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Analysis of Health of Transformer using Different Loading Conditions

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***Abstract*—**Transformer is one of the most crucial and expensive part of the power system. Any failure in its components may cause major loss to the economy of a country. The healthy operation of the transformer actually ensures the reliable and secure operation of the power system. Keeping in mind the importance of the transformer, this study mainly focuses on the online health monitoring of the transformer in order to detect the fault in its initial stages. This study provides cost effective, real time online monitoring system for the health of the transformer. Real-time data of the transformer is recorded through phasor measurement unit (PMU). Signal to noise ratio (SNR) of voltage and current of the transformer has been calculated. The width of signal to noise ratio is employed as an indicator for the occurrence of fault in the transformer. When transformer operates in its normal conditions the width of SNR band is small, when fault occurs in the transformer the width of SNR band starts to increase. As fault in the transformer continues to increase the width of SNR also increases. Thus this technique can help the transformer operators to take significant steps in order to mitigate the fault before major accidents.

Keywords: Signal to Noise Ratio (SNR), Health Monitoring, Transformer and Phasor Measurement Unit (PMU).

I. INTRODUCTION

A power grid is a potent being, and its health needs to be monitored at all times. Transformer plays vital role for the reliable and continuous operation of the power system. Therefore, transformer is one of the most significant constituents in the power grid. Its condition has the major impact on the stability of the power grid. . Large power transformers are complex in design and operation. Transformer condition monitoring and assessment of their remaining life is most salient task for transformer operators. Transformer condition monitoring covers many areas closely related to transformer structure and operation. The condition of the insulation system contributes significantly in deciding the life span of a transformer. Similarly, winding/core integrity, bushing, and tap changer health are also important in maintaining the overall reliable operation of a transformer [1].Transformers can transfer the required electricity to the residential, commercial and industrial areas to fulfil the electricity consumption demand. But overloading of transformer can significantly affect its health which may result in the instability and outage of the power system and multiple monetary losses to the distribution companies. The transformer failure could affect major equipment of the interconnected power subsystems and, thereby, cause switching off of the latter by means of relay protection [2].Like other parts of power system, many different types of faults also effect the health of the transformer. As a result of these faults serious economics losses are faced by the consumers, it also greatly impact the social conditions of a country. Hence effectual and accurate fault analysis and health monitoring should be done in order to detect the fault, monitor the transformer health and to remove the associated affects to the lowest possible level.This study will mainly focus on the distribution transformer and it will develop the more accurate, cheap and efficient monitoring method for the health of the transformer on the basis of different load change. If the distribution transformers are operated under the normal conditions for which they are designed for, then they have long life span.

Figure 1 Faulted pole top Transformer

However, their life span eventually decreases if they are overloaded and operated in under abnormal conditions resulting in unexpected failures and loss of electrical power supply to a greater number of consumers which may affect the overall system reliability and efficiency. Transformer overloading and un-necessary cooling are the main aspects for the internal damages and failure in the distribution transformer. Explosive failure may occur due to the re-energizing of the pole top transformers that contain an undetected internal fault which is

very dangerous to human life. Such event is shown in the Figure 1 [3].

