Remote condition Monitoring Technique of Transformer using single board computer

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Abstract : *In this paper remote condition monitoring system is developed using single board computer and data acquisition system which senses different parameters and communicated to the remote end using internet. The economical aspect of transformer with remote condition monitoring system which givesnecessary information of operating condition isanalyzed. The performance of remote condition monitoring system is tested on 16 KVA transformer in the laboratory. Transformers with remote condition monitoring system can be provided maintenance as and when required.*

I. INTRODUCTION

Transformer is a static piece of equipment with a complicated electromagnetic circuit inside. Although the transformer is a complex piece of equipment, proper designing of an insulation system, magnetic circuit, structure and selection of proper transformer auxiliaries make transformer extremely reliable equipment. Utilities are very much keen to control and monitor the status and condition of all transformers fleet so they can intervene before a failure or malfunction of it. Many of the transformers in use at utilities have already exceeded design life. Most power transformer will encounter emergency overloads on occasions, with subsequent loss of life. The load peaks may be predictable or non predictable, unexpected generates high temperatures which shortens transformer lifetime. Presently the load and the age of the apparatus is increasing and therefore the monitoring and diagnosis of power transformers becomes more and more important, whereby monitoring is the collection of relevant data during service (online) or during maintenance or test periods (offline) and diagnostic is the technical evaluation and interpretation of the recorded data. Monitoring improves the reliability of the assets by continuously keeping a watchful eye on the most critical transformer components. Inordinate temperature rise in a power transformer due to load current have known to be the most important factor in causing rapid degradation of its insulation and decides the optimum load carrying ability or the load ability at a transformer.

In [1] hourly load and ambient temperatures obtained through condition monitoring are used to assess the operating profile of the equipment. The only inputs to the IEEE life consumption models to assess the consumed life of insulation estimated are restricted toload factors and ambient temperatures. However, thisapproach needs to be extended to include the long-term shift effects in load and ambient temperature variations. A laboratory controlled thermal aging experimental method has been described in [2] to obtain information on the status of insulation by diagnostic testing and condition monitoring has been suggested. However, to correct the results to field conditions, a correction factor is required for certain diagnostic parameters. The monitoring methods presented in [3] are based on the existing IEC and IEEE standards and neural-network analysis. These methods are used in to calculate the topoil and hot-spot temperature as well as the loss of life of a transformer. This requires measured data from the studied or same type of transformer supplying similar loading. Article [4], classified the defect sources using phaseresolved partial discharge patterns. But, this requires an understanding of the traits associated with, andrelationship between, observed partial discharge activity and responsible defect sources. The application of Fiber Bragg Grating (FBG) sensors for monitoring power transformer hot-spot temperatures has been demonstrated in [5].

However, the temperature sensors are based on proprietary encapsulated FBG sensors and the optical interrogation unit requires a special designed narrowband high power broadband fiber conducted in this work, a further investigation needs to be undertaken to verify source. Model-based identification approach has been developed in [6] to determine parameters of a demagnetized transformer core such as magnetic permeability and electrical conductivity, of power transformers on the basis of frequency response analysis (FRA). However, only simulation studies are the proposed identification approach with experimental measurements. In [7] an evidential reasoning ER-based approach to transformer winding condition assessment using FRA is proposed to formalize a frequency response analysis (FRA) evaluation process for the first time. In this study, only the experimental FRA data from a normal transformer is used as a winding condition evaluation. Much research needs to be carried out to establish more reliable interpretation features with regard to different FRA diagnoses using experimental FRA data related to various winding failure conditions from real transformers. The technique of Conditional Anomaly Detection and its application to transformer monitoring described in [8]. However, various system components are needed to provide a solution that supports engineers in decision making. The main components of power transformer are the windings, bushings, transformer oil, core, tank, cooling system, and tap changer. Failure analysis of large power transformers can be beneficial in determining which component is more important in evaluating the condition of transformers.

