Prediction of Transformer Health Index Using Condition Situation Monitoring (CSM) Diagnostic Techniques

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Abstract. This paper presents newly developed condition situation monitoring (CSM) diagnostic techniques for predicting the health index and health condition of practical cases in any working transformer. Investigation on measurement and testing can produce results on the insulation resistance between phase and ground test, polarization index with different time duration test, winding resistance of transformer while winding tap changer rating transformer can be determined by the performance health index of the transformer. Real data was collected from 8 units of transformers from Company Transformer Manufacturing and Servicing (CTMS) in Malaysia. The data was applied to calculate the healthy index to provide the transformer performance indicator condition. The main purpose for the use of transformer health index is to indicate the condition of the transformer and attend to failures that can be prevented, with consequences on safety and cost.

1 Introduction
Currently, many industries monitoring condition transformers specially in insulation. It also diagnosis and data interpretation for asset management. Condition Transformer is base on the electrical, mechanical and also environmental stresses.

Previously, the transformer insulation systems of the oil paper transformer normally using the oil characteristic tests for evaluating the quality. Some also using the dissolved gas analysis (DGA) to indicate health condition. It may detect the fault by using the dissolved gas analysis technique which happens in the transformers. Besides that, the ageing condition transformer insulation system using oil characteristics test is used to evaluate. Therefore, it was very costly by used the oil characteristics test and also time consuming.

Previously several researchers were proposed various methods to determine the transformer conditions. A.E.B Abu Elainien et al. [1] recommended technique transformer asset management. A. Jahromi et al. [2] proposed health index transformer asset management. D. Hughes et al. [3] proposed condition base risk management (CBRM) to corporate decision making. J. Young et al. [4] proposed the equipment condition assessment index. Liu, L. X et al [5] proposed feedback artificial learning algorithm for the state. M. Koch et al [6] proposed transformer diagnostic moisture equilibrium.
M. Martins [7] proposed transformer as an alternative to mineral oil. Q. Liu et al [8] proposed the characteristic and breakdown transformer under lightning impulse. S. Besner et. al [9] proposed on unusual ethylene service transformer at low temperature. S. Miletic et al [10] proposed health index benchmarking asset assessment and Z. Yang et. al [11] proposed transformer on rule mining based for fault diagnosis.

The entire health transformer represents by index forms according performance incidence replacement, explosions and also system failure. Besides that, it also to manage control maintenance. Abu Elanien et al., [12]. Wang et.al proposed improve transformer performance due to demand, and asset maintenance cost. Wang et al., 2004 [15]. The transformer design base on the industrial. Hughes, 2010 [3].

Naderian proposed the asset health index to identify investment needs, minimize operation and maintenance cost. Previously, researchers proposed like reliability life, transformer life span and consumption. Naderian et al., 2008 [14]. Proposed by calculate transformer health to analysis complex asset and also not reflect repair nor inspection for the transformer. Jahromi et al., 2009 [13]. The health index may indicate transformer life span also the risk. It also can define capital cost like replacement, repairing and prevent increase maintenance.

Purpose the Health Index (HI) to monitor transformer and also to improve quality transformer insulation system. The factor increasing age insulation may to system failure. It is because life span insulation base on the strength and reliability of the electrical and mechanical.

The paper insulation may indicate the transformer life span and ageing. Normally, the information its test on windings faults and problems of dielectric. It is also included measure temperature and dissolved gas analysis. These tests may detect fault such as ageing, moisture and electrical & mechanical faults.

This paper presents a developed condition situation monitoring (CSM) technique to predict transformer health using methods calculate health index and performance conditions. It also provides about knowing transformer life span condition.

Among all the electrical equipment from a power grid, a case study in the power transformer was chosen because it is the most important equipment due to its operational role and due economic reasons. Monitoring system status through this, knowing the transformer health index may help to plan and operation more reliable and also effective.

2 Condition Situation Monitoring (CSM) Techniques

This paper proposed the new condition situation monitoring (CSM) diagnostic technique for prediction of power transformers health index and monitoring a condition of a transformer. The new condition situation monitoring (CSM) technique was developed for the purpose of detecting faults in condition transformer. Besides that, it can be monitored online by several parameters without sent oil sample to test.

