Research on On-line Monitoring Technology of Pressure Drop in Secondary Circuit of Voltage Transformer and Directional Push Technology of Alarm Information

Songhui Zhang, Tao Liu, Jian Yang, Yuqi Wang, Yu Xing, Ran Zhao
State Grid Shandong Electric Power Research Institute Jinan, Shandong 250003, P. R. China
zskdky@163.com

Abstract. Traditional energy metering technology cannot monitor energy metering devices which number has been growing in real time and realize timely notification of alarm information, so it is difficult to effectively control the occurrence of metering accidents and reduce the amount of power. Through the analysis of the metering circuit, this article provides real-time monitoring the secondary circuits of voltage transformers which are the most error-prone. Ensure that the alarm information can be promptly notified when the voltage loss of the power meter and the secondary pressure drop are exceeded. And use a more stable operation board to reduce the occurrence of secondary circuit open-circuit faults. Finally, the practicality of the technology was verified through experiments.

1. Introduction
Nowadays, power grid and power plants pay more attention to the technical management of electric energy metering devices to ensure the reliability and accuracy of energy measurement during trade settlement. When energy metering technology management is increasingly important, grid and power plant business scale continues to expand, so the contradiction between the limited human resources and the realization of standardized electric energy measurement technology becomes more and more prominent [1]. Traditional measurement technology cannot provide real-time monitoring of metering equipment and timely warning and reporting of failures, so it is difficult to effectively control the occurrence of metering accidents and reduce the amount of power.

Several energy loss events occurred in Shandong in 2017, the maximum time which electric energy does not measure is up to 14 hours and 50 minutes, and the maximum amount of electricity that needs to be recovered is 7737500 kWh. Through the analysis of the cause of the accident, most accidents occur when the circuit is inspected and the relay contacts are not in close contact. This caused the voltage transformer secondary circuit to open, and then the electric energy meter voltage loss. The technical management personnel did not discover the alarm signal of the electric energy meter in time. Therefore, this is due to a combination of factors that have caused a large amount of electricity loss.

To effectively reduce the occurrence of power loss events and the amount of power loss, we must adopt reasonable technical means to timely inform real-time monitoring and alarm information of electric energy metering devices.

2. Design of Secondary Voltage Drop Detection and Alarm Information directional Push Technology for Voltage Transformer based on Carrier Technology
To ensure the accuracy of energy metering, DL/T 1664-2016 《Inspection regulation of electric energy metering device on-site installation》 has strict regulations on the errors of the energy metering system[2-4]

With the development of power technology, the accuracy and stability of power meters and transformers are getting higher and higher, and they have less and less effect on the overall error. So the error caused by the voltage drop in the secondary circuit of the voltage transformer becomes an important factor in the overall error [5-6]. By real-time monitoring of voltage drop in secondary circuit of voltage transformer, we can effectively monitor the error caused by the secondary pressure drop online. When a voltage drop exceeds a threshold or a breakdown of voltage loss occurs, it needs to send alarm information in time, to avoid the error excess or the time of power meter voltage loss is too long.

2.1. Analysis of Monitoring Principle of Voltage Drop in Secondary Circuit of Voltage Transformer

Voltage transformer secondary voltage drop monitoring principle is shown in Figure 1.

Fig 1. Principle diagram of Voltage transformer secondary circuit pressure drop monitoring

$U_M$ is the voltage at the secondary terminal box of the voltage transformer. $U_T$ is the voltage at the input of the energy meter, then

$$\Delta U = U_M - U_T$$  \hspace{1cm} (1.1)

The ratio difference, angle difference of Voltage transformer secondary circuit voltage is

$$\frac{\Delta U}{U_T} = f + \delta j$$  \hspace{1cm} (1.2)

The pressure drop of the secondary circuit of voltage transformer is

$$|\Delta U| = U_T \frac{|\sqrt{f^2 + \delta^2}|}{100}$$  \hspace{1cm} (1.3)

When $|U_T|$ is up to 100 $V$, and $\delta$’s unit is converted to radian,

$$|\Delta U| = \sqrt{f^2 + 0.0291\delta^2}$$  \hspace{1cm} (1.4)

