Analysis of Energy Metering Equipment Performance under Typical Environmental Conditions

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Abstract. Through the performance analysis of electric energy metering equipment under typical environmental conditions, data of working conditions of metering equipment under typical environmental conditions are collected to determine the operating characteristics and related performance changes. Through the recurrence of fault phenomena that are likely to occur in several typical environments, the causes of the faults are analyzed, preventive measures are identified, and an optimization design scheme is proposed for the metering equipment. Through long-term follow-up tests, the operating data of metering equipment in a typical environment are accumulated to provide a basis for comparison in laboratory environments, and a reasonable and effective evaluation system for the operation characteristics of metering equipment is established. It provides the basis for the formulation of relevant standards for environmental testing, and provides technical support for the tendering of measurement equipment and the upgrading of technology.

Keywords: Typical environment, Energy metering, Failure analysis.

1. Introduction

As the basis for trade settlement of various interconnected power grids, metering equipment has laid an important foundation for building a global energy Internet. At present, under the harsh weather conditions of certain areas, measurement equipments have occurred at times and are affected by climatic factors. The reliability of metering equipment not only affects the safety, stability, and economic operation of the smart grid, but also relates to the reliability and safety of electricity consumption for households. Therefore, it is necessary to strengthen the acceptance test for the design, procurement, production, operation and management of metering equipment. There is a need to improve the adaptability of metering equipment under various adverse weather conditions.

In the severe cold environment, various failures of key components of the metering equipment may occur. Such as sampling resistance temperature drift, capacitor capacity, clock error, liquid crystal display smear, battery capacity decline. These faults directly affect the accurate and reliable operation of the metering equipment, and impair the immediate economic interests of the supply side and the demand side. In order to ensure the fairness and fairness of the trade settlement of interconnected power grids under different climates, we have established an international leading test field for natural outdoor equipments. The defects of the metering equipment were exposed, the manufacturing process was improved, and the quality of the metering equipment was upgraded from compliance to suitability and high reliability. Accumulate typical environmental operational data, lead the formulation of international standards, and implement the strategy of building a strong country and a strong manufacturing country.

2. Metrology Equipment Verification Overall Design Plan

48 single-phase meters, 24 three-phase meters, and 10 concentrators were placed in walk-in refrigerators for low-temperature tests. The entire system adopts the separation mode of the testing equipment and the hanging watch rack. The walk-in refrigerator test area places the measured single-phase meter, three-phase meter, and concentrator by means of a hanging watch rack. The indoor laboratory implements the verification and test functions of smart energy meters and concentrators by configuring power supply and error processor detection devices. Metering equipment functional verification scheme is shown in Figure 1.

