Smart Three-Phase Power Transformer Utilizing Fuzzy Logic Approach

Yeong-Hwa Chang[a], Yi-Cheng Cheng[b], Sau-Lie Lie[b], Chen-Chin Lin[b], Chang-Hung Hsu [a*,b], Chia-Wen Chang[a], and Wei-Shou Chan[a]

[a]Department of Electrical Engineering, Chang Gung University, Tao-Yuan, Taiwan.
[b]Division of Research and Development, Fortune Electric Ltd, Co., Tao-Yuan, Taiwan.
(Corresponding Author: Mr. C.-H. Hsu, Email: chshiu@fortune.com.tw)

Abstract: - There are a large number of power distribution transformer stations due to it is far away from city, cable-line, wireless network, GPRS, and 3.5G single transmission device provides a good communication solution to supervise power transformer stations. This paper develops a novel device used to monitor on-line signal for power transformers. The measured-data is captured from multi-sensors and stored in the server equipment database. Besides, these data is used for the prediction of the power transformer life consumption. The transformer life consumption is satisfied with IEEE Standard. Various faults could occur in a transformer such as overload current, overheating, partial discharge and arcing, which can diagnose various fault-related conditions. According to the conventional way of the dissolved gas analysis, the fault is probably determined. As researcher knows, the IEC codes cannot determine the fault in many cases. Therefore, this paper presents a fuzzy logic tool that can be used to diagnosis multiple faults in a transformer and monitor the trend. It has been proved to be a very useful tool for transformer diagnosis and customer servicing.

Key-Words: - Smart maintenance system (SMS), power transformer, fault diagnosis, fuzzy logic.

1 Introduction

Recently, there is an increasing interest in the development and application of remote monitoring terminal unit techniques for power system such as power transformer and substation [1-3]. In order to promote effective management of the life-cycle costs of power transformer, an accurate prediction of time for minimization the risk of power transformer is important concerns. Therefore, this method can be reduced the risk disturbance for power systems. This is due to the transformer duration a long operation without any remote sensor for monitoring fault condition. A high probability risk induced from power transformer is easily obtained [4].

Therefore, most of these research studies are involves the component aging effects on transformer parts and catastrophic events due to the vagaries of nature. As author know, development and application of new equipment to predict the transformer operated-life with remote monitoring device is vary important. In insulation material with immersed liquid cooling approach, the main factors determines to the life of insulation are: a) rated current, b) load on the transformer, c) ambient temperature, d) oxygen content in oil, and e) moisture content. These researches have been used statistical approaches on test results for practical insulation life assessment [5].

In literature [6, 7], it is described that accelerated life testing methods to assess the degradation of the insulation have been used for determining the effect of thermal loading. In recent years, improvements in condition-based monitoring techniques have been supported transformer life management in order to detect the progressive deterioration insulation of the material. However, for captured-data analysis, most of concern issues are interest captured data in load operation or dissolved gas analysis for prediction the life consumption of transformer. As authors understand, according to the above-mentioned integration is seldom considered.

This paper is organized as follows. In Section 2, it is introduced a newly developed signal captured device of system architecture. In Section 3, the remote monitoring equipments to detect several types of sensor-captured data to diagnose fault condition of transformer is present. Also, it demonstrates through cases the use of the IEEE Standard for transformer operation a lot of parameter in this study case during operation almost one month in order to determine consumed-life and equipment working stability for power transformer. In Section 4, by using fuzzy logic method, the transformer fault detected condition and diagnosis, is presented. The discussion and analysis is concluded in Section 5.

2 Description Sensor Set-up and Monitoring System

For sensor component setting in transformer consideration, a multi-sensor of different measurable signal source variable condition is displayed as Fig. 1. Therefore, development of a sensor technology must be adapted to the specific requirements of a general power transformer; this is due to transformer capacity depending on their age and condition. According to the worker experience of remote monitoring devices, the following general set-up of sensors, is proposed for the use at power transformer with 1000 kVA:

(1) PT100 for measurement of top oil and ambient temperature in tank inside.
(2) Current transducer measurement load current.
(3) Voltage transducer measurement voltage signal at transformer tap of bushing sides.
(4) Sensor for measurement of oil humidity, setup in device insides.
(5) Sensor for measurement of gas-in-oil content.