Statistics [9] show that the most frequent causes followed by long outage damages are in tap changer, active component and in bushings, as shown in table I. Power organizations today use either or both of the following traditional maintenance models. On the one hand, "failure-based" or "reactive" maintenance occurs when equipment is left un-monitored until one or more failure modes have been observed. On the other hand, "preventive" maintenance approach involves physically visiting an asset on a regularly scheduled basis, assessing the performance of that asset and then applying necessary maintenance to ensure optimal performance. On the bases of CIGRE report, the failure pattern of power transformers follows a "bath-tub" curve for 400 transformers, as shown in Fig. 1 [10]. The first part of the curve is failure due to infant mortality; the second part of the curve is the constant failure rate; and the last part of the curve is failure due to aging. The numbers of transformer failures in the second part is greater than the last part. Electrical stresses, Electromagnetic stresses, Dielectric stresses, Thermal stresses, and Chemical stresses can cause premature failure.The accuracy of the predictions is not always as good as are desired. Unacceptable temperature rise may occur due to several fault conditions other than overloading, and hence the need of an online monitoring of the transformer becomes more prominent.

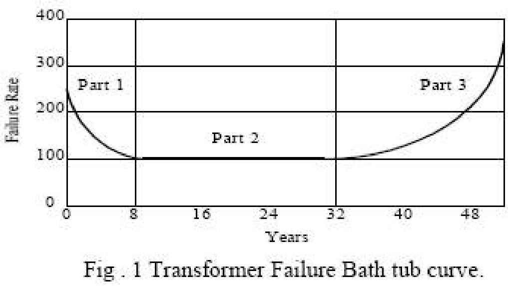

Fig . 1 Transformer Failure Bath tub curve.

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II. CONDITION MONITORING

Condition Monitoring Techniques are broadlyclassified as conventional and non conventional.Thermography, Dissolved Gas Analysis, Furan Analysisand Tan Delta tests are conventional where as SweepFrequency Response analysis SFRA, Partial DischargeMeasurement PD, Recovery Voltage MeasurementRVM, Size exclusion Chromatography SEC, ExpertSystem are the Non Conventional Condition MonitoringTechniques. As per the literature available DifferentMethods Used for Condition Monitoring of Transformerare studied .Different Types of Condition Monitoringtechniques with procedure and type are as follows.

1. IR measurement : Application of DC voltage fromthe instrument (Megger) and comparative study of IRvalues at different time (15 sec60sec,600 sec) gives risethe idea of the insulation. It gives Condition of theinsulation (Oil and solid) Procedure is OFF line andIndecisive for fault location but provides conditionassessment Routine/ investigation Type.

2. Capacitance and tanδ measurement :By the use ofSchering bridge technique and other available methods,the capacitance of dielectric materials and associatedfactors (Dissipation factor, Tanδ factor) are calculated. Itgives Condition of the insulation (Oil and solid)Procedure is OFF line / On line and Indecisive for faultlocation but provides condition assessment. Routine/investigation Type.

3. Low voltage injection tests (Voltage Ratio, VoltageBalance, Excite current, SC current etc) :Supply of Low voltage to one side of transformer andmeasurement of different electrical parameters on opencondition and short condition, gives rise the idea fordiagnosis. It gives overall conditions of Transformercore and winding. Procedure is Offline and is partiallydecisive for fault location. Routine / FundamentalInvestigation type.

4. Dissolve Gas Analysis : Because of the insulationdecomposition, different characteristic gasses evolveand dissolve in oil. The concentrations of these gases areregarded as the primary diagnosis for obtaining thecondition of the insulation as well as the diagnosis offault. It gives Condition of insulation and Primarydiagnosis of fault. Procedure is Offline and gives Partialdecisive for fault location. It is a Routine/ Investigationtype.

5. Laboratory Testing of In-service Oil (Water content,Acidity, Inhabitation content, Interfacial tension, flashpoint, Pour Point, Viscosity, Dielectric strength, sp.resistance According to the IS Methods, Oil tests areconducted to obtain different electrical, physical andchemical properties for comparison of the same with thestandard values. It gives condition of Transformer oil.Procedure is Off line and Indecisive for fault locationbut primary detection of faulty portion. It is a Routinetype.