In Pakistan, the transformers are monitored physically by a lineman but this monitoring is not scheduled due to which proper data is not present. This type of monitoring cannot give data about over-loading, overheating of transformer oil and windings or any internal fault. Neither can it give any indication about the health of transformer. Every one of these variables can essentially decrease transformer life [4]. These parameters greatly affect the health of transformer and thus causes many financial losses. Therefore, there should be a system that can provide an indication about the health of the transformer, so that the operators can be able to take quick actions before the occurrence of any major accident. This can assist in extending the life and performance of the transformer. Transformer has the most important place in the electrical network. It is the expensive equipment in power industry, any inadequacy in transformer can result in life long interference and repairing of the transformer components are costly and very time-consuming. Hence as an important part the study of the faults and failures of the transformers is also very important. Therefore, the purpose of this research study is to propose a stable, reliable and less time consuming real-time health monitoring system, analyse all the operating parameters of the transformer i.e. voltage and current and to detect any internal abnormal conditions in its initial stages. This will help to identify problems before any major failure or accidents which can results in significant cost savings to the distribution companies and ensures greater reliability to the consumers. In this study an online monitoring of the main operational parameters i.e. voltage and current of the transformers will be provided that will give useful information about the health of the transformers. And also this study will provide the technique that can save the transformer from serious failures because on the bases of the information alert alarms can be used for the predictive maintenance of the transformer. This will also help the consumers to make best use of their transformers and keep it in working condition for larger duration. Power transformers provide a connection between the generation and distribution of produced energy. Such static equipment is subjected to different types of disturbances during operation in generation and distribution stations and thus it can lead to catastrophic failures [5]. Power transformer occupies almost 60% of the total investment that's why it is one of the most complex and costly units of power system. Due to the complexity and expensiveness of transformer components, proper monitoring and maintenance of transformer components are the important tasks in the field [4]. Transformers can transfer the required electricity to the residential, commercial and industrial areas to fulfil the electricity consumption demand. But overloading of transformer can significantly affect its health which may result in the instability and outage of the power system and multiple monetary losses to the distribution companies. During transformer operation, they are continuously open to thermal, mechanical and electrical stresses. Environmental disturbances also effect the transformer operating conditions because transformers are open to unpredictable conditions that they are not designed for [6]. Thus researches should be done to perform effective and suitable fault analysis and health monitoring techniques in order to analyse all types of transformers, detect all types of faults in the transformer and diagnose their respective effects on the consumers and the economy.

A. Phasor Measurement Unit (PMU)

It is the instrument which is used in the electrical grid to measure different electrical quantities like voltage, current and frequency. For synchronization PMU uses a similar time source. GPS mostly provide the time synchronization which helps to measure synchronized real time values of electrical quantities. Voltage and current signals can be measure with the help of potential transformers PTs and current transformers CTs in the power system but using PMUs can provide voltage magnitude and phase angle, current magnitude and phase angle and frequency. Particularly high transient goals can be achieved by using PMU, in the order of 30-60 estimations for every second. This helps in examining the unnecessary events in the power system. This type of benefits are not possible when Supervisory control and data acquisition (SCADA) is used in the grid that create one reading after 2 or 4 seconds. The data which is given by PMU is further used in order to take different control actions. The reporting rate of PMU is quite fast and for the system of frequency 50Hz and 60Hz its reporting rate is presented in the table 1 below [7].

B. Transformer Health Monitoring

Transformer is a very important component in the power system. It provides the connection between the generation and the customers. Now a days, transformers are present in wide area therefore, health monitoring of transformer has become a serious problem. Because transformer is exposed to the environment which effects its various properties such as thermal, electrical and physical properties. As the greater number of transformers are present in power system manual monitoring has become impossible for the operators of transformer. Therefore, many techniques have been developed for the online monitoring of transformer so that it can be prevented from any catastrophic failure that causes major damage to the customers and distribution companies.

There are many diagnostic tests and condition monitoring techniques employed for the analysis of the health of the transformer. The main parts of the transformer like Tap-changer, bushing, winding Integrity, paper and oil Insulation and Magnetic circuit, require good condition monitoring methods for their reliable operation.

II. METHODOLOGY

The detailed methodology for monitoring system of the transformer in real time is proposed in this paper. This study is actually based on programming of real time data provided by PMU using MATLAB programming. PMU is connected with transformer at Sheikh Muhmandi grid station in Peshawar. PMU provides magnitude of voltage, phase angle of voltage, magnitude of current, phase angle of current, frequency and power of the transformer at a very high rate usually 60 cycles per second. Using this data a technique is developed to monitor health of transformer at low cost and with less time consumption. Signal to noise ratio (SNR) based technique is used to monitor health of transformer. With the help of real time

PMU data healthy and unhealthy conditions of transformer are observed by calculating the signal to noise ratio of magnitude and phase of voltage and current of the transformer. Band of SNR is observed which clearly shows the difference between healthy and unhealthy conditions of transformer.

A. Signal to Noise Ratio (SNR)

The definition of SNR which is used in this study is the reciprocal of coefficient of variation i.e. the ratio of mean of a signal to the standard deviation of a signal [4].

$$\text{SNR (in dB)} = 10 * \log \frac{\mu}{\sigma} \qquad (2.1)$$

In Eq. 2.1, μ is the total mean of a signal or expected value while σ is the standard deviation. It is very tough to observe different signals provided by PMU (i.e. currents (A) and Voltages (V)). However, SNR (in dB) is a relative criterion and therefore, it can be employed to compare different signals and generate signals for awareness [4].