Newly developed devices with remote monitoring function; the outputs of the above-mentioned sensors are acquired data signal into the server system via Internet transmission line.

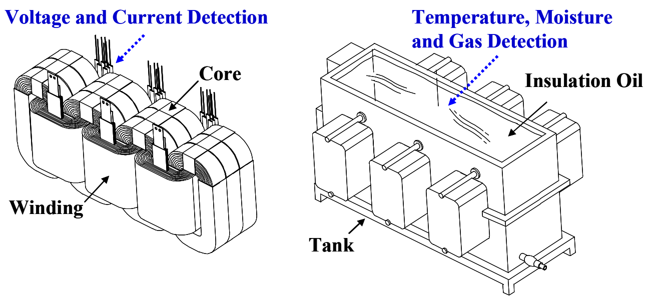

Fig. 1. Sketch of sensor setup position of three-phase power transformer: consideration, assembling, and signal measurement.

3 Multi-Sensors Development and Installation

3.1 Remote Monitoring Sensor and System Architecture

This paper develops a remote monitoring device was performed via high-speed central process unit chip. In Fig. 2, it is displayed a condition remote monitoring device and sensor testing and implementation. Eight groups cover the basic signal receiver, analog input ports, and digital input ports and digital input ports, respectively, have been developed. An one SD memory card slot, a group of serial communication port, a group of TCP/IP communication port, a group of USB slots, a group of GSM/GPRS, 10x1 LED Lights (Display the load), 16x2 Text-Based display state LCD, input voltage of 100 to 240 V (50-60Hz, 1.5A, AC), and fault signal buzzer, respectively, are obtained.

Besides, a field-programmable gate array (FPGA) is installed and used to be a CPU system. This is due to the FPGA has a good ability to update the functionality after shipping, partial re-configuration of the portion of the design and the low non-recurring engineering costs relative to an ASIC design. Therefore, it is offer advantages for many applications in industry. A field-programmable gate array is an integrated circuit configuration by customer or designer after manufacturing. In this paper, the data-acquisition card is used the Field Programmable Gate Array (FPGA) model, the system of phonotype equipment is shown in Fig. 2. The contribution of this research is the development of a real-time remote monitoring system.

As the need for data acquirement from sensor devices, including as current transducer, voltage transducer, oil temperature and moisture detector, data transmission rates to increase for analog to digital converters (ADC) and the associated FPGA unit has provided a solution to interface to the ADC and other parts of the system. So, manufacturers of ADC and FPGA chip have responded with faster, more capable devices at a lower cost. This allows the sensing of large area fields with a system capable of monitoring crop local environmental or physiological status; the data transmission and storage in the computer is made in real-time.

3.1 Development of the humidity and moisture sensors

Both for the humidity and atmosphere temperature of Newly developed remote monitoring device, is designed and installed into device circuit board, where the sensor function is satisfied with fully signal calibrated, digital output detector, low power consumption diagnosis, excellent long term stability and SMD type package, respectively. The proto type of the humidity temperature sensor is developed in Fig. 3(b).

The sensor is an inexpensive, highly accurate, temperature and humidity measurement module for remote monitoring inside circuit an application that communicates is directly transfer by digital signal protocol. Originally designed and manufactured for the automotive industry applications, this sensor has excellent long-term stability and is friendly detector for a wide range of applications in this case.

