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Current on-Line Measurement of High-Voltage Switch Board

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ABSTRACT: According to the disadvantages of small dynamic range, large size and high cost for traditional current transformer, a new measuring method based on the TMR magnetic sensor for the 10kV switch board was proposed. Based on the analysis of the measurement principles and methods of the TMR magnetic sensor, a current measurement system was designed which was applied in the high voltage switch board. The hardware design and software testing process were introduced in details. The feasibility and measurement performance of the TMR magnetic sensor were verified through experiment, then a few modified measurement methods were proposed.
Keywords: TMR magnetic sensor; 10kV high voltage switch board; current measurement; linearity; repeatability

I. INTRODUCTION

High-Voltage switch boardisan important electrical productabouton-off, control andprotectionin the power system, due to the long-term operation in high voltage, large current and full load under the condition[1]. It is importantfor the normal operation of the whole power system to make the real-time measurement. The use of electromagnetic current transformer measurement bus traditional 10kV High-Voltage switch board, the electromagnetic current transformer has small dynamic range, high current through the magnetic saturation phenomenon occurred, resulting in two output waveform distortion, unable to realize the accurate measurement of the dynamic current[2]. In recent years,at home and abroad, there are many new current measurement methods, such as the use of bus current indirect measurement of Holzer sensor, but because the Holzer sensor is difficult to simultaneously meet the requirements of large range and high precision requirements, the methods for the measurement of the limitations of device; photoelectric transformerbased on Faraday optical effect has good insulating properties and resistance interference characteristics[3], and needsto improve the precision of; the Rogowski coil has the advantages of high precision, large measuring range, light weight, but becauseof its high cost, frequency response is not good, it is only used in the experiment system[4].

With the rapid development of magnetic sensing technology, it is possible to measure the large current by magnetic sensing technology. At present, the widely used magnetic sensors are mainly based on the principle of electromagnetic induction, Holzer effect and magnetoresistance effect. Due to its high sensitivity, small size, low power consumption and easy integration, the sensor based on magneto resistanceeffect is replacing the traditional magnetic sensor. Currently on the market the magnetoresistance sensor chip is based on anisotropic magnetoresistance (AMR), giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR) effect and development, dueto the wide dynamic range of TMR magnetic sensor AMR and the high sensitivity of the advantages of GMR in one, and in all kindsof magnetic sensor technology. The TMR sensor has the advantages oftechnology. There is incomparable technical advantage[5].

The TMR magnetic sensor is applied to High-Voltage board busbar current to research linear relationship between the sensor output voltage and current. This method has high precision, fast response, good insulation, smaller volume and lower cost.

II. MEASURING PRINCIPLE AND METHOD

1.1 TMREffect

In the magnetic film -nonmagnetic film -magnetic film structure, weak magnetic field can lead to the change of resistivity changes relatively 20%~30%, while in the magnetic thin film sandwiched between a thin insulating layer (0.7nm) structure, the relative magnetic resistance greater changes, can reach more than 30%, and make more sensitiveto magnetic field,electronic can thread very thin insulating layer, and keep its spin direction. This is the tunnel magnetoresistance (TMR) effect[6].

In magnetic multilayers, exchange coupling between layers, the adjacent layers from the magnetic moments aligned parallel to the magnetic field of antiparallel arrangement or from parallel to antiparallel alignment should be of high sensitivity, so the magnetic resistance is very small. But when the two magnetic layers are separated by nonmagnetic layer, exchange coupling does not exist (or it is very small) between adjacent ferromagnetic layers, the smaller magnetic field can makethe adjacent layers from aligned parallel to antiparallel alignment or arranged in antiparallel alignment to parallel[7], it will be led tothe magnetic resistance change, so the TMR effect sensor can change sensitive magnetism and related physical quantity based, and transformed into electrical signal detection.