TABLE I. PARAMETERS OF 3 PHASE TRANSFORMER

Parameters	**Values**
Rated voltage	12KV
System voltage	11KV
Frequency	50 Hz
Maximum current	653 A
Rated capacity	13 MVA

III. RESULTS & DISCUSSION

Different results have been obtained with the help of the data provided by PMU. At first the raw data was plotted and then signal to noise ratio was observed using this data.

A. Results of Raw Data of PMU

Data is collected from the transformer in the form of current and voltage. Figure 2 and Figure 3 shows the magnitude and phase of 3 phase current obtained through PMU. Figure 4 and Figure 5 shows the magnitude and phase of 3 phase voltage.

B. Signal to Noise Ratio of Current Mangnitude

At first the SNR of current magnitude was calculated as it gives clear indication of fault in the transformer. The variation in the value of SNR is shown in figures 6, 7, 8 below reflects the occurrence of fault in transformer.

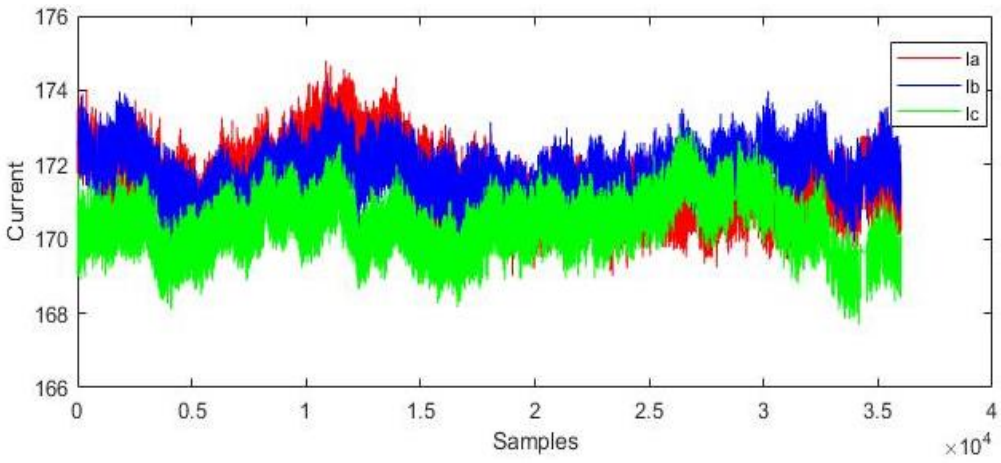

Figure 2: 3 phase current magnitude

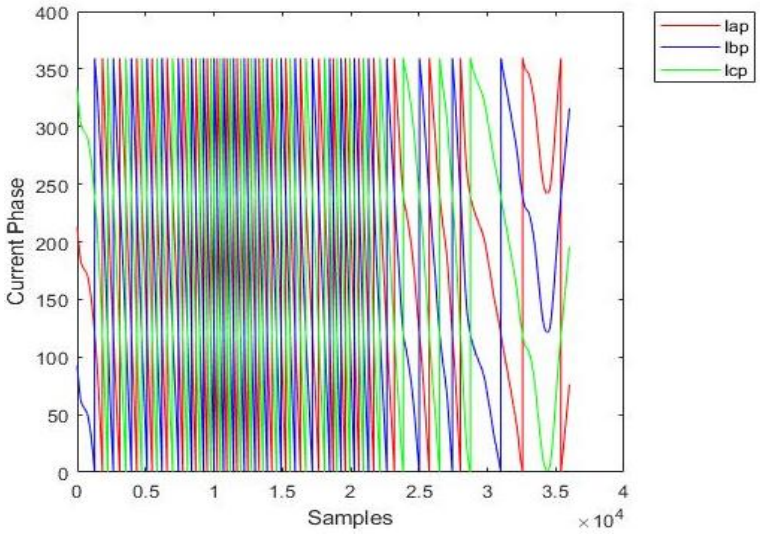

Figure 3: 3 phase currents phase angle

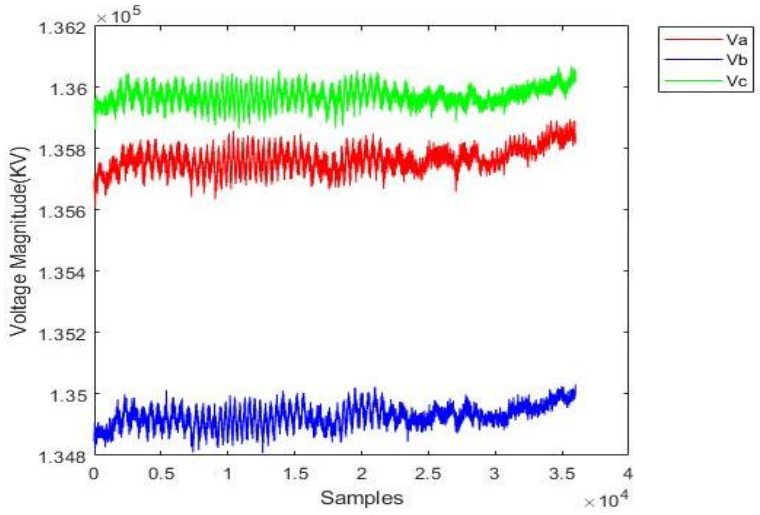

Figure 4: 3 phase voltage magnitude

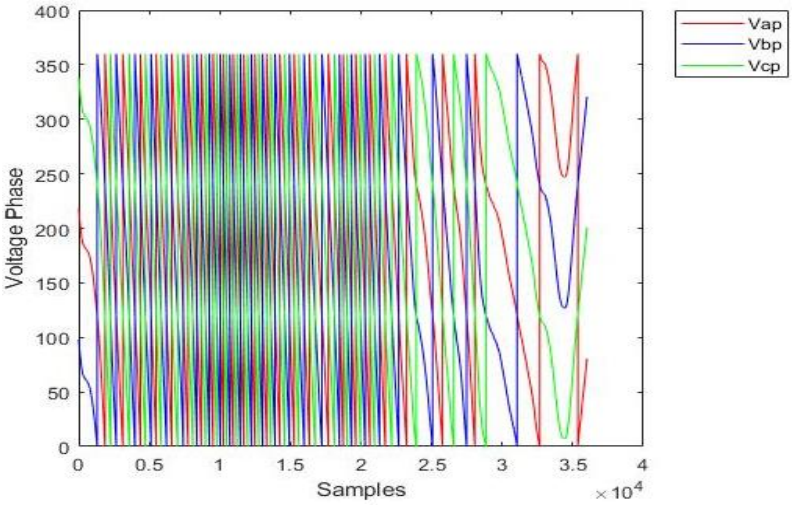

Figure 5: 3 phase voltage phase angle

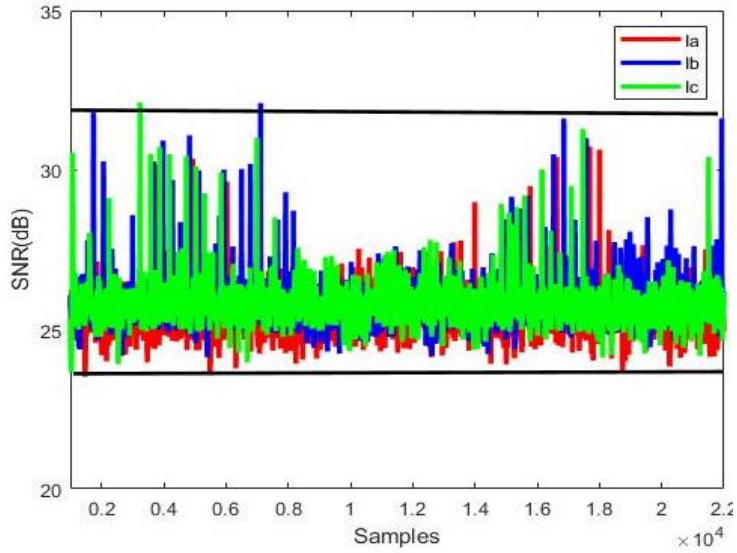

Figure 6: SNR of Transformer current (I) samples 1-22000

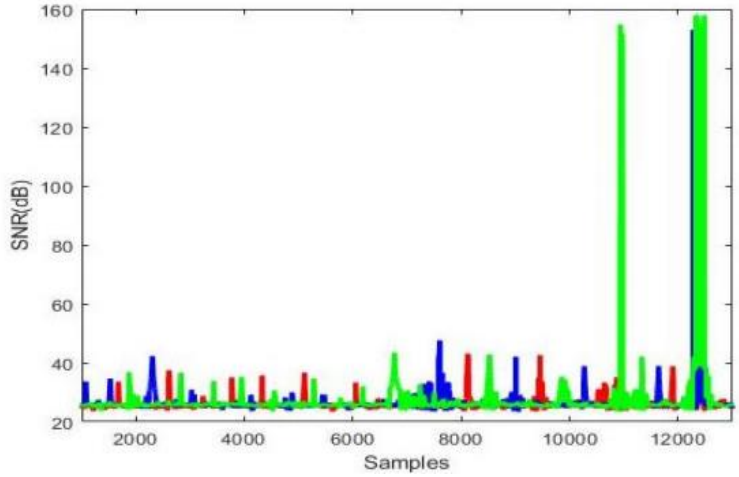

Figure 7: SNR of Transformer current (I) samples 22000- 35000

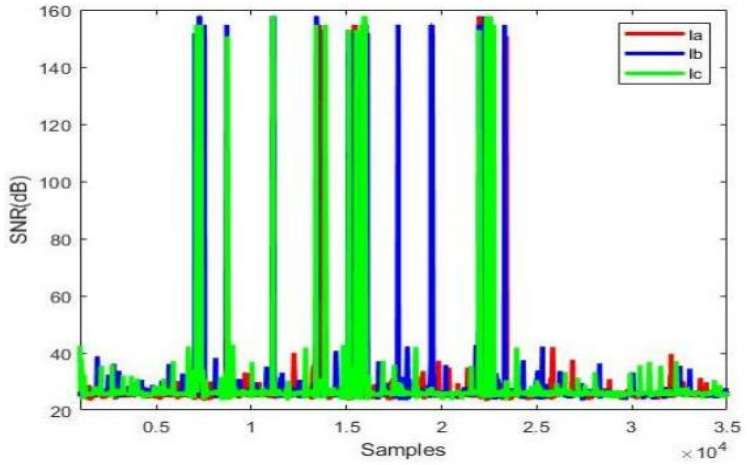

Figure 8: SNR of 3 phase current (increase in phase A)