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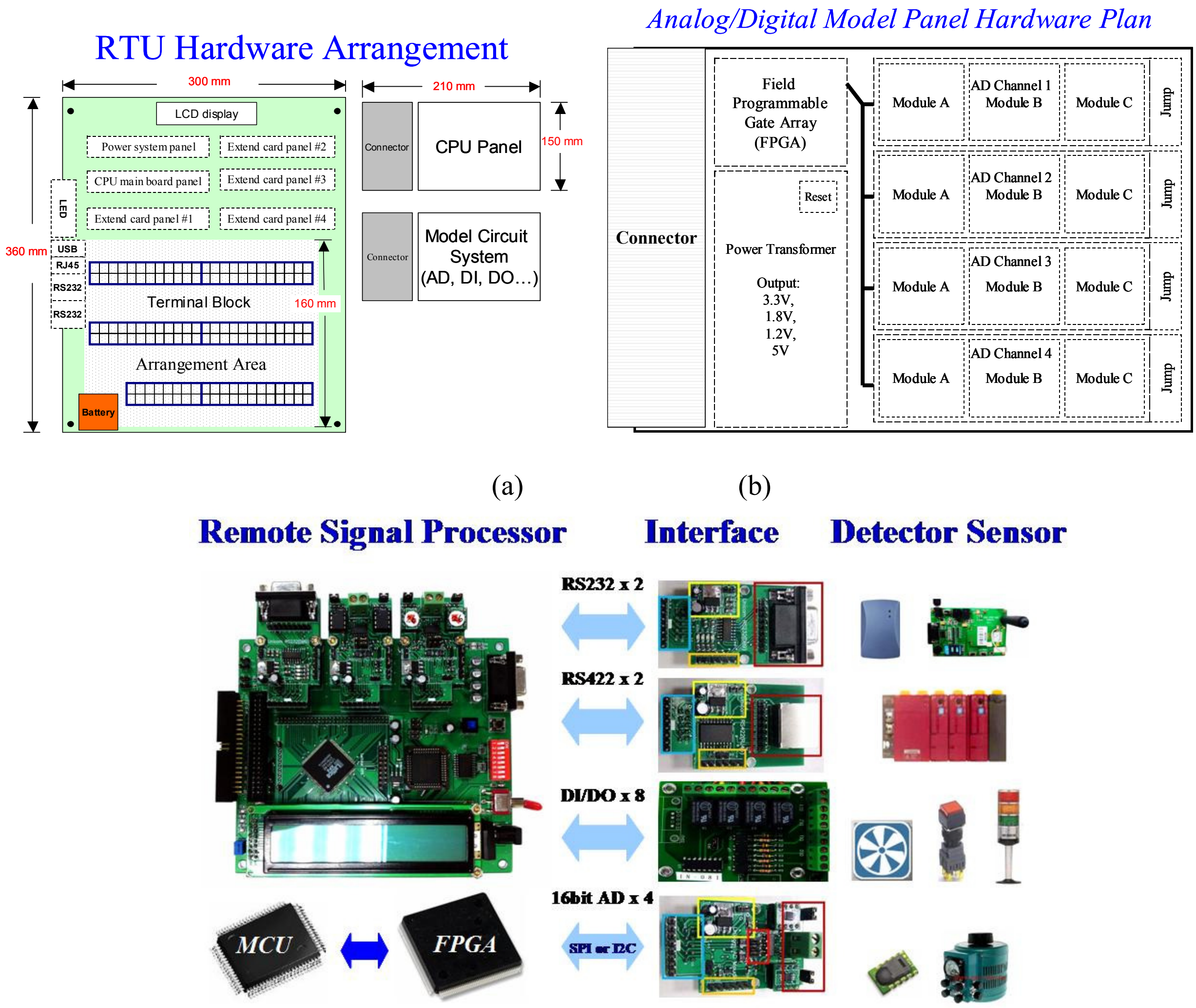


(a) (b)

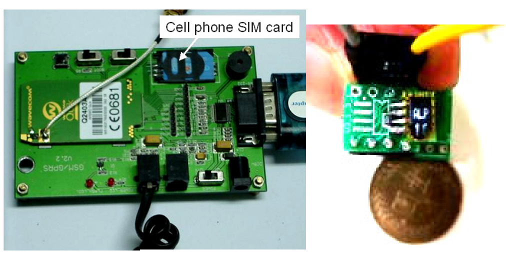
(c)

Fig. 2. The condition remote monitoring device, design and impalement. (a). FPGA arrangement. (b). Signal detector. (c). System measurement sketch.

It is specially to require remote by on-line moisture and humidity temperature measurements. The module design also allows for ambient air monitoring or measurement of surface humidity and temperature to detect near-condensation conditions. For advanced-implement of remote terminal unit device using for transformer, this device is also available with an optional especially case.