The new condition situation monitoring diagnostic technique measures and tests the insulation resistance from high voltage to ground (HV-E), low voltage to ground (LV-E), high voltage to low voltage (HV-LV). It also includes winding resistance primary winding and secondary winding. The method that is used to predict the trends of the monitored transformer to calculate the transformer’s indicator of whether it is in good, fair or poor conditions. The data collections were tested and measured using 8 units of transformer from different locations. Besides that, the health index result was provided.
by CTMS for comparison. The new condition situation monitoring (CSM) diagnostic technique can determines the health index for the transformer’s life span. It saves cost without the need to send the sample oil for testing and maintenance.

3 Measurement Method for Data Collection Transformer

The initial contact resistance has very strong influence on life contact resistance. If the connection contact resistance is known, it may to define remaining life contacts. This can make by the resistance test of temperature oil transformer and electrical connection design in this research.

3.1 Winding Resistance Measurement

Winding resistance measurement is performed with a low resistance ohmmeter. For a three-phase wye-connected transformer, the resistance is measured for each phase to neutral winding. If delta is connected, the resistance is measured for each phase to phase winding. For delta connected transformers, the measured resistances for each phase compose of a parallel combination of the winding under test and the series combination of the remaining windings. It is therefore recommended to make three measurements for each phase to phase winding in order to obtain the most accurate results. It is also recommended to allow the transformer to be de-energized until the temperature is equalized before making resistance measurements.

In order to reduce measurement errors due to changes in temperature, some precautions should be taken before the measurement is made. For oil immersed transformer, the transformer should be under the oil and without excitation for at least 3 hours. In addition, it is important to ensure that the average oil temperature is approximately the same as the winding temperature. To avoid an inadmissible winding temperature rise during the measurement, it is also recommended that the measuring current should be limited to no more than 10 percent of rated current of the winding.

In order to diagnose the possible problems, the measured results are compared to the factory values, value of other phases of the same transformer. Consistency in measurements and record keeping are the keys to making the proper analysis using this test.
3.2 Insulation Resistance Measurement

The insulation resistance test or Megger test is used to indicate the insulation leakage current resistance. The resistance is a moisture function and insulation impurity content and also the insulation temperature. The resistance depends on the electric field strength across the insulation. Primarily, this measurement provides information regarding the insulation condition and make sure that the leakage current is small.

Transformer insulation resistance is measured by resistance meter using DC voltage. In measuring resistance, it has to make sure that the core and tank are grounded. Each transformer winding is short circuited at terminals. Resistance measurements in between of each winding and also other winding grounded. Windings never left floating during insulation resistance measurements. When winding is installed with solid ground, the ground must be removed to measure winding insulation resistance to another winding grounded. If the ground is not removed, the winding insulation resistance could not be measured. It is a part of the circuit grounded section. Insulation resistance is determined into mega ohms (MΩ).
Two winding transformer the following measurement configurations are used:

i. Measure from the high voltage winding to ground (HV-E)

ii. Measure from the low voltage winding to ground (LV-E)

iii. Measure from high voltage winding to low voltage winding (HV-LV)

This test is easily performed and many manufacturers required to emerging transformer, to preclude start up failure caused by entry moisture into the transformer during shipment or storage. The test can detect other ground circuits in the transformer that have been caused by shipping damage, the test checks complete circuit bushings and coils.

The measurement for the duration is in minutes. Normally, the resistance readings are taken 15 seconds and 60 seconds. It is very important to record all the tests in report because these readings may use to compare for future likes measurements, the mater used, measuring voltage and the measured resistance. Reading or any comparisons measurements must in the same voltage because vary of the insulation resistance with applied voltage.

Precautions should be taken when doing the insulation resistance test as following:

i. If it is found out the current in begins to increase, the test must be discontinued immediately without stabilizing.

ii. Under no conditions should the test be made while the transformer is under the vacuum.

iii. All terminals should be grounded after the test has been completed. It allows trapped charges to decay until negligible value in certain period.