1.2tmrmagnetic Sensor Current Measuring Principle

According to Ampere's law, current flowing through the infinite wire willproduce magnetic field, the magnetic field around a point is inversely proportional tothe vertical distance between the point and the wire, and is proportional tocurrent flowing through the wire. It is [8].The High-Voltage board busbaras infinite conductor in measurement of busbar currentusing magnetic sensor, the law also applies tothis.d I B/ □

TMR magnetic sensor using TMR multilayer film made by modern integrated technology, contains four high sensitivity TMR sensitive resistor, a push-pull type Wheatstone bridge structure design. When the bus current produces a magnetic field along the direction parallel to the sensor changes, Wheastone bridge provides differential output voltage, the output voltage of a linear relationship with the current size of the busbar in a certain range.

1.3 TMR magnetic sensor current measurement method

The TMR magnetic sensor for High-Voltage switch boardbusbar current, the magnetic field strength in sensor point is ,

$B \propto I/d$, it can be expressed as

$$B = k_1 * I/d \tag{1}$$

above formula： k_1 as the constant coefficient.

By the output characteristics of TMR sensor, it can be known that the output voltage is linear with the magnetic field intensity of the point in a certain current variation range, which can be expressed as

$$u = k_2 * B + c \tag{2}$$

above formula: k_2 、 c as the constant coefficient.

If $k = k_1 * k_2$, then relation between input and output for the sensor can be expressed as

$$u = k * I/d + c \tag{3}$$

above formula: k 、 c as the constant coefficient; I (unit: A) as High-Voltage switch board busbar current; d (unit: cm) as the distance between the sensor and busbar; u (unit: V) as peak value of output voltage of sensor。

In determining the TMR magnetic sensor input and output relation coefficient, when the value of the corresponding processing to the output voltage can be obtained in high voltage switchgear busbar current, then realizingthe measurement of the current bus. The value of 、 is determined by the current calibration in the experiment. Because of the high voltage switch cabinet of each bus in the whole cabinet has a magnetic field distribution, corresponding to the measured magnetic field sensor is actually each phase currentgenerates a magnetic field in the vector and the point, therefore, in the calculation of each sensor output voltage, the magnetic field effect of removal of the other two bus currents.k c

III. MEASUREMENT SYSTEM

2.1The overall structure and working principle of the measuring system

The general structure of the online measurement system of high voltage switch cabinet is shown in figure 1. The hardware structure of the measurement system mainly includes: TMR magnetic sensor power supply and signal output circuit,signal processing circuit, A/D conversion unit,CPU and its peripheral unit[9]. TMR magnetic sensor which uses MMLP57H type of sensor; A/D converter using MAX197; CPU using S3C2440; touch screen display control chip for ADS7843[10].

The measuring system, TMR magnetic sensor bus current generated by the magnetic field, the magnetic field intensity is proportional to the output voltage signal. The signal processing circuit of filter processing the output signal of the sensor, and the processed signal is transmitted to the A/D converter, the analog signal of each channel A/D converter sampling at a rate of up to 2MS/s, and convert it to a 16 bit of digital data sent to the CPU storage calculation, the calculation results on the screen display and digital waveform.

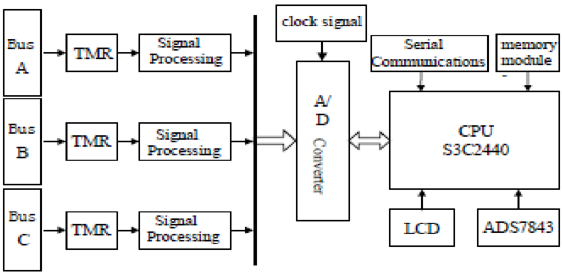


Figure1 Schematic diagram of the overall structure of the measurement system

2.2TMRmagnetic sensor current measurement node hardware circuit

TMR magnetic sensor current measurement node hardware circuit including sensor power supply circuit and voltage signal output circuit. Using the working power supply module to supply power to the sensor, the external 220V alternating current through the buck, rectifier and voltage regulator processing into +5V DC voltage supply sensor. The sensor is packaged in SOP8 format, which is provided with the function of each pin. In the design, two kinds of signal output modes are adopted. The hardware circuit is shown in figure 2. Where N/A is the empty pin, V-, V+ for analog differential output pin.

