Journal of Electrotechnology, Electrical Engineering and Management (2024)
Clausius Scientific Press, Canada
DOI: 10.23977/jeeem.2024.070219
ISSN 2560-6697 Vol. 7 Num. 2

Research and Design of Power Transformer Online Monitoring System

Yincheng Li

Noncommissioned Officer Academy of PAP, Hangzhou, Zhejiang, 310000, China
1322432990@qq.com

Keywords: Transformer, Online monitoring, Temperature, Vibration, Video Signal

Abstract: As the most important equipment in the power grid, the safe and reliable operation of the power transformer is of great significance to ensure the stability of the power system. On-line monitoring of power transformers can ensure the safe and stable operation of transformers. This paper introduces an on-line monitoring system for temperature, vibration and internal video information of power transformer. The system is allowed to be applied under harsh industrial conditions. This paper describes the design of the system in detail, including the realization of hardware and software. Finally, an example of field test and simple reliability analysis are given to confirm its reliability and function in transformer on-line monitoring. The system can monitor the running state of the transformer, so that the monitoring personnel can find the abnormal and hidden faults of the transformer in time. This can not only prevent the occurrence of sudden accidents of the transformer, but also carry out the maintenance of the transformer without power outage, prolong its operating life, and improve the reliability, safety and economy of the power grid operation.

1. Introduction

As the core equipment in the power system, the transformer is very important for power transmission and distribution. It is safe and reliable operation provides an important guarantee for daily production and life and the safe operation of the power grid [1][2]. According to relevant research, temperature [3] and vibration [4] have a very important factor in the life of the transformer. Excessive oil temperature and abnormal vibration will greatly increase the probability of transformer failure risk [5][6]. Due to long-term operation, the insulation performance of power transformers is aging [7][8], which reduces the short-circuit bearing capacity of power transformers. Transformer winding deformation faults caused by short-circuit faults of power transformers occur from time to time [8]. It will not only lead to the damage of the transformer itself, but also may cause power grid failure in severe cases, leading to the collapse of the power system, causing huge economic losses to the society, if the power transformer fails[7][9]. The focus of power transformer condition monitoring is to monitor the state of the transformer in operation and the internal faults of the transformer that may be caused [7].

For the transformer in operation, if the transformer fails, it can only be effectively known through the subsequent disassembly, but this method cannot accurately restore the state of its failure [8]。In the case of transformer failure, if it can provide the staff with accurate and intuitive embodiment of the temperature, vibration, video information during the winding failure, it will be of great help to the staff to analyze the transformer failure and improve the structure of the transformer. Therefore, it is important to carry out condition monitoring of power transformer windings, discover abnormalities and hidden faults of the transformer in time and give early warning to prevent the occurrence of sudden transformer accidents, carry out non-stop condition maintenance of the transformer, prolong its operation life, and improve the reliability, safety, and economy of the power grid operation [10].

2. Measurement principle and program design

2.1 Fiber Optic Grating Sensors

Due to the large amount of electromagnetic interference contained within the transformer, and in the case of oil-immersed transformers, internal temperatures of over 100 degrees Celsius are also generated. In such a harsh environment of temperature and electromagnetic interference, traditional electronic sensors cannot be adapted to, so the need for a kind of anti-electromagnetic interference, and can operate at high temperatures under the sensor, fiber grating sensors are able to better meet the above requirements [7]. Therefore, we use fiber grating temperature sensors and fiber grating vibration sensors for transformer internal information acquisition. Therefore, we use fiber grating temperature sensors and fiber grating vibration sensors for transformer internal information acquisition. Fiber optic communication technology is used between the sensor and the demodulator, as shown in Figure 1, which mainly uses a light source at the transmitting end to emit a beam of a specific wavelength and sends it out through an optical fiber, which is measured by a fiber grating sensor, and then the signals are sent back through the optical fiber to the receiving end, where temperature or vibration information is obtained by demodulation through optoelectronic conversion [7].