3.1 Oil-temperature measurement of AKM sensor

For measurement temperature, this paper is used for AKM sensor. This device that is the oil or winding temperature transmitters consist of a resistance thermometer with a built-in electric heating element. The winding temperature transmitter simulates the temperature of the hottest part of the transformer winding. This approach, the AKM sensor can simulates the temperature in the hottest part of the winding. The reference of all these PT100 is satisfied with IEC60751 standard, and sensor of AKM have existed a temperature coefficient α =0.00385055 $°C^{-1}$. The AKM sensor is shown in Fig. 4.



(a) (b)

Fig. 3. Moisture and UPS system: (a) Moisture sensor prototype, (b) Uninterruptible Power System circuit.
Voltage signals are directly connected to inputs of the condition card, and current signals are previously translated from precision resistors. Consequently, the winding temperatures in top oil and bottom sides are measured by using AKM sensors.

(a) (b)

Fig. 4. Application of oil temperature of AKM sensor: (a) Oil temperature indicator, (b) Thermometers.

The temperature hot spot is calculated as below of follow description. The equations that model the hot spot temperature and the thermal aging acceleration factors from IEEE Std. C57.91-1995 are obtained [8]. The hot spot temperature is given by

$$\Theta_{HS} = \Theta_A + \Theta_{TO} + \Theta_H \qquad (1)$$

Detailed models for temperature measurement calculation are given in [8]. The thermal aging acceleration factor is given by

$$F_{AA} = e^{\left[\frac{15000}{383} - \frac{15000}{\Theta_{HS}+273}\right]} \qquad (2)$$

where a value greater than 1 for winding, the hottest-spot temperatures greater than the reference temperature 110 °C and less than 1 for temperatures below 110 °C. The equivalent life (in hours or days) at the reference temperature that will be consumed in a given time, this equation period for the given temperature cycle is the following:

$$F_{EQA} = \frac{\sum_{n=1}^{N} F_{AA,n} \Delta t_n}{\sum_{n=1}^{N} \Delta t_n} \qquad (3)$$

where the equation (3) parameter is define in Table 1.

Table 1. IEEE standard parameters define for temperature calculation.

Θ_A :	Ambient temperature $^\circ C$
Θ_{HS} :	Temperature of hot spot $^\circ C$
$\Delta\Theta_{TO}$:	Top oil temperature rise $^\circ C$
$\Delta\Theta_H$:	Winding temperature rise $^\circ C$
F_{AA} :	Thermal aging acceleration factor for insulation.
F_{EQA} :	Equivalent aging factor for the total time period.
n :	Index of the time interval t.
N :	Total number of time intervals
$F_{AA,N}$:	Aging acceleration factor for the temperature which exists during the time interval.
Δt :	Time interval (in hours).