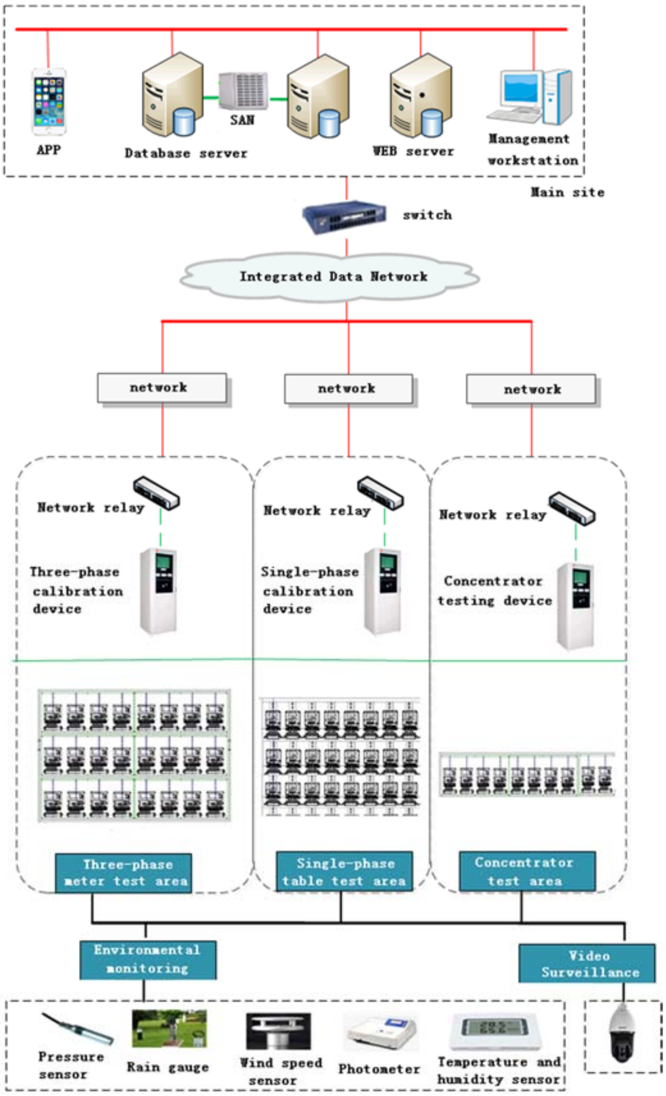

Fig. 1 verification equipment design plan

Metering equipment in the inside of the walk-in refrigerator mainly investigates measurement error, carrier communication, charge control tripping, meter reading time, liquid crystal display and other functions. All test tasks are configured by the system software to detect tasks and issued to verify the various functions of the metrology equipment in a low-temperature environment.

3. Metering equipment monitoring platform construction

The signal source adopts advanced digital frequency modulation, amplitude modulation and phase modulation digital composite signal technology. It is composed of a powerful programmable digital logic array CPLD chip, MCU MCU, and D/A chip. The MCU digitally discretes the sinusoidal fundamental wave or superimposed harmonic values as required and stores them in RAM. The frequency reference generator inputs the sine wave digital value stored in RAM to the D/A converter through a calculator. A synthetic sinusoidal signal with a certain phase relationship between each other is obtained. After active low-pass filtering, voltage and current signals with a distortion less than 0.2% are input to the power amplifier as voltage and current signals. Amplitude adjustment of the signal source adopts 16 D/A converters, so that the regulation fineness reaches less than 0.01% of full scale.

The power amplifier adopts advanced pulse width modulation technology and has the characteristics of high conversion efficiency, large output capacity, high output reliability, strong load carrying capacity, and stable output. Abnormal protection was designed, main circuit over-current protection, device over-temperature protection, output short circuit overload, output open circuit protection, etc. The power amplifier can work stably and reliably for a long time. Power amplifier structure shown in Figure 2.

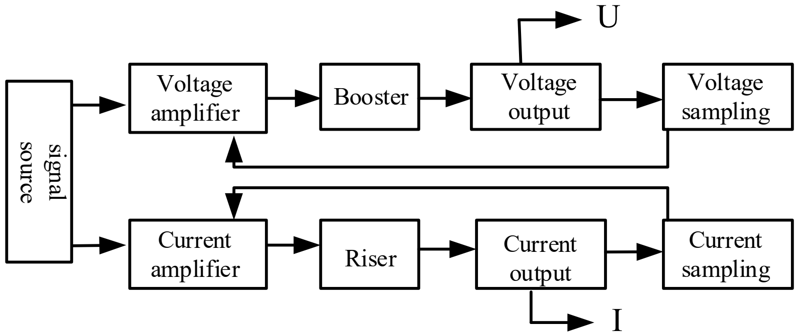

Fig. 2 the working principle of the power amplifier

The voltage and current generated by the signal source are respectively sent to the voltage amplifier and the current amplifier through their respective feedback compensation adjustment circuits for power amplification. The amplified sinusoidal signal is transformed by a voltage output transformer and sent to a calibrated meter and a standard watt-hour meter. After the amplified sinusoidal current signal is boosted by the current transformer, it is output from the current output terminal of the device, and is connected in series with the standard meter and the current coils to be calibrated to return to the current booster. The output voltage and current signals are sampled by current and voltage feedback sampling transformers and fed back to the feedback compensation adjustment circuit of the preamplifier. If the device generates an alarm signal, it can quickly feed back to the signal source, stop the signal output through the signal source, and make an alarm.

The standard electric energy meter is an intelligent multi-functional high-precision electric energy measuring instrument that adopts the latest digital electronic technology and uses DSP high-speed processor as the core. Standard power meter working principle shown in Figure 3.

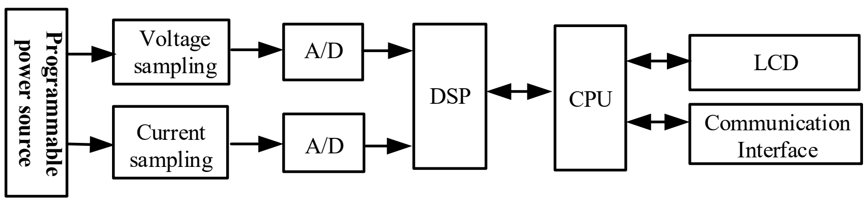

Fig. 3 working principle of standard electric energy meter

The voltage and current to be measured are sampled and sent to a digital processing system via their respective analog-to-digital converters. The DSP performs real-time voltage and current calculations to find the actual power, angle, and power factor. A high frequency pulse output is generated by the power control frequency generator. This pulse is a high pulse of electrical energy. The low frequency pulse of electrical energy is obtained by the frequency divider and used when verifying the standard table. The SCM and DSP communicate in real time and the measured values are displayed through the LCD.