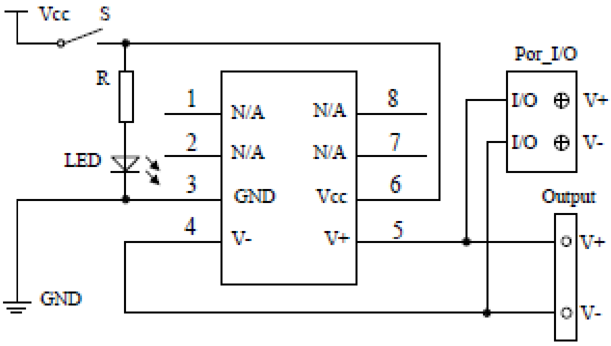


Figure 2 TMR magnetic sensor current measurement node hardware circuit

2.3Signal processing circuit

Due to the influence of the sensor itself and the circuit on the board, the sensor output signal contains complex high frequency noise signal. Before sampling the sampling circuit, the output signal of the sensor should be filtered and processed. The voltage controlled voltage source low pass filter circuit with excellent performance in low frequency range filter is adopted to realize the noise reduction processing of the output signal of the sensor, and the stability and reliability of the output signal is enhanced. Voltage controlled voltage source low pass filter circuit as shown in figure 3.

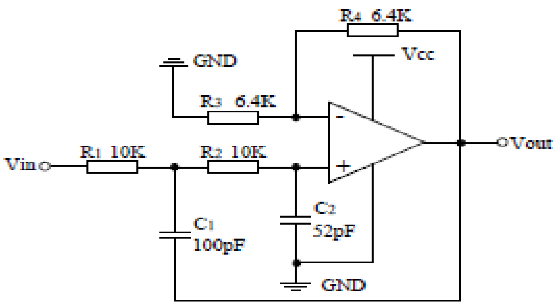


Figure 3 Voltage controlled voltagesource low pass filter circuit

2.4 Analog Digital Conversion And CPU Peripheral Introduction

Measurement system of the A/Dconverter using MAX197, with 8 channel analogdigital synchronous conversion channel, in the measurement channel and the sampling rate have a large redundancy, easy to extend the system after. The clock circuit is used to start the A/D conversion to ensure that the data is equal interval sampling. The CPU peripheral circuit comprises a serial port communication interface circuit, a liquid crystal interface and a subsidiary circuit and a touch screen driving circuit.

2.5TMR magnetic sensor installation and signal line

Due to the strong electromagnetic environment in the switch cabinet, the installation of the sensor and the signal line have a great influence on the measurement results. The sensor should be installed in the original location away from the current transformer, vacuum circuit breaker, and can be applied to the magnetic induction magnetic field changes, sensitive. Signal transmission cable using shielded twisted pair. The switch cabinet body with electromagnetic leakage, so to avoid the weak signal along the bus room with walk the line, especially to avoid the sharp metal surface in the bus room, away from the other one electrical components and two times line area. From the junction of the 3~5cm closed at the installation of special signal cable, metal materials and the selection of high permeability[11].

IV. SYSTEMS SOFTWARE

The software design of the system includes driver and application program design. The application program mainly includes data processing and man-machine interface program. Data processing process is mainly for data synchronization and data calculation. The man-machine interface mainly displays the effective value of measuring current, peak value and waveform.

The software flow chart of the system is shown in Figure 4. Before starting to collect the sensor output signal, the system initialization process, including: to judge whether the end of the first test, data synchronization processing and check whether the normal operation of the system hardware. After the system initialization is complete, the acquisition channel, range and selection trigger mode should be set according to the actual situation. In order to change the current bus size and reaction better, set for each measurement cycle is 5 times the number of acquisition.