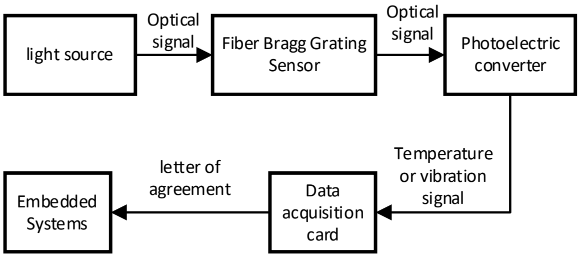


Figure 1: Fiber Optic Grating Sensor Acquisition Principle

2.2 Transformer internal video signal acquisition

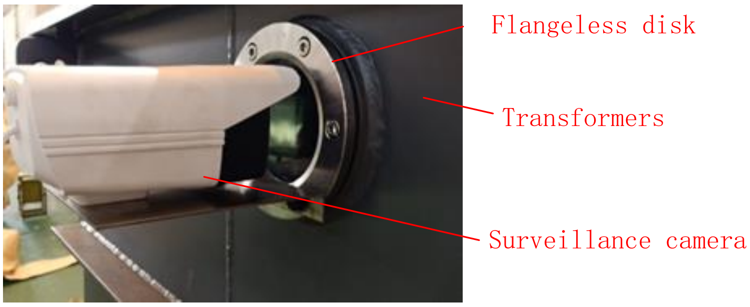


Figure 2: Camera and Viewing Window Installation Diagram

Installing the camera inside the transformer needs to consider high voltage and waterproof problems, and needs to consider the transmission of video signals. Since the transformer is an autonomous design, we have designed it in such a way that there is an observation window on the front and one on the side of the transformer. This is a perfect solution to the problem of installing a camera inside the transformer. As shown in Figure 2, the camera is placed outside the observation window to observe the state of the windings inside the transformer.

2.3 Specific program design

As shown in Figure 3, the fiber grating temperature sensor and vibration sensor are connected to the demodulator through fiber optics, the demodulator is connected to the embedded system through a serial port, and the camera module is connected to the embedded system at the same time. The embedded system processes the data from the sensors and the camera and transmits it to the terminal through wireless or wired means.