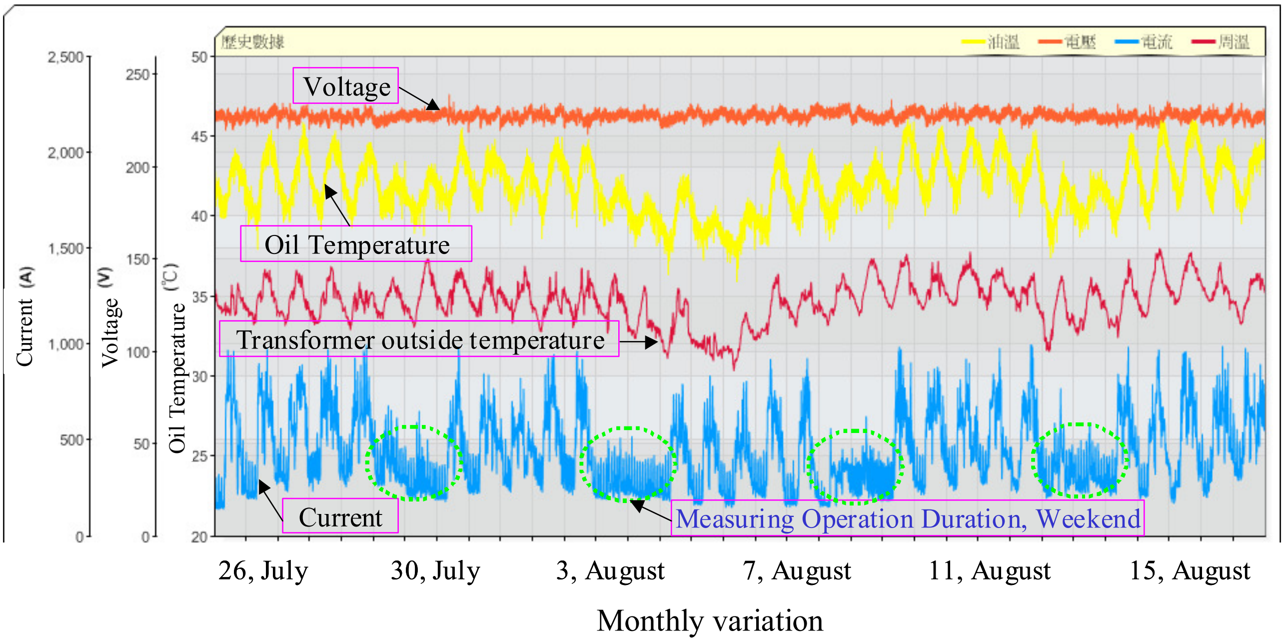
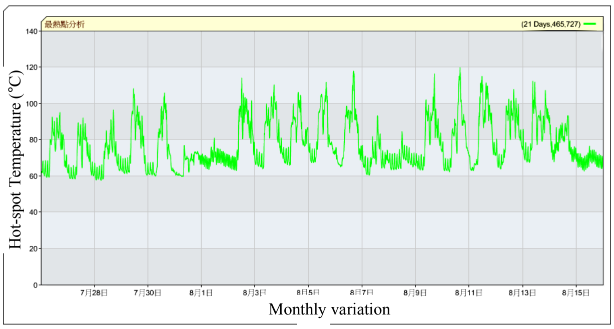
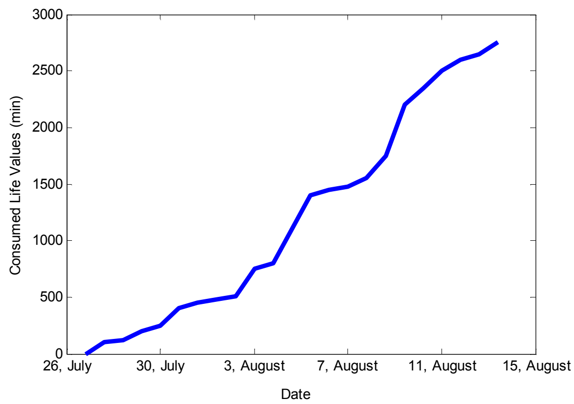


Fig. 5. The measurement of the monthly value of a daily captured-data via RTU device.

The variation of ambient temperature is assumed to have an immediate effect on oil temperature. Moreover, experimental work has shown that at the onset of a sudden overload, oil inertia induces a rapid rise of oil temperature in the winding cooling ducts. The top oil temperature in the tank does not reflect this phenomenon. Therefore alternate sets of equations are being developed, taking into account all these factors. In addition, it is important evolution providing the disappearance of the guide on definition of transformer. This paper, it is defined that an especially phenomenon is called the thermal duplicate. In general, that was often used to provide default values for winding temperature rise at rated load. This reference will not be available anymore to provide support to the hot-spot temperature rise estimated by the manufacturer. This might reduce the credibility of transformer manufacturer in providing that critical thermal parameter. The captured signal data, current, voltage, and temperature, is shown in Fig. 5. Besides, in order to understand the probabilistic nature factor and its statistical distribution, this paper is compute its expectation and variance. The measured results of transformer temperature of hot spot and life consumption of power transformer, is shown in Fig. 6. In Fig 7 is shown SMS device installed in three-phase power transformer.



(a)



(b)

Fig. 6. The measured results of consumed life values with IEEE Standard. (a). Hot sopt (b). Consumption.