After the cycle collection is completed, the CPU is the calculation of the parameters of electric power and data storage, and the calculation results and waveforms are displayed by the data output module.

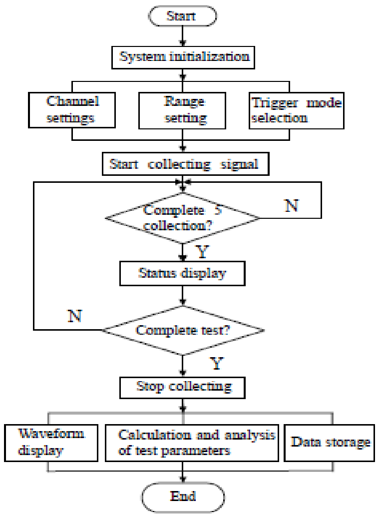


Figure 4 Measurement system software flow

V. EXPERIMENT AND ANALYSIS

4.1Experimental device and experimental method

The experimental site is shown in figure 5. The current generator will power step-down and upstream to the 10kV high voltage switch cabinet. The bus is divided into 6 sections along the lateral surface, the length of each segment 10mm, corresponding to 7 markers, using Gauss meter to measurethe magnetic intensity of each point, compared with the current bus.

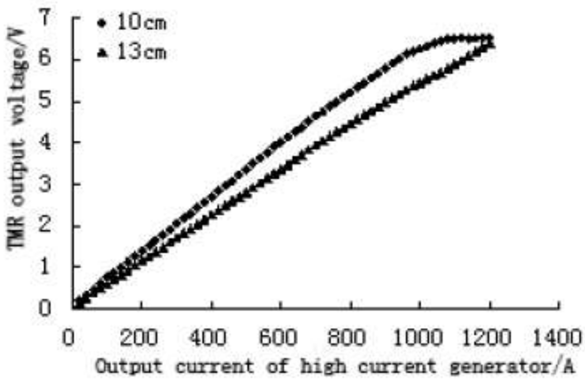
It is found that the first and seventh points of the magnetic field intensity change of current great mother row jump, the sensor should avoid installed on the busbar edge. Select the middle position sensor installation bus. Considering the high voltage equipment in the creepage distance to reach more than 10cm, so the relative sensor bus placed a distance not less than 10cm.

In addition, experiments show that when the sensor bus placed relative distance is greater than 15cm, output large distortion, therefore, the relative sensor bus placed distance should be kept within 10~15cm.

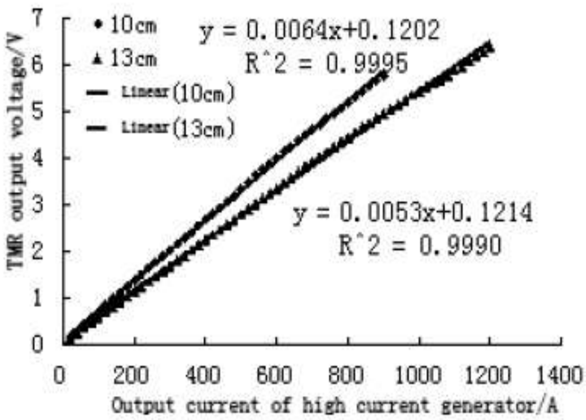
4.2Linear range and linearity

The A phase current measurement and analysis, adjust the current generator output current in the range of 0~1200A, the step is 20A, the experiment was repeated 5 times, the linear range and linearity of 10cm bus and 13cm distance sensor. The average value of the peak value of the output voltage and the average value of the actual current is linearly fitted to the average of the 5 times of the experimental sensor. The results are shown in Figure 6 (a). When the sensor is placed in 10cm, the linear range is 0~900A, while in the 13cm place, the linear rangeis not less than 1200A. Thus, placed in different distance bus position sensor, linear range, and the sensor output distortion does not exceed the range, increase the speed between the placement distance, can increase the linear range of output.

