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Research Status and Prospects of Monitoring Sensor Energy Supply Technology

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Abstract. The self-powered technology of the power system measuring device is a power-taking method from the power source to the load according to the principle of electromagnetic induction or energy exchange. Compared with the traditional wired method, it does not need independent power supply to power the device, and has the advantages of high intelligence and high reliability, especially in some special occasions, and will be more widely used. It mainly expounds the existing four mainstream self-powered implementation methods, and analyzes its working principle, transmission efficiency and existing problems. According to the research status of various power supply methods, the future development trend of self-powered technology is prospected.

1. Introduction

In recent years, with the rapid expansion of the power grid, the national grid has continuously improved the intelligent operation and maintenance level of transmission lines and substations, and the application of digital online monitoring technology in power equipment is becoming more and more popular. However, due to the wide variety of monitoring sensors and the limitations of the field application environment, the monitoring sensor power supply often cannot work reliably for a long time, and the field application problems are increasingly prominent. Therefore, in order to ensure the stable and effective operation of the monitoring device, the energy-receiving or power-supply problem of the device monitoring sensor has become the focus of attention [1].

At present, the mainstream self-powered modes include CT energy supply, laser energy supply, solar-battery energy supply, and capacitor voltage division supply. The laser energy supply has high precision and stable energy supply, but the cost is high [2]. The photocell is a renewable energy source that does not generate greenhouse gases, but is susceptible to the external environment and cannot achieve continuous energy supply. Capacitor voltage divider energy supply due to the lack of electrical isolation has certain safety hazards. In view of this, the above self-powered mode is summarized, the characteristics and application of each power-taking mode are analyzed, and prospected in combination with the existing problems.



2. Basic Structure and Working Principle Analysis

2.1. CT Energy Supply

The basic structural principle of CT energy supply extraction is shown in Figure 1, mainly includes power take-off part, electric energy processing part, energy storage and protection part. The power-acquisition part is composed of a dedicated current transformer; the power processing part is composed of rectification, voltage dividing circuit, filtering circuit, and voltage stabilizing circuit; the energy storage and protection part is composed of a bleeder circuit and a storage capacitor.

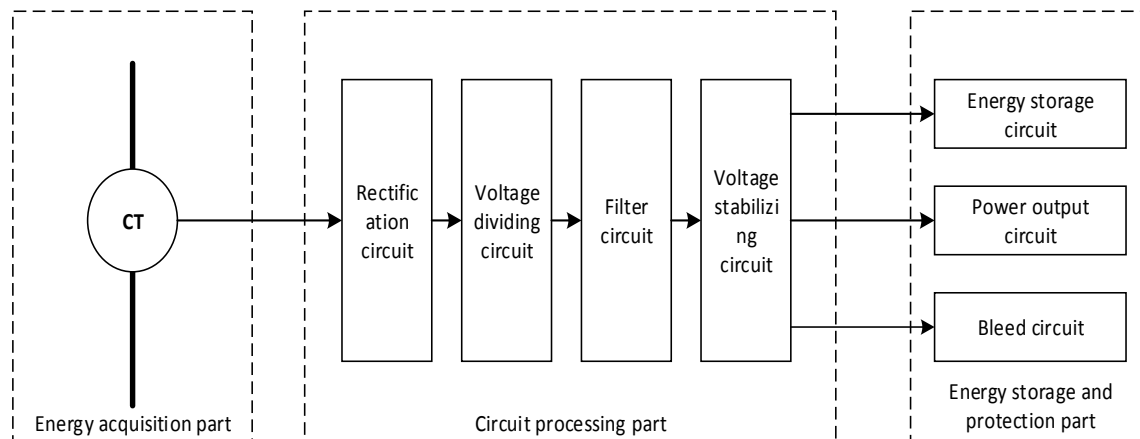


Fig. 1 The basic structure principle of CT energy supply

The working principle of CT energy supply is that, according to the principle of electromagnetic induction, the electric energy is sensed from a busbar through a dedicated CT, and after being rectified by a bridge rectifier circuit and divided by a voltage divider circuit, since the output DC power contains a large AC component, it does not meet the requirements of circuit power supply, so it needs filtering circuit filtering. Finally, it is processed by the voltage regulator circuit to output stable DC power for the terminal equipment.

The function of the voltage divider capacitor is to convert the current into a voltage and prevent the voltage from mutating, absorbing the spike voltage and powering the terminal equipment. The bleed circuit is controlled by micro-controller that when the circuit energy is excessive, the micro-controller controls the current bleeder circuit to discharge energy, so that the output voltage remains stable [3].

2.2. Photocell Energy Supply

The basic structural principle of photocell energy supply is shown in Figure 2. The device is mainly composed of a photocell array, a control unit, a power conversion part, a confluence box and an energy storage part.