4 Calculation of HI Transformer Method

The transformer health index is determined by condition indicator applying data in MS Excel spreadsheet and also given the total health index.

Through CSM methodology, these data were provided by various diagnostic techniques. Currently, the problem facing of the transformer is difficulties to evaluate for condition transformer and may also have high risks. Therefore, a new technique for health index is formulated for calculation, analysis and prediction to indicate condition of the transformer.

The formula health index was derived to evaluate, determine and calculate the condition transformer according performance transformer, like example testing insulation resistance high voltage to ground (HV-E), low voltage to ground (LV-E), high voltage to low voltage (HV-LV). It also includes winding resistance primary winding and secondary winding. The weighting factor is according the previously or any historical data condition transformer from CTMS.

5 Result and Discussion

There are three stages involved in the diagnostic techniques. The first stage is using high voltage to ground (HV-E), low voltage to ground (LV-E), and high voltage to low voltage (HV-LV) to determine insulation resistance. In the second stage, it tests on the winding resistance of 11kV transformer in primary winding and secondary winding. The result of the health index test is based on 8 unit of transformers in CTMS.
The result of the health index will be compared with the result from the CTMS health index from industrial facilities to compare the transformer conditions measured in accuracy.

From the result, the transformer health index more than 0.85 is considered good condition. The transformer health index more 0.6 until 0.85 health index is considered fair condition. For the transformer health index below 0.6, it is considered poor condition. The transformer in poor condition, it may have high risk and the risk will increase. Therefore, transformer in poor condition needs for repair or replacement transformer.

5.1 Result Transformer Health Index between Calculate and Transformer Health Index Given by CTMS

The result of the health index using the proposed method is compared with the health index which given by the Company Transformer Manufacturing and Servicing in Malaysia are shown in Figure 2 and Table 1. From Figure 2 and Table 1, it is found out that the error percentage of the health index result is between range 7% to 10%.

5.2 Performance of the calculated Health Index and CTMS Data

It can be concluded that the calculated health index which is based on the condition indicator can classify the condition of the transformers with an acceptable result. The result also indicates that the calculated health index from the proposed model show an acceptable value compare to the data given by CTMS.

The results of the calculated health index are based on the condition indicator for all of 10 transformers. From the result, the transformer which has health index value more than 0.85 is considering good. The health index value between 0.6 until 0.85 is considers Fair condition where an enhance maintenance and service is expected. For the transformer health index below 0.6, it is classified as poor condition. In other word the transformer is in risk condition and need to be repair or replaced immediately.
Figure 2. Comparison of transformer health index between calculated and CTMS

| Transformer Number | Transformer Rating kVA | Health Index |
|--------------------|------------------------|--------------|
|                    |                        | CMTS         | Calculated  |
| 1                  | 1000/11/0.433          | 0.0897       | 0.12        |
| 2                  | 1000/11/0.433          | 0.8417       | 0.87        |
| 3                  | 1000/11/0.433          | 0.7887       | 0.68        |
| 4                  | 1000/11/0.433          | 0.5130       | 0.65        |
| 5                  | 1000/11/0.433          | 0.8187       | 0.86        |
| 6                  | 1000/11/0.433          | 0.0870       | 0.08        |
| 7                  | 1000/11/0.433          | 0.8397       | 0.85        |
| 8                  | 1000/11/0.433          | 0.8287       | 0.86        |
| 9                  | 1000/11/0.433          | 0.2177       | 0.23        |
| 10                 | 1000/11/0.433          | 0.9140       | 0.93        |
6 Conclusion

This paper presents new approach to condition situation monitoring (CSM) diagnostic technique, a health index to determine health condition of the transformer. This method is based on the transformer condition to evaluate the health index. The condition situation monitoring (CSM) diagnostic technique models may able to determine the health index for identify of the transformer. The results of the health index showed by (CSM) diagnostic technique models. It provides results faster compared to method using oil testing which need analysis for few days.

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