When the ratio difference and angle difference of the secondary circuit of the voltage transformer are measured, the actual value of the secondary pressure drop can be obtained. Because only the error caused by the voltage drop of the secondary circuit of the voltage transformer is considered, we do not consider the impact of current changes. Take A phase as an example:

The power at the secondary terminal box of the voltage transformer is

$$P_a = U_{M,a} I_a \cos \varphi$$  \hspace{1cm} (1.5)

The power at the input of the energy meter is

$$P'_a = U_{T,a} I_a \cos (\varphi + \delta)$$  \hspace{1cm} (1.6)

And A phase secondary pressure drop error is
Because the δ value is small, so
\[ \cos \delta = 1; \sin \delta = \delta; \delta' f = 0 \]
Then
\[ \gamma_a = f_a - 0.0291 \delta_a \tan \varphi \]  (1.8)

The overall error of the secondary pressure drop of the three-phase four-wire system is:
\[ \gamma_{3/4} = \frac{1}{3} (\gamma_a + \gamma_b + \gamma_c) \approx \frac{1}{3} (f_a + f_b + f_c) - 0.0097 (\delta_a + \delta_b + \delta_c) \tan \varphi \]  (1.9)

From the above analysis, we can see, through the measurement of the voltages at the two ends of the secondary circuit, the ratio difference and angle difference of the secondary pressure drop can be obtained. Then the error of the secondary pressure drop can be obtained and the pressure drop of the secondary circuit can be monitored.

2.2. Realization of Secondary Circuit Voltage Drop Monitoring Device Based on Carrier Technology

This technology adopts carrier technology for full-duplex communication, which has no effect on relay protection of the line, small interference, and stable communication [4-5]. The working principle is shown in Figure 1.2

Secondary voltage drop monitoring device of voltage transformer based on carrier technology is composed of a pressure drop host and a pressure drop extension. The voltage drop host is installed in the main control room power metering cabinet, and the extension is installed in the electromagnetic voltage transformer terminal box. The host measures the pressure drop in a polling manner and can monitor the voltage drop of up to 6 lines at the same time. The hardware structure is shown in Figure 1.3 and 1.4 respectively.
Pressure drop test module adopts synchronous frequency multiplying algorithm, and implements a full digital multiplier on four high-speed, high-density programmable devices. The frequency of output signal of full digital frequency multiplier strictly maintains the integer ratio of the input signal frequency. Thus it effectively avoids the measurement error caused by the mismatch between the measured voltage signal and the sampling period caused by the frequency fluctuation of the power network. So it accurately measure voltage amplitude and phase at two ends of voltage transformer.

The carrier transmission module transmits the measured voltage information, and the physical layer can be the voltage transformer secondary circuit [7]. According to DL/T 395-2010 《Low-voltage power line carrier communication broadband access system technical requirements》,The carrier signal output power spectral density in the operating frequency band is not greater than -50dbm/Hz.
The MCU module mainly processes the measured voltage information and calculates the secondary pressure drop including the information of difference and angular difference and measurement error caused by secondary voltage drop of voltage transformer. Comparing the calculated pressure drop with the national standard.

Data storage module stores voltage and alarm information for 1 year, providing data support for battery resupply work and other tasks, and can download data through RS485 downlink serial port.

2.3. **Alarm information directional push**

When the MCU module determines that the secondary circuit is out of tolerance or there is a loss of voltage in the power meter, alarm information directional push module uses EDGE network platform to realize transparent bidirectional transmission of alarm information. The data storage module stores the alarm information and transmits information to the alarm information directional push module through the serial port. It formats alarm information in the module and is sent to the power plant management back-end and multi electric energy measurement technology manager's mobile phone at an interval orientation. When the power plant power technicians confirm the receipt of information, the module stops sending information. Alarm information directional push module uses 5V~15 wide voltage power input strengthen module overvoltage protection to prevent module burn out due to high voltage when powering the module.