The data logger uses embedded technology, modular structure, self-contained liquid crystal display, and can connect various sensors. The system adopts a modular structure, which can flexibly increase or decrease corresponding modules and sensors according to the needs of users, and meet the needs of various users. The system comes with display, automatic save, real-time clock, data communication and other functions. The data logger has the advantages of advanced technology, high measurement accuracy, large data capacity, micro power consumption, long distance to telemetry, friendly man-machine interface, and high reliability.

The schematic diagram of the three-phase electric energy meter and the concentrator hanging table rack is shown in Figure 4.

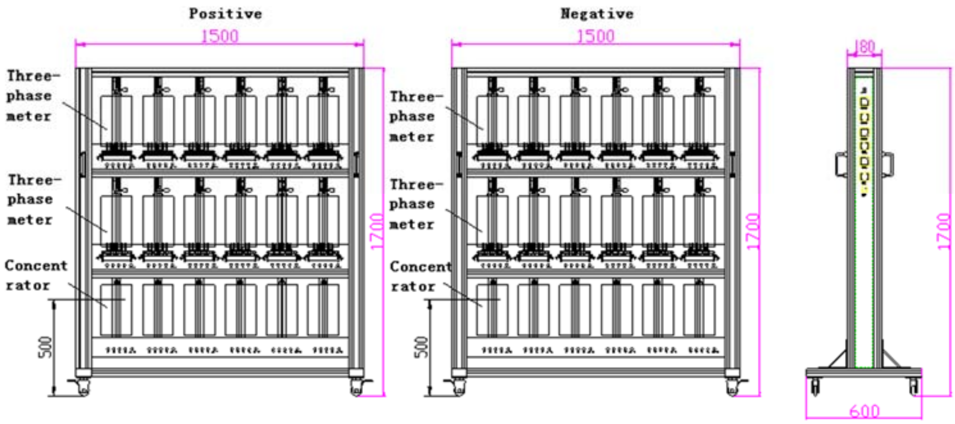

Fig. 4 Three-phase energy meter and concentrator hanging table structure

Hanging table configuration instructions:

The single-phase aging car has multiple built-in PT. Multi-channel PT adopts oil-immersed type to ensure normal operation in low temperature and high humidity environment. Hang table frame profile using 6063-T5, strong corrosion resistance. The table support uses aluminum alloy table tops and springs. All pulse lines and communication lines are in the form of pins, and the terminals of the meter are connected by screwing screws. All voltage lines use U-type wiring forks for connection to the meter. Hanging table frame signal connection uses low-temperature, high-humidity air outlets. The current and voltage connections between the watch rack and the testing equipment are connected to terminals that are resistant to low temperatures. The signal transfer uses air outlets.

4. Metering equipment performance impact analysis

When analyzing the effect of temperature, the temperature error of all operating conditions with a voltage of 220 V and a current of 1 A is first extracted. Analyze the effect of temperature on sample measurement error. Since the sample error is large due to the small voltage, the measurement voltage is 187V and the current is 1A. Samples from different manufacturers are shown in Figure 5.