6. Turns Ratio Test : By the use of referencetransformer, the testing transformer turns are compared.The ratio meter has null detector. According to thevoltage excitation and current through the windings ofthe transformers, adjustments are tried to obtain nulldeflection for

turn's ratio. Digital ratio meters are alsoavailable for finding the ratio. It gives Condition ofwindings and Condition of Tap Positions. Procedure isOff line and Indecisive for fault location but primarydetection of faulty portion. It is a Routine/Primary
Investigation type.

7) Winding Resistance Measurement : Basic ethod isvoltmeter ammeter principle. Some cases Kelvin'sdouble bridge principle is also used for finding the DCresistance of the winding. It gives Condition of windings2.Condition of Tap ositions.

8) Partial discharge measurement :

1. Electrical detectionmethod – By the application of Power frequencyvoltage, called PDIV (Partial Discharge Inception
Voltage), certain charge is allowed to develop, acrossthe insulations. Then the developed charge is dischargedby decreasing the voltage called PDEV (PartialDischarge Extinction Voltage). According to the patternof PDIV and PDEV; the status of insulation isdetermined.

2. Acoustic Method – Because of the fault inthe transformer, the solid insulation parts being heatedproduce acoustic waves. By this method the sensors thatfixed on the inner wall of the transformer, receive thesignals for analysis of the fault by computing machines.It gives Condition of Insulation (Solid).Off lineprocedure, Acoustic method is decisive for fault locationIt is a Investigation type.

9) Polarization spectrum technique / Recovery voltagemeasurement (RVM) :It is similar to PD Electricaldetection method. But charging and discharging of theinsulations are done for a certain pre-determined time.According to the recovery voltage that obtained duringdischarge condition, the status of insulation isdetermined.Moisture Trend analysis of winding and paperinsulation. It is Expensive and Offline, Indecisive forfault ocation but primary detection of faulty portion and
Investigation type.

10) FRA (frequency Response Analysis) : By the use ofstandard spectrum analyzer, sweep frequency sinusoidalsource of approx. 2V RMS is applied across the windingterminals. For different range of frequency, theimpedance is measured. The curve (Impedances versusfrequency) becomes indicative to know the status of thewinding. The other curves for voltage ratio versusfrequency are also used. It gives Mechanicaldisplacement of winding and Dynamic response ofwinding. is a Expensive Offline and disconnectionrequired .It is Partial decisive for fault locationInvestigation type.

11) DP measurement: By this method DP (Degree ofPolymerization) value is counted for etermination ofthe status of solid insulation and accordingly theassessment of residual life of transformer. D.P. Value: -It is average number of glucose rings in cellulosemolecule. D.P. value for new paper 1000-1400 It givesCondition of Solid Insulation. And Residual lifeassessment.xpensive and Offline routine type.Indecisive for fault location but only assess thecondition of the insulation.

12) ARY-MAP Analysis : The graphic resentation ofthe amount of (CO + CO2) gas versus the service periodtransformer represents the degree of ageing ofinsulation. It gives Condition of Solid Insulation,Residual life assessment. It is Expensive, Routine typeOffline and Indecisive for fault location.

13) FFA (Furfuraldehyde Analysis) :By HPLC (HighPerformance Liquid Chromatography), furan compounds are detected and according to the concentration and rate of generation of 2-furfural, theassessing of condition and remaining life of paper ofinsulation are obtained. It gives Condition of SolidInsulation, Residual life assessment. Procedure is Easyand Simple, Off line and Indecisive for fault location butonly assess the condition of the insulation. It is aRoutine type.

