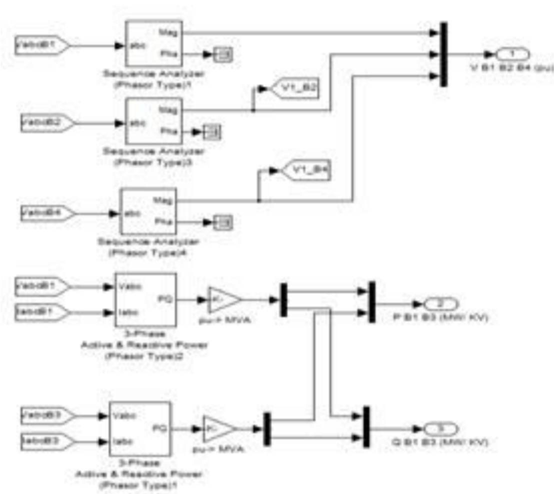
OUTPUT RESULT



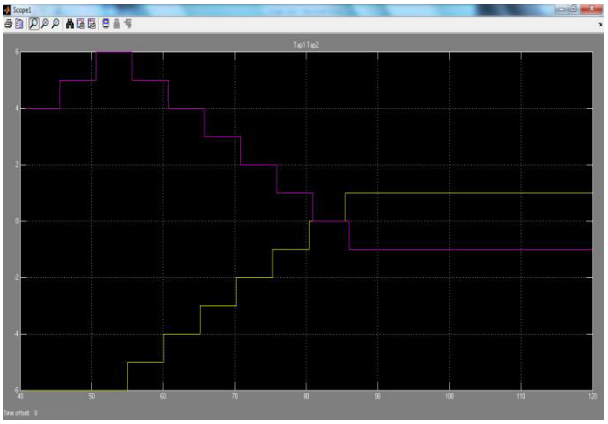
OUTPUT



OLTC SIGNAL PROCESSING



OLTC OUTPUT



CONCLUSION

A proof-of-concept joint vibration and arcing measurement system for online condition monitoring of OLTC. By resourcefully integrating arcing measurement with vibration measurement, this system noticeably identified the closing and opening events of OLTC's switching contacts and subsequently revealed the event sequences in OLTC operation. The completion and fitting of this system was straightforward without disorderly the standard transformer operation. It can cover a method for online situation assessment of OLTC switching contacts.

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