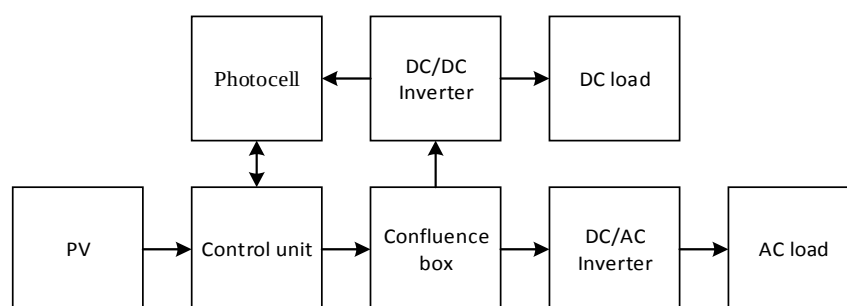


Fig. 2 The basic structure principle of photocell energy supply

The working principle of photocell energy supply is that when the light is sufficient, the light energy is converted into electric energy according to the photoelectric effect. When the output is connected to the DC load, the DC/DC conversion is applied to the load, and the excess energy is stored to the battery pack; when the output is connected to the AC load, the control unit controls the DC power of the combiner box and is used by the load after DC/AC conversion. When the light is insufficient, the battery pack supplies power to the load. The energy of the control unit is provided by the battery pack [4]. Photocells are a core part of photocell power. Its conversion efficiency is

$$\eta_{power} = \frac{P_{out}}{P_{in}} = \frac{FF \cdot V_{OC} \cdot J_{SC}}{P_{in}} \times 100\% \quad (1)$$

Where: P_{out} is the output power; P_{in} is the surface illumination power of the battery; FF is the fill factor; V_{OC} and J_{SC} are the open circuit voltage and the short circuit current. In order to improve the photoelectric conversion efficiency, the common methods include: forming a photocell into a stack type, raising the anti-reflection layer technology, changing the appearance of the photocell to increase the amount of illumination incident, and adjusting the angle of the panel.

2.3. Capacitor Voltage Division Energy Supply

The basic structural principle of capacitor voltage division energy supply is shown in Figure 3. The device mainly comprises an energy acquisition part, a circuit processing part and an energy storage part. The energy acquisition part is composed of a high voltage bus, a capacitor divider, an isolation transformer and a compensation reactor; the circuit processing part is composed of a rectifier bridge and a DC/DC converter; and the energy storage part is composed of a battery.

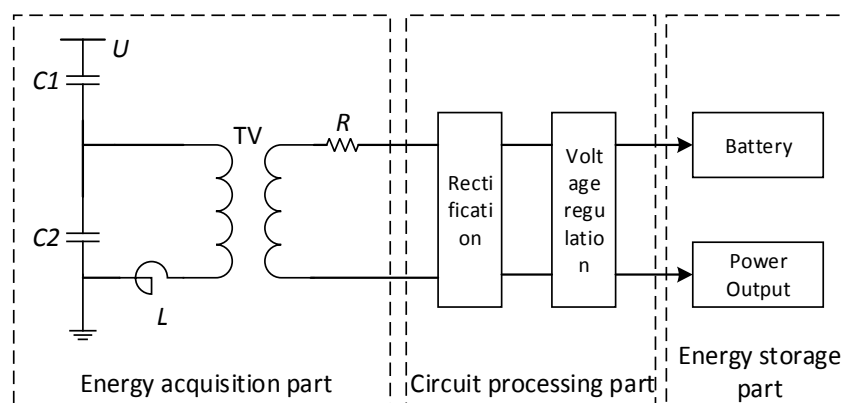


Fig. 3 The basic structure principle of capacitor voltage division energy supply

The working principle of the capacitor voltage division energy supply is to obtain electric energy from the power frequency voltage source on the primary side. According to the principle of capacitor voltage division, the voltage is divided by a series capacitor divider, and the isolation transformer is stepped down twice, the transformer transfers electrical energy to the secondary side, the rectifier circuit converts the alternating current into a pulsating direct current, and obtains a stable direct current after DC/DC conversion. The effect of the compensating reactor L is to compensate for the capacitive impedance of the capacitive divider.

2.4. Laser Energy Supply

The basic structural principle of laser energy supply is shown in Figure 4. The laser energizing device is mainly composed of a power supply part, a high voltage side of the collected signal, a low voltage

side of the signal processing, and a signal transmission part. Wherein, the power part is composed of a high voltage bus and a Rogowski coil; the high voltage side is composed of a DC/DC converter, a photoelectric converter, a photocell, an analog signal processing circuit, an A/D converter, and an electro-optical conversion circuit; Low-voltage side consists of laser diode power supply, laser diode and signal processing circuit.