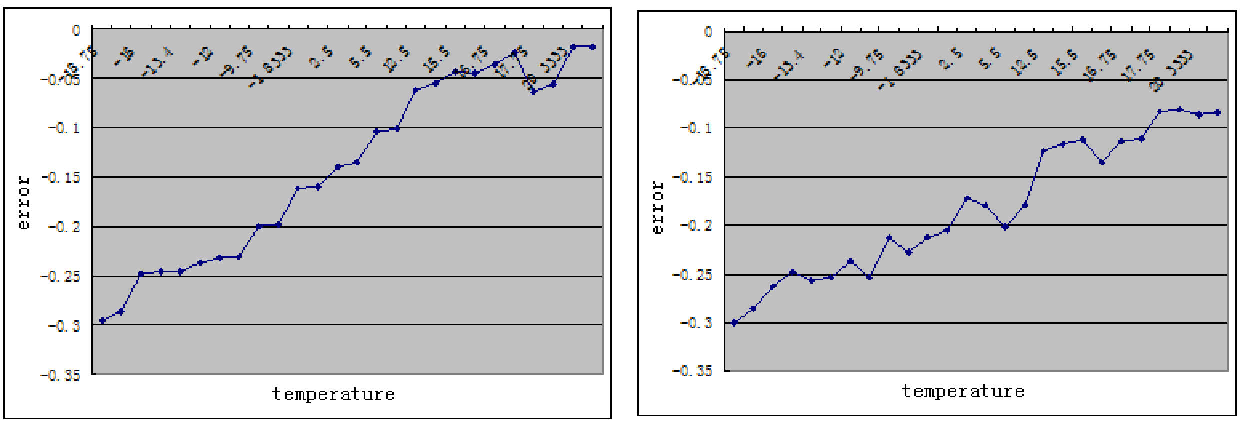

Fig. 5 Sample error of different manufacturers varies with temperature at low voltage

In order to study the effect of phase on the measurement performance of a single-phase energy meter, the collected errors were screened. The fixed voltage parameter is 220V, the current parameter is 1A, and the temperature is about -20°C. The power factor changes from 0.5 to 1 at this time.

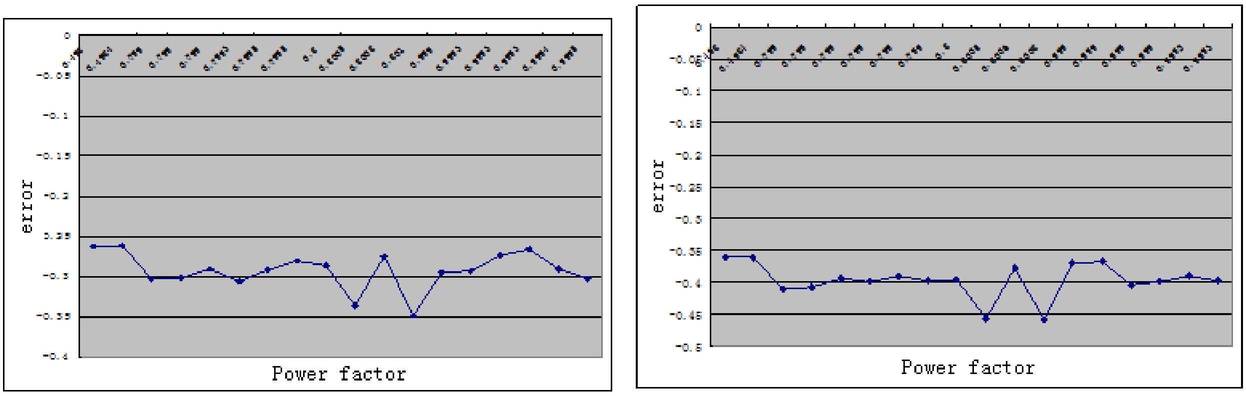

Fig. 6 Sample error of different manufacturers varies with power factor

To study the effect of voltage on the measurement performance of the sample, the fixed load is 1A and the temperature is about -20°C. Extract the test data to analyze the voltage effect. Since the influence of power factor is not obvious, the power factor is set to 1.

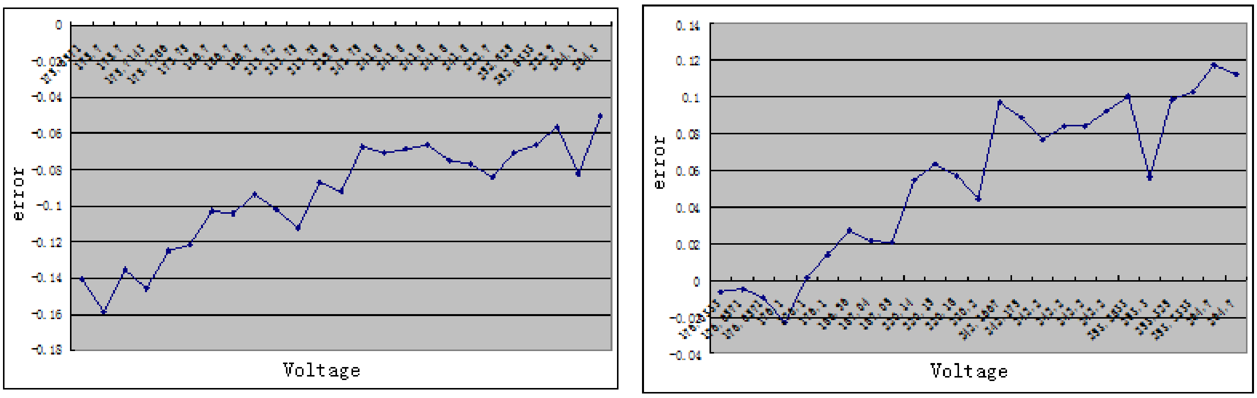

Fig. 7 Sample error of different manufacturers with voltage change under heavy load

According to the trend of the sample error in the above figure, the sample error decreases when the voltage increases. All error curves increase with increasing voltage.