A linear fitting of the data in the linear range of the sensor is carried out, and the regression equation and the linearity of the fitting curve are obtained, as shown in Figure 6 (b). The output of the sensor can maintain a high degree of linearity in the linear range by the result of the processing.



(a) Linear range

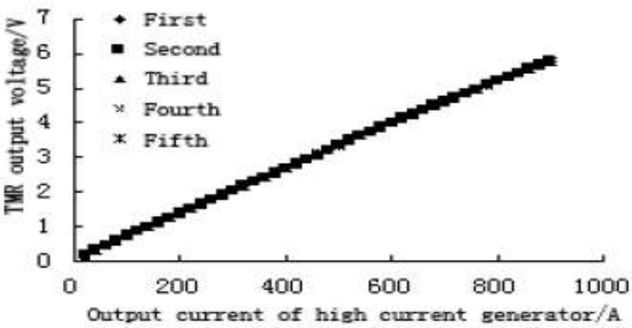


(b) Linear degree

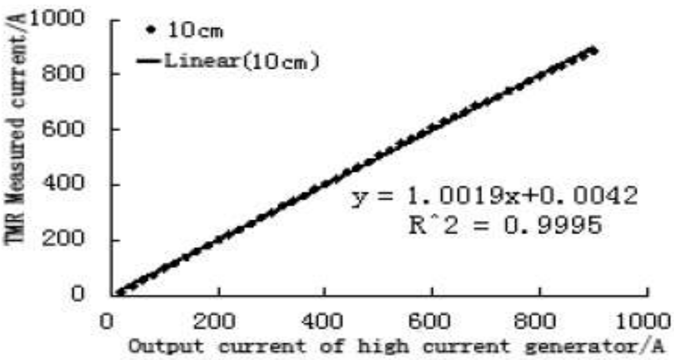
Figure 6 Linear range and linearity of TMR magnetic sensor

4.3 Repeatability and measurement accuracy

Repetitive analysis of sensor bus at 10cmdistance within the linear range of data. A linear fitting of 5 repeated experiments was performed to observe the repeatability of the 5 experiments, and the results were shown in Figure 7 (a). The analysis results show that the repeatability of the sensor is good, the performance is more stable. The measuring current of the position sensor is analyzed and the actual output current of the large current generator is analyzed, and the result is shown in Figure 7 (b). Through the analysis, it is known that the measuring current of the sensor is linear with the output current of the large current generator, and the two are basically the same, which shows that the measurement accuracy of the sensor is higher.



(a) Repeatability



b) Correlation between measured current

Figure 7 Repeatability and measurement accuracy

4.4 Nonlinear range analysis

The same experimental method is used to study the nonlinear characteristics of the sensor when the sensor is placed in the 10cm. The output current range of the high current generator is 0~1300A, and the output of the 1100~1300A is taken as the analysis object, and the result is shown in Figure 8.The analysis results show that the output characteristics of the sensor in the nonlinear range has a large change, the output is not regular, and the results of the 5 repeated experiments are quite different, and the repeatability is very poor. As a result, the output of the sensor has a large distortion in the nonlinear range.

Therefore, in the selection and installation of sensors to the attention of the linear range of the sensor and the sensor with the bus between the place distance, so that it can accurately measure the large current.