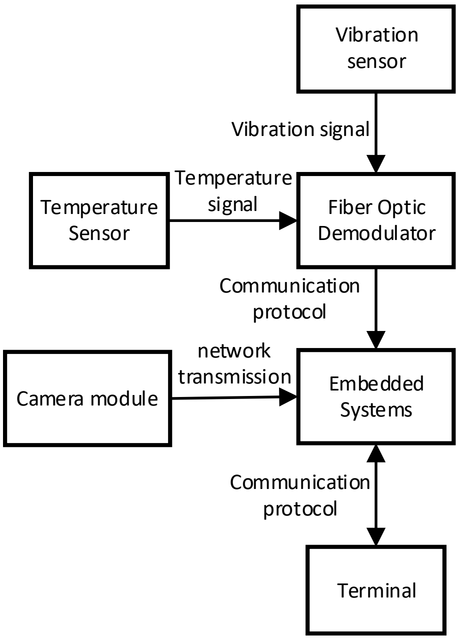


Figure 3: Block diagram of the overall design

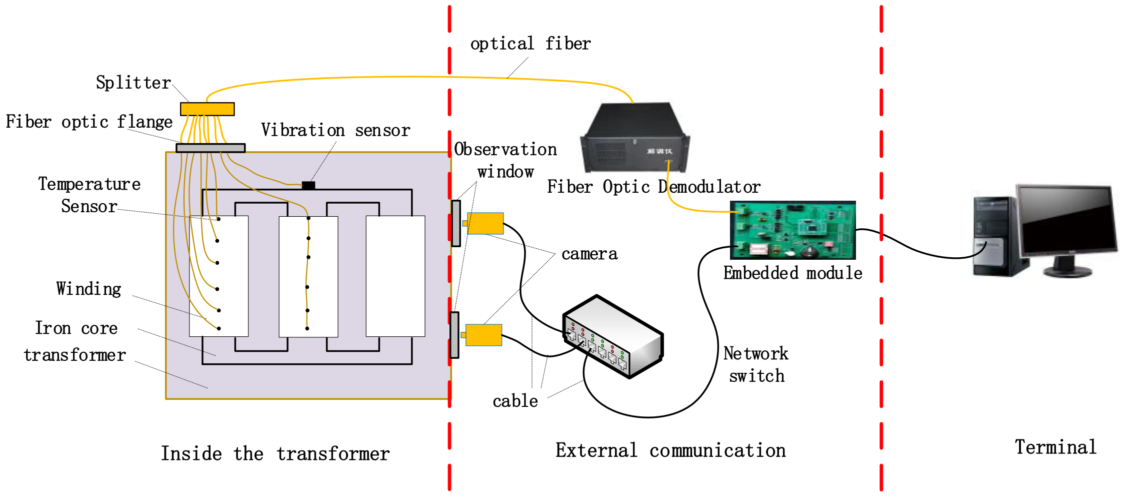


Figure 4: System detail layout

As shown in Figure 4, to intuitively reflect the temperature of the transformer winding, a temperature sensor is arranged at the A and B phases of the transformer winding from top to bottom at intervals of 5cm. The fiber grating vibration sensor is arranged on the core and according to the literature, the maximum displacement is on phase B. Therefore, the vibration sensor is arranged at the position of phase B and is connected by means of a strong glue. The camera is observed through two external observation windows. The collected temperature information, vibration information and video information are processed by the embedded system and then transmitted to the terminal for data display, storage and processing. Its physical diagram is shown in Figure 5.

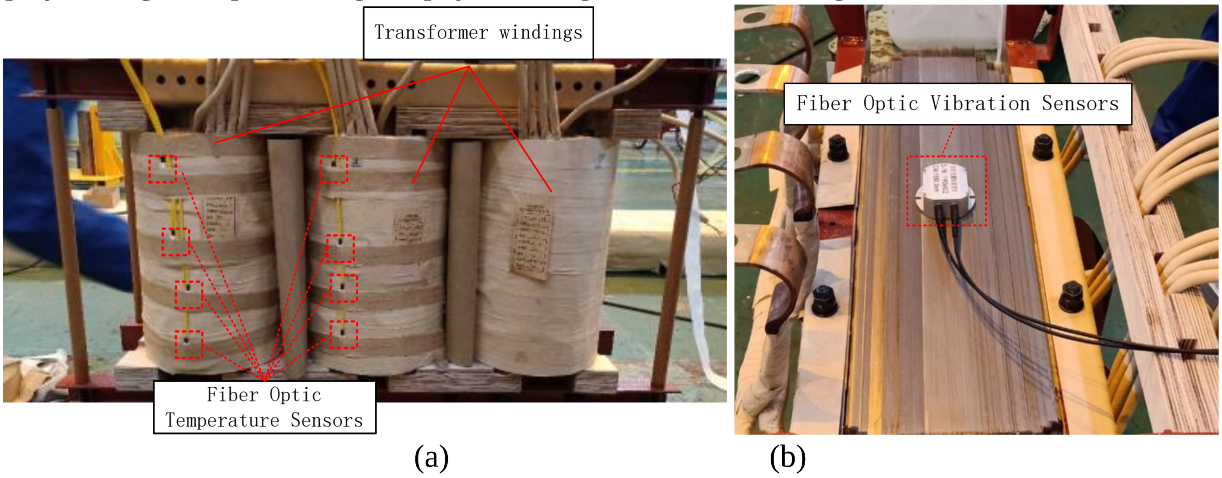


Figure 5: (a) Arrangement of fiber-optic grating temperature sensor on the winding (b) Arrangement of fiber-optic grating vibration sensor on the iron core

3. Overall system design

3.1 Hardware Design

The temperature detection sensor is mounted in a specific way on the surface of the coil on the low-voltage side of the transformer to realize the real-time transmission of the coil temperature signal back to the embedded system module, which processes the signal and then transmits it to the automation terminal. Fiber optic vibration sensors are mounted and fixed on the core inside the transformer in a specific mounting way. The fiber optic vibration sensors transmit the vibration signals from the core to the embedded system, which processes the signals and transmits them to the automation terminal. Ultimately, real-time monitoring of coil temperature signals and vibration signals of the iron core inside the transformer is realized. In order to be able to visualize and monitor the internal working status of the transformer and the operation process of the internal devices, holes are punched in the case shell of the transformer, the case is sealed through the flange, and finally the camera is installed near the openings, and the video signals collected by the camera are transmitted to the terminal display device through the wired method.

3.2 Software design

The program on the embedded system first needs to read the internal temperature and vibration signals and video signals of the transformer and upload them to the terminal host computer for display. The overall flow chart of the system is shown in Figure 6.