Transformer condition monitoring techniques availablein literature are mainly used for power transformers. Allmonitoring techniques are applied periodically on oilpower transformer for full assessment. The result ifthese procedures are used to evaluate the most costeffective option when transformer is in service. or undermaintenance or under repair. It helps to takereplacement decision also. There is a need of developinga remote condition monitoring system incorporatingmore parameters like temperature, oil level, humming
noise etc. Advancements in information technology andcommunication can aid such a system effectively.

III. PROPOSED MODEL: INTRODUCTION

It is evident that an RCMS for transformer isessential. A proposed model for remote condition
monitoring of transformer is presented here. It includesboth hardware and software implementation. Thecommunication based on GSM or GPRS is not takingthe data continuously, which again is a drawback. In thenew model proposed different parameters liketemperature and oil level that directly acts as a healthmonitor are incorporated. The monitoring system isexplained by going through different aspects like dataacquisition, processing, communication and theapplications.

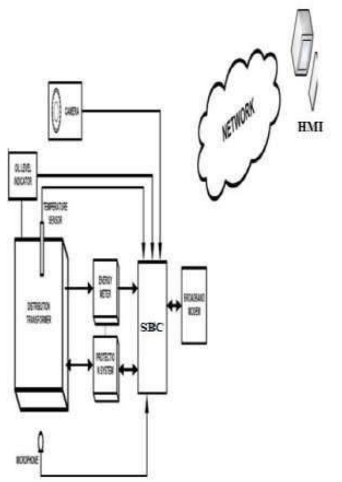
A) System Architecture

The proposed model is explained using thefunctional diagram as shown in Fig2. It consists of dataacquisition, power supply for different components,processing, communication and a Human MachineInterface (HMI). Different parameters are sensed usingsensors and passed to processing unit, which is SingleBoard Computer (SBC) Friendly ARM Mini2440. Thenit is communicated to the remote end where decisionneeded to be taken regarding maintenance andprotection. Computational Algorithm is developed andimplemented in RCMS.

B) Algorithm

Computational Algorithm is developed which includes following steps.

1. Number of parameters available at the user end is checked. HI calculation accuracy depends on available parameters.
2. Five parameters are monitored using RCMS. Among these four parameters, which are temperature, oil level, loading and humming noise can be directly used. Image needs proper processing. Nameplate details and test results of a transformer gives the rated values as well as allowable maximum limits of these parameters. With respect to its rated values, all parameters are normalized.
3. The value of each parameter is used to calculate the Health Index Factor (HIF) which varies between 0 to 4. Zero corresponds to the most severe condition and 4 corresponds to healthy state. Range of parameters for making this discretion have to be made after testing.
4. Each parameter is given weight age according to their effect on overall HI. This value varies etween 10 to 1in this algorithm.
6. The value of HI can be used to identify health status of transformer and is shown in application.



IV. EXPERIMENTAL SETUP

A transformer is constructed for testing thissystem. Special arrangements have been made forincorporating all sensors and to change the internalconditions. The parameters are varied to test RCMS. Allelectrical parameters can be sensed from energy meterdata read out which is a serial port using RS232.Voltages, currents, power, power factor and othertampering data are available in energy meter systemmemory. An L & T energy meter is used for thispurpose. It is interfaced with SBC and thencommunicated to the remote end. Temperature of oil inthe top of the tank is sensed with a thermistor typesensor (LM3). The output of the sensor that will be avoltage in accordance with temperature can beinterfaced with SBC after passing through ADC.Temperature as well as oil level is interfaced with SBCusing the PIC16F877A microcontroller. Its ADC's areused for converting the analog signal output of sensorsto digital values. Then serial communication usingRS232 passes this data to SBC When float moves,resistance varies and thereby PIC ADC senses thevariation in output voltage. Interfacing with SBC issame as shown for temperature sensor. Both temperature
and oil level are sent using same serial port from PIC.

The application software developed consists of two windows. In first window, parameter values are shownand in second window, analysis is done. Health indexalgorithm is written in MATLAB but the results areshown in first window. Humming noise analysis consistsof frequency spectrum of noise. This MATLAB figurewill be shown on the application window.