When the sample voltage is 220V, the power factor is 1, and the temperature is -20°C, the sample error of different manufacturers changes with the load as shown in Fig.8.

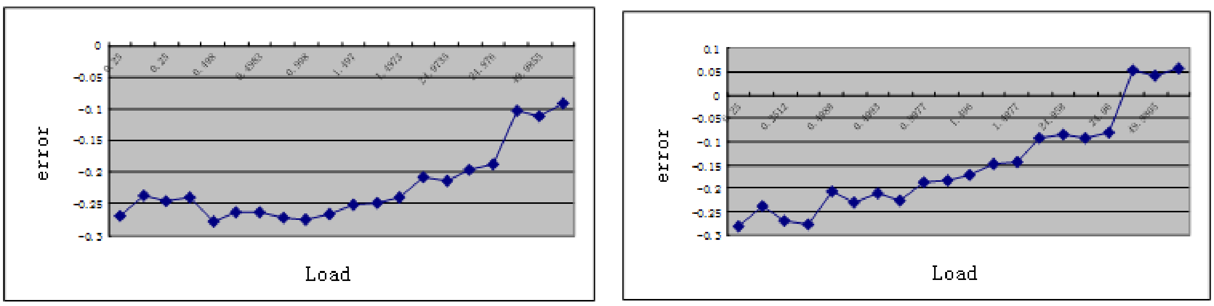

Fig. 8 Sample error of different manufacturers varies with load

From the above figure, we can see that the sample tables of each watch factory show the same regularity when the load increases. That is, when the load increases, the error tends to decrease, and the margin is not large.

The effects of temperature, voltage, load, phase, and time on the meter were examined. The temperature is the local natural environment temperature. Voltage, load, phase and other electrical parameters are supplied by a controllable power source. Experimental prototype shown in Figure 9. Power meter and concentrator hanging table stand shown in Figure 10.

Fig. 9 Experimental prototype physical map. Fig. 10 physical map of the power meter and concentrator hanging table

5. Summary

State Grid Corporation of China established a unified development strategy for the smart grid. The overall optimization of the power grid's resource allocation capabilities and the efficiency of the power system has been enhanced, ensuring the safe, high-quality, and reliable supply of electricity. In order to study the adaptability of metering equipment in various extreme natural environments, four regions, namely Heilongjiang, Xinjiang, Tibet and Fujian, under the extreme environmental conditions of high and low temperatures, high dry heat, high altitude, high salt spray and high humidity Metering equipment reliability verification work. Provides technical guidance for the differential configuration of metering equipment in different regions. This will lay a solid foundation for the promotion of the global energy internet.

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References

[1]. Pasdar, A.; Mirzakuchaki, S., "A Solution to Remote Detecting of Illegal Electricity Usage Based on Smart Metering," in Soft Computing Applications, 2007. SOFA 2007. 2nd International Workshop on, vol., no., pp.163-167, 21-23 Aug. 2007.

[2]. Deb, S.; Bhowmik, P.K.; Paul, A., "Remote detection of illegal electricity usage employing smart energy meter - A current based technique," in Innovative Smart Grid Technologies - India (ISGT India), 2011 IEEE PES , vol., no., pp.391-395, 1-3 Dec. 2011.

[3]. Bat-Erdene, B.; Lee, B.; Kim, M.-Y.; Ahn, T.H.; Kim, D., "Extended smart meters-based emote detection method for illegal electricity usage," in Generation, Transmission & Distribution, IET, vol.7, no.11, pp.1332-1343, November 2013.

[4]. Mimmi L. M., Ecer S. An econometric study of illegal electricity connections in the urban favelas of Belo Horizonte, Brazil [J]. Energy Policy, 2010, 38(9):5081-5097.

[5]. MENG Anbo, LI Jinbei, YIN Hao. An efficient crisscross optimization solution to large-scale non-convex economic load dispatch with multiple fuel types and valve-point effects [J]. Energy, 2016, v113: 1147-1161.