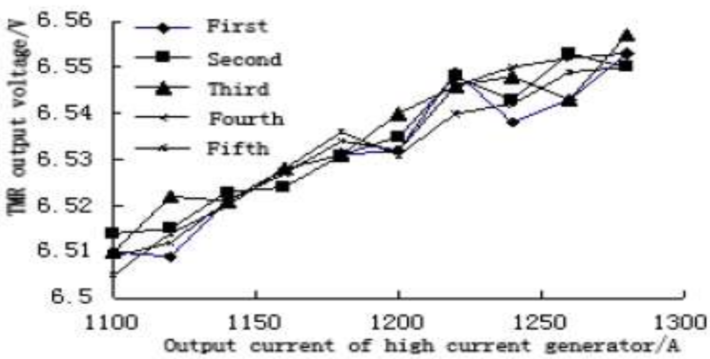


Figure 8 Nonlinear range characteristic

4.5 Improvement of experimental method

By the analysis of the A phase current measurement, it can be known that in the linear range of TMR magnetic sensor, the linearity and measurement accuracy of the sensor is higher, the repeatability is better, and the performanceis more stable. However, taking into account the actual operation process, the high voltage switchgear in the electromagnetic environment and the existence of interference in the power grid, in the future experiments, the experimental method to make the following improvements:

(1) in which the two phases are connected and the third phase has no current, the output of the current phase sensor is studied, and the effect of the magnetic field generated by the two phases currents on the noncurrent phase sensoris analyzed;

(2) to add harmonic components, analysis of the sensor's linearity, measurement accuracy and repeatability, the study of the performance stability of the sensor;

(3) based on magnetic sensor array measurement of busbar current, mathematical model and topological model of magnetic sensor array, so that more accurate current measurement of high voltage switch cabinet.

V. EPILOGUE

Magnetic measurement is a new measurement method in power system, which has attracted wide attention with the advantages of non-contact, low power consumption and low cost. In this paper, based on the 10kV high voltage switch cabinet, this paper introduces a method of measuring the current of high voltage switch cabinet based on TMR magnetic sensor, which overcomes the shortcomings and defects of the traditional current transformer in the current measurement. The measurement system is verified by experiment, and the measurement performance of the sensor is studied. In the future, we need to introduce various error factors into the actual measurement, and further improve the measurement accuracy of the magnetic sensor, so that it can be applied in engineering.

Reference

[1]. Xu Ming, Yang Xian-hui. Wireless monitoring system of high voltage switch contact temperature. Measurement and control technology and instrument, 2009,4:98-101.

[2]. Zhang Hua-wei, Sun Yue-qiang. Techniques of noninvasive current measurement. Modern electronic technique, 2005,21:80-83,88.

[3]. Xie Wan-cheng, Dai Yu-xing. A new method of current measurement based on Holzer sensor. Journal of electronic measurement and instrument, 2012,26 (8): 705-709.

[4]. Wang Yan-yun, Luo Cheng-mu, Tian Yu-xin. Study on optical current transformer in power system. Automation of electric power systems, 2000,24 (1): 38-41.

[5]. Qiao Hui, Liu Hui-jin, Wang Qun-feng, and so on. Study on optical current transformer Rogowski sensor based on relay, 2002,30 (7): 40-43.

[6]. Lv Hua, Liu Ming-feng, Cao Jiang-wei,and so on. Characteristics and application of tunnel magnetoresistance (TMR) magnetic sensors. Magnetic materials and devices, 2012,40 (3).

[7]. Sun Yi-cai, Liu Xin-fu, Song Qing-lin. The latest development and application of magnetic random access memory GMR and TMR effect based on semiconductor technology, 2001,26 (6): 46-50.

[8]. Zheng Rui-chen, Zhang Yu-hua, Qin Liang, Liu Kai-pei. Three phase current measurement and application of power system based on giant magnetoresistance. Electrical measurement and instrumentation, 2004,10 (41): 19-23.

[9]. Cheng Wu-shan, Gao Sheng. Design of automatic measurement and control system used in low voltage circuit breaker test. Manufacturing automation, 2011,34 (8): 46-48.

[10]. KongWu-yang, application Xu Qun.MAX1320 in synchronized phase measurement. Micro computer information, 2007,23 (22): 290-291.

[11]. Wang Xiao-hua, Rong Ming-zhe, Xu Tie-jun,and so on. Medium voltage switch cabinet hardware online monitoring system of anti-electromagnetic interference. High voltage apparatus, 2007,43 (5): 321-324.

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