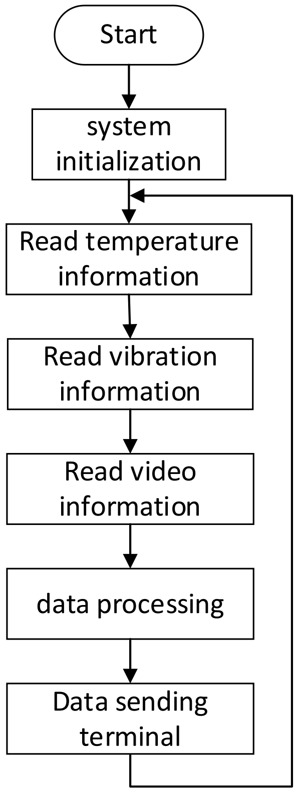


Figure 6: Overall flow chart of the system

The upper computer of this system is designed with LabView software. Its main function is to display and save the transformer winding temperature information and core vibration information, internal video information. As shown in Figure 7, the upper computer interface of the system terminal is able to read and save temperature and vibration information, and watch the video signal of the internal winding captured by the camera in real time.

(a) (b)

Figure 7: (a) Temperature and vibration signal reading and saving interface (b) Camera reading video signal interface

4. Field application experiments

This system is used for transformer field testing at a transformer plant in Yunnan. The transformer is a 35kV test transformer, at double the power, the windings start to warm up at 12:00, and at 18:00 the temperature of the windings and the core vibration is watched. The temperature sensors on the windings are labeled 1-6 from top to bottom. 12 temperature sensors were analyzed for the tests conducted on phases A and B. The temperature sensors on phases A and B were analyzed for the test. Figure 8 shows the plot of hot spot distribution of temperature field at rated power for phase A and phase B.

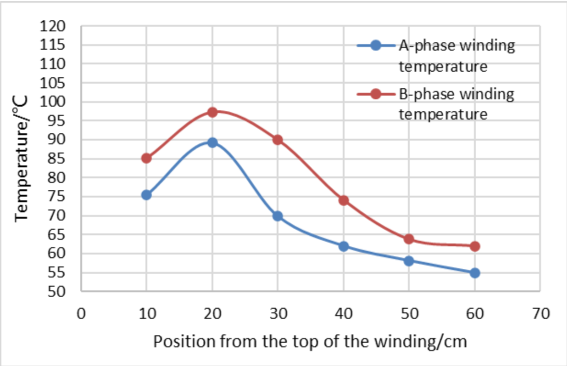
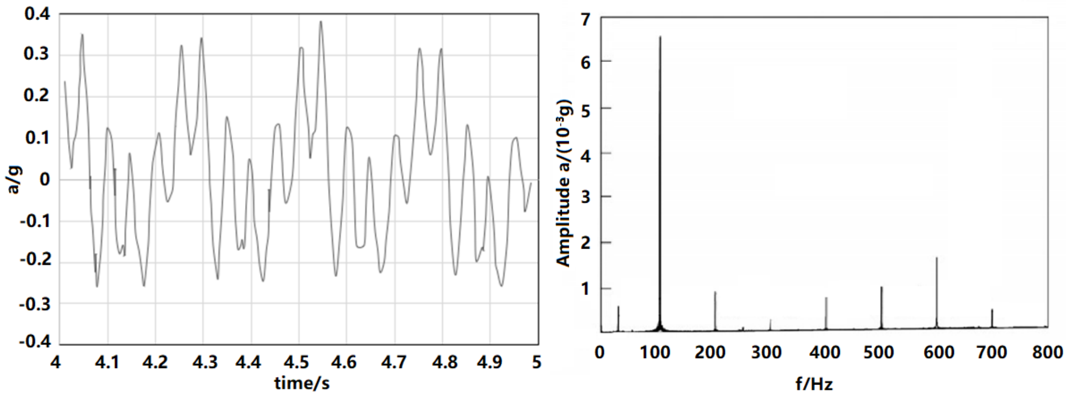


Figure 8: Plot of hot spot distribution of temperature field at rated power

According to Figure 8, it is evident that the temperature at a distance of 20 cm from the top of the windings is significantly higher than the temperature at other locations. According to the actual conditions, phase B is in the middle of the transformer and has poor heat dissipation, so the temperature of phase B is higher overall. Phase A is located on the edge and is directly in front of the heat sink, so the temperature is lower. The core vibration is subjected to data processing, as shown in Figure 9(a) for the vibration signal time-domain diagram, and the amplitude-frequency response characteristics are obtained after amplitude-frequency response characterization in Figure 9(b).