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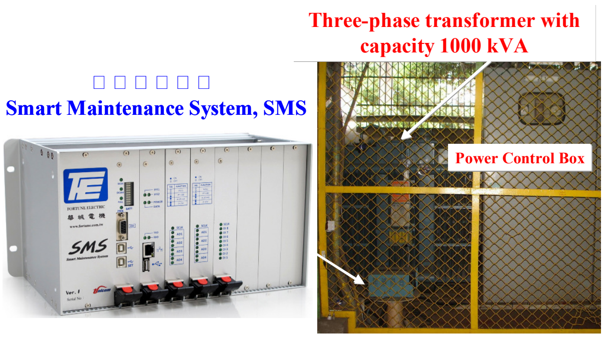

Fig. 7. Power transformer life consumption. (a). Weibull distribution. (b) Sensors and RTU system installation.

4 Transformer Health Diagnosis and Analysis by using Fuzzy Logic Method

4.1 Manufacturing Experience System

In order to understand the manufacturing experience system (MES) built process, MES are considered and determined to facilitate tasks in the fields of accounting, signal process control, customer service, and fabricated productions etc [11-13], is shown in Fig. 8.

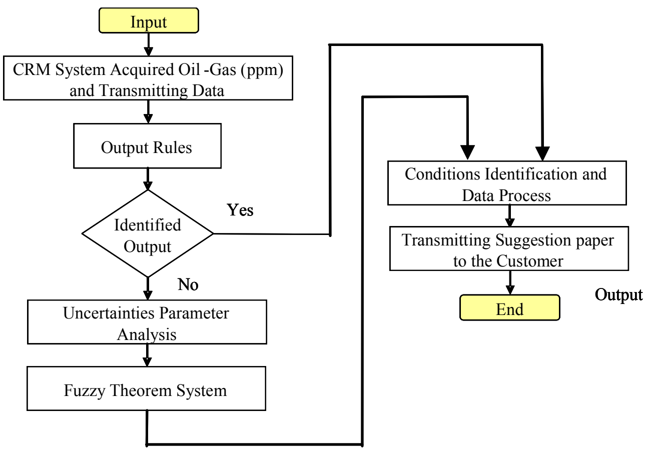

Fig. 8 Flow chart of the intelligent transformer health diagnosis

In general, the original problems are complex enough such that a simpler conventional algorithm is insufficient to provide the proper solution. This is due to the foundation of a successful MES depends on a series of technical procedures and development. Therefore, it is indicated that may be designed by certain technicians and related to the manufacturing. Consequently, MES do not typically provide a definitive response, but it can provide a probabilistic recommendation for system.

4.2 Fuzzy Logic Approach

In order to validate the arcing hypothesis gas release, the temperature over probably reference measurement should also be confirmed. The final of monitoring power transformer is to prevent catastrophic failures, but also eliminate unnecessary maintenance. In this paper, to build a manufacturing experience database, the proposed method is to prevent incorrect diagnosis by some unstable signals. Therefore, incorrect warning signals based on designed system can be validated using other measurements as well. This paper is to present an example of intelligent fuzzy logic method incorporated into an experience database in order to detect transformer overheating and over load condition to predict transformer life consumption factor. In general, the description of judged-code is displayed as follows.

Fuzzy Logic Approach Diagnosis for Transformer

IF (Hot-Spot Temperature Above Reference) > IEC code standard.
THEN
IF (Winding Secondary Rated Voltage)
> Transformer designed health value.
THEN
IF (Winding Secondary Rated Current)
> Transformer designed health value.
THEN
IF (Ethylene Concentration) > IEC code standard.
THEN
IF (Moisture Concentration) > IEC code standard.
THEN
Transformer Overheating, Take Off-line to Service
ELSE
Check DGA and Moisture Analyzer for Proper Functioning
ELSE
Check Thermocouple Sensor
ELSE
Check Current and Overload Condition
ELSE
Check Voltage and Overload Condition
ELSE
Cooling System not Automated Operation in Transformer,
Have Serviced
ELSE
Transformers Operating Normally

5 Result and Discussion

This paper is successfully developed a smart maintenance system for fault diagnosis and life consumption detector of power transformer. A commercial remote terminal unit installed in this application presents important advantage such as easily integration with distributed data-acquisition equipment from a lot of sensor date from transformers. Besides, this paper is also discussed the fault diagnosis condition of transformer; it was proposed a method with fuzzy logic, where an expanding field of study is used for transformer and substation diagnostics.

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