2.4. **Voltage Switching Board**

The power plant adopts the metering voltage switching circuit mainly based on the old type electromagnetic relay. After performing the bus switching operation, it can't move in time, causing frequent loss of pressure in the metering circuit. We provide a set of voltage switching plug-in board to replace the old electromagnetic relay switching device to significantly improve the voltage stability of the measurement loop.

![Fig 5. Voltage Switching Board](image)

Voltage switching board adopts self-holding mode. In addition to YQJ relays, all are magnetic latching relays to increase the stability of the voltage loop after switching. Bus disconnectors provide
normally open and normally closed pairs of auxiliary contacts. If the fieldbus isolation switch can only provide a pair of normally open auxiliary contacts, connect n1 and n4 in parallel to access the normally open contact of the # I bus switch. Connect n2 and n3 in parallel to access the # II bus switch normally open contact.

3. Experiment
In the laboratory, the accuracy of this technical device is tested and the experimental results are as follows:

| Check point | Difference | Standard indication | This technical indication |
|-------------|------------|---------------------|--------------------------|
| Phase A     | $f / (10^{-2})$ | -1.00               | -1.005                   |
|             | $\delta / (')$ | 10.00               | 10.02                    |
| Phase B     | $f / (10^{-2})$ | -1.00               | -1.004                   |
|             | $\delta / (')$ | 10.00               | 10.04                    |
| Phase C     | $f / (10^{-2})$ | -1.00               | -1.004                   |
|             | $\delta / (')$ | 10.00               | 10.02                    |

From the experimental data, it can be seen that the present technical apparatus can achieve accurate measurement of the secondary pressure drop and ensure the reliability of comparison with the threshold value.

We apply this set of technology to the power metering circuit of the power plant. Because the voltage switching board with more stable performance is used, no voltage loss failure occurs during the operation of the technical device. According to laboratory experiment and on-site work experience, after using this technical device, the average time of non-metering electricity is 20min. The time chart for the non-metering of energy is as follows.

![Fig 6. Electricity metering time comparison chart](image_url)

The use of voltage switching board reduces the probability of voltage loss failure of the energy meter. In the event of a loss of voltage in the watt-hour meter, the directionally-pushing of alarm information can promptly notify the management personnel of the alarm information, avoiding the long-term non-metering of electrical energy.
4. Conclusions
To sum up, through the transformation of this technology, it is possible to reduce the occurrence of voltage loss failure of the power meter with a high probability. Even if the power meter loses pressure, it can immediately notify the target population and achieve rapidly processing of the fault.

References
[1] Zhikun Luo. Development of On-line Monitoring and Remote Calibration System for Electric Energy Measurement[D]. Hunan University, 2011.
[2] Zhongliang Zhou, Ziye Yang, Kuixian Gu, Chuan Li. Research on Secondary Voltage Drop Testing Technology of Voltage Transformer Based on Carrier Communication[J]. Hebei Electric Power, 2018, 37(01): 38-39+45.
[3] Lei Luo, Bingyuan Tan, Hao Wu, Chongming Chen. Research on the Secondary Voltage Drop Tester of New Voltage Transformer Based on Carrier Communication [J]. Appliance Industry, 2016(07): 70-72.
[4] Fan Zhang, Weitao Zhu, Shanshan Chen. Analysis on the loss of voltage of three phase multi-function electric energy meter [J]. Gansu science and technology, 2013, 29(08): 60-61.
[5] Miaoxian Dong, Yong Peng. Calculate method and improvement measure of measurement error caused by voltage drop of secondary conductor of voltage transformer[J]. Metrology Technology, 2000(08): 16-19.
[6] Hui Li. A Simple Analysis of the Error of PT Secondary Wire Voltage Drop in Electrical Energy Metering [J]. Measurement & Measurement Technology, 2005(02): 21-22.
[7] Yihui Guo, Shi Peng, Chengmin Wang, Zhikun Xing, Guixian Song, Pengpeng Wang. Research on multi-band power line carrier communication device based on OFDM [J]. Electric Measurement & Instrumentation, 2017, 54(23): 60-67.