(a) (b)

Figure 9: (a) Time-domain plot of the vibration signal (b) Spectral analysis of the vibration signal

According to Figure 9(b), the frequency spectra of the vibration signals of the transformer are all based on 100 Hz and its octave as the main frequency components. Subsequent studies can provide a comprehensive assessment of the transformer core condition by examining the distribution pattern between the multidimensional vibration signals of the core as well as the correlation. Real-time monitoring of the video signal inside the transformer and saving it to the terminal can effectively provide the staff with accurate and intuitive embodiment of the video information of the winding failure when the transformer fails, which is of great help to the staff in analyzing the transformer failure and improving the structure of the transformer. Its camera real-time monitoring winding status information is shown in Figure 10.

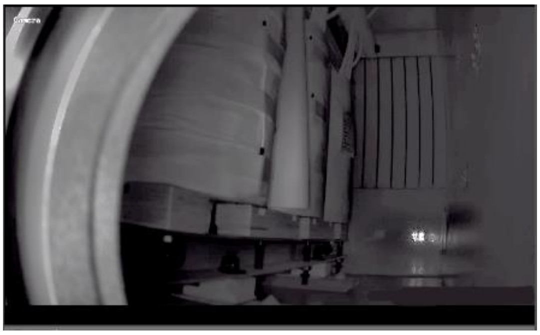


Figure 10: Cameras monitor winding status information in real time

5. Conclusions

The on-line monitoring system of power transformer developed in this paper can effectively improve the condition monitoring quality of power transformer and optimize the monitoring effect. Through the fiber grating sensor, the vibration signal of the inner core of the transformer, the temperature signal of the winding and the video monitoring signal of the transformer winding are realized. The on-line monitoring of the running state of the power transformer has good promotion and application value. The monitoring effect is in line with the expected evaluation results of the transformer state. The main conclusions are as follows:

1) Through the monitoring of the transformer, it is found that the intermediate phase of the three-phase power transformer has a higher temperature during operation. Under the rated power, the highest hot spot of the transformer is in the middle of the intermediate winding.

2) Through the amplitude-frequency analysis of the vibration signal of the iron core, the frequency spectrum of the vibration signal is 100 Hz and its frequency doubling as the main frequency component.

3) When monitoring the video, we can consider the way of opening an observation window in the box of the transformer, which can realize the real-time video monitoring of the internal winding of the transformer and save the workload and time cost of the operator.

References

[1] Vitolina S. Development of Lifetime Data Management Algorithm for Power Transformers[C], International Conference on Intelligent Systems. IEEE, 2014.
[2] Zhang Bin. Combined diagnosis of transformer faults based on multiple Bayesian classifiers [D]. North China Electric Power University (Hebei), 2009.
[3] Zhao Feilong, Xian Tiantian, Rong Qingyu, et al. Analysis of temperature rise characteristics and insulation loss of distribution transformers under three-phase unbalanced conditions [J]. High voltage technology, 2023, 49 (10) : 4364-4372.
[4] Cao Chen, Lu Dunlin, Xu Bowen, et al. Magnetostrictive vibration model and looseness fault diagnosis method of transformer core based on elastic mechanics-thermodynamics [J]. High voltage technology, 2024, 50 (05): 2146-2157.
[5] Cao Chen, Lu Dunlin, Wang Xue et al., Simulation and analysis of temperature and mechanical vibration characteristics of transformers [J]. Transformers, 2024,61 (01): 17-23.
[6] Simplice A ,Issouf F ,Zi é Y , et al. On the Feasibility of Monitoring Power Transformer's Winding Vibration and Temperature along with Moisture in Oil Using Optical Sensors [J]. Sensors, 2023, 23 (4): 2310-2325.
[7] Ye Yang. Experimental study of fiber grating sensor in transformer temperature and vibration monitoring [D]. Huazhong University of Science and Technology, 2017.
[8] LI Yincheng. Research on performance evaluation method of distribution transformer winding based on short-circuit test [D]. Kunming University of Science and Technology, 2021.
[9] Yu Haiqiang. Research on transformer state detection based on vibration analysis [D]. Xihua University, 2012.
[10] Qi Shiwei. Research and development of on-line monitoring and diagnosis system for power transformer faults [D].North China Electric Power University, 2014.