From figure 6 – figure 7 it was observed that some abnormal power system event has occurred because the value of SNR of current magnitude was first varying from 25 dB to 31 dB when 22000 samples were analysed after that from samples number 22000 to 35000 the value of SNR was not same as before, it increases as fault started to grow. The increased value of SNR for sample number 22000 to 35000 can be seen in fig 7. As the data continues in sheet 2, the value of SNR of that data was also analysed and it was observed that fault continues to grow causing the increase in the value of SNR of phase A as shown in figure 8. And the value of SNR for phase B and C is still high which depicts the existence of fault in all the three phases. Consequently, if fault in transformer grows with time and it is not monitored properly, then the value of signal to noise ratio (SNR) of voltage and current of transformer also continues to increase.

CONCLUSION

Direct observation or analysis of raw current magnitude, angle, real and imaginary components did not give any conclusive indication regarding the nature or occurrence of any power system event (or deterioration of health of an asset).With the help of SNR it is concluded that as the fault increases in transformer the value of SNR of all the phases of transformer also increases. We can also conclude that as the transformer reaches to failure the value of SNR or SNR width increases. By continuously monitoring the real time data of transformer and analysing its signal to noise ratio width we can easily predict the health of transformer. If the value of SNR remains constant it means that transformer is working in normal conditions but if continuous increase in the value of SNR is observed, then this is the indication of poor health of transformer which tells the operator to do predictive maintenance of transformer before the occurrence of any unnecessary power system event. Thus this technique can prevent major transformer failure and ensures reliable operation of power system.

FUTURE WORK

Many researchers have done researches for the health monitoring of the transformer to increase the life of a transformer using different techniques that includes the use of different sensors and controllers. But these methods are sometimes slow due to the slow output of a sensor. Before this study to get real time data of the transformer was not possible in Pakistan. This paper has mainly focused on the online monitoring of the transformer to find the optimal results which should be cheap and less time consuming, the actual and real time data of transformer was analysed in this study and the results can be further used for the health monitoring of transformer where the measurement sensors are present. Pakistan has only one PMU connected with transformer in Sheikh Muhmandi grid station in Peshawar. By increasing the number of PMUs in Pakistan we can further implement this study for the reliable and secure operation of transformers.

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Conflicts of Interest: The authors declare no conflict of interest.

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