V. EXPERIMENTAL RESULT.

Detailed test results prove that RCMS can be used for transformers. Different parameter variations are discussed and corresponding HI is also calculated usingprogram written in MATLAB. So it is evident that thissystem is efficient in determining the earth status ofTransformer. Operator will be able to make a decisionwithout inspecting the transformer on site.

TABLE.1

Sr No	Temperature	Oil Level	Loading	Health status
1	Low	High	70%	Good
2	High	High	110%	Alarm state
3	Low	90%	70%	Good
4	High	70%	70%	Alarm state
5	High	70%	100%	Maintenance is required

VI. CONCLUSION

A remote condition monitoring system is developed and tested. The analytical method used is based on health index, which is found to be effective fortransformers.Condition based maintenance and control oftransformers is achieved through this work. This newsystem is monitoring other internal parameters alsowhich directly influence the internal condition of thetransformer and thereby ageing. RCMS implementationcan reduce failure and ageing rate of transformers. It is acompletely online system where instantaneousparameter variations are monitored.

REFERENCES

1) Kshira T. Muthanna, Abhinanda Sarkar, Kaushik Das, and KurtWaldner, "Transformer Insulation Life Assessment",IEEE Transactionon Power Delivery, Vol.21, No.1,Jan2006.

2) M. K. Pradhan, "Assessment of the Status of Insulation duringThermal Stress Accelerated Experiments on Transformer Prototypes",

IEEE Transactions on Dielectrics and Electrical Insulation Vol. 13,No. 1; February 2006, pp. 227.

3) Jouni K. Pylvänäinen, KirsiNousiainen, and PekkaVerho, “Studiesto Utilize Loading Guides and ANN for Oil- Immersed Distribution Transformer Condition Monitoring”, IEEE Transaction on PowerDelivery, Vol. 22, No. 1, January 2007, pp.201-207.

4) S. M. Strachan, S. Rudd, S. D. J. McArthur, M. D. Judd, S. Meijerand E. Gulski, “Knowledge-Based Diagnosis of Partial Discharges in Power Transformers”, IEEE Transactions on Dielectrics and Electrical Insulation Vol. 15, No. 1; February 2008,pp.259-268.

5) A. B. Lobo Ribeiro, N. F. Eira, J. M. Sousa, P. T. Guerreiro, and J.R. Salcedo, “Multipoint Fiber-Optic Hot-Spot Sensing NetworkIntegrated Into High Power Transformer for Continuous Monitoring”,IEEE Sensors Journal, Vol.8 no.7, July 2008, pp. 1264 – 1267.

6)A. Shintemirov, W. H. Tang, and Q. H. Wu, “Transformer CoreParameter Identification Using Frequency Response Analysis”, IEEETransactions on Magnetics, Vol. 46, No. 1; January 2010, pp. 141 –149.

7) A. Shintemirov, W.H. Tang and Q.H. Wu, “Transformer windingcondition assessment using frequency response analysis and evidential reasoning”, IET Electric Power Applications, 2010, Vol. 4, Issue 3, pp.198–212.

8) Victoria M. Catterson, Stephen D. J. McArthur, and Graham Moss,“Online Conditional Anomaly Detection in Multivariate Data forTransformer Monitoring”, IEEE Transaction on Power Delivery, Vol.25, No. 4, October 2010, pp. 2556 – 2564.

9)M. Wang and A. J. Vandermaar “Review of condition assessment ofpower transformers in service”, in IEEE Electrical insulationMagazine, vol. 18, no. 6, pp. 12-25, November/December 2002.

10)David Woodcock “Risk-Based Reinvestment-Trends in Upgradingthe Aged T&D System”, Energy Pulse, March 12, 2004.

11) Saha T.K. Purkait P., Understanding the impacts of moisture andthermal ageing on transformer's insulation by dielectric response and molecular weight measurements, IEEE Transactions on Dielectricsand Electrical Insulation April 2008, Volume: 15 , Issue: 2 pp: 568 –582