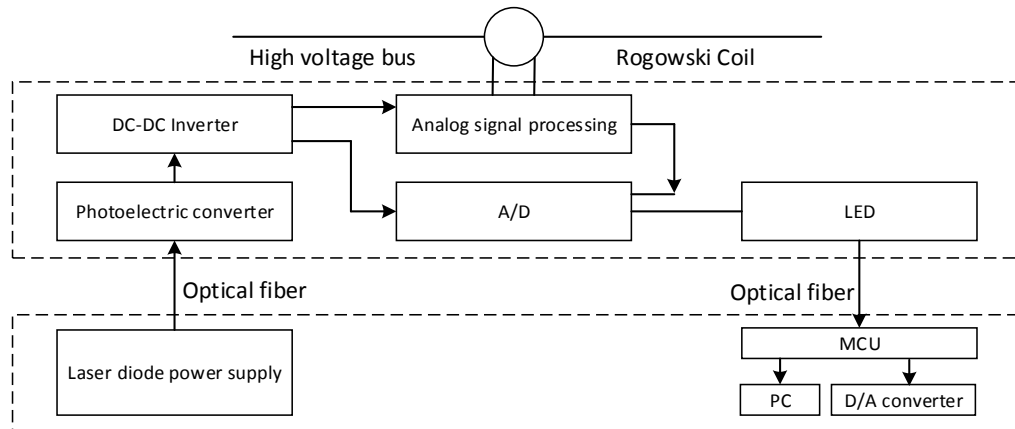


Fig. 4 The basic principle of laser energy supply

The working principle of laser energy supply is to transfer the laser from the low voltage side to the high voltage side by means of optical fiber, convert the light energy into electric energy through the photoelectric converter, and output the signal processing circuit for the high voltage end. The high-voltage analog signal processing circuit processes the current signal outputted by the Rogowski coil into a voltage signal. After A/D conversion, the data transmission part converts the electrical signal into an optical signal, and sends the optical signal to the low-voltage end through the optical fiber, and the data receiving part of the low-voltage end will be the received optical signal is converted into an electrical signal, and after being processed by the MCU, the signals are respectively output to the PC and the D/A converter.

3. Research Status

3.1. CT Energy Supply

In recent years, some research results of induction energy utilization have been obtained in China and have been successfully applied to transmission line sites. Wei Jie et al. studied a device that uses current transformers to extract energy for Guangxi Power Grid Corporation. It has successfully supplied power to the on-line temperature measurement system of four ring network cabinets; In order to supply power to the LED indicator system of the transmission line, Xia Shengfen et al. studied a power supply device using a current transformer combined with a super capacitor was successfully applied in the field; Li Weifeng and others studied a high-power power supply device for the high-voltage line inspection robot. This device uses a current transformer and battery, and the maximum power supply can reach 40W; In addition, the CT energy supply device is widely used in electronic current transformers. Researchers from abroad have also conducted some research on the way of power supply for wires, and have achieved some results. Although the CT energy supply method has achieved great results in research and application, there are still some problems that have not been well solved.

3.2. Photocell Energy Supply

China began researching solar cells in 1958 and applied it to various fields of the power industry after 1970. Photovoltaic solar power supply is widely used at home and abroad because it is easy to use,

geographically unrestricted, and recyclable. Most of the high-voltage transmission line online monitoring equipment is installed outdoors, so, it is very convenient to use solar cells as a power supply solution. At present, most researches on the field of photocell are concentrated in the field of large-scale solar power generation. There are not many in-depth researches on the field of monitoring sensor energy supply, which limits the development of technologies such as miniaturization of photocell energy supply and improvement in service life.

3.3. Capacitor Voltage Division Energy Supply

In August 2010, ABB used the high-potential energy-receiving technology based on capacitive voltage divider for the first time in the series supplement of the 500kV Guyuan substation of the State Grid Power Company, which was used for CapThor's Operation and Monitoring Unit (OSU), but during system commissioning, the line pulls the gate and causes multiple damage to its power supply components, exposing the power supply unit in terms of EMC design has many shortcomings. In order to fully consider the system over-voltage conditions, improper design of equipment insulation and insufficient electromagnetic shielding measures, some domestic manufacturers use the capacitive voltage divider technology to obtain power on the low voltage side in the electronic transformer, thus realizing the passive working mode of the electronic transformer. Although the basic principle is similar to the technique proposed in this paper, the high potential energy draw is more difficult than the low potential energy. Some domestic universities have done some theoretical and simulation research on high-power high-potential power supply based on capacitive voltage divider technology to verify its technical feasibility, but no relevant applications.

3.4. Laser Energy Supply

Recently, laser energy supply systems have been widely used in the measurement of current and voltage parameters of power systems. CT and PT are the key equipments of the power system, and most of them are traditional electromagnetic transformers. With the increase of voltage level and the application of communication systems, electromagnetic transformers have many shortcomings, and the new photoelectric transformers using laser energy supply scheme have significant advantages. These advantages make OECT and OEPT widely used in power systems. The active photoelectric transformer is a relatively mature photoelectric transformer. The high-voltage side power supply scheme mainly includes laser power supply, bus power supply and battery power supply. Huazhong University of Science and Technology Zhang Mingming and others developed an active high-voltage side data acquisition circuit using laser power supply. Shang Qiufeng and others of North China Electric Power University have developed a high-accuracy active OECT, and the high-voltage side data acquisition circuit is powered by laser. A large number of applications show that the anti-interference ability of the laser energy supply system has obvious advantages, but the problems of system reliability, cost and conversion efficiency still need to be further studied and solved.

4. Key Issues to be Solved

4.1. CT Energy Supply

The power supply of the wire is the hotspot of the power supply device for the online monitoring of the transmission line. The current is mainly determined by the load of the load grid, so the current flowing through the transmission line is not stable. For example, current fluctuations can range from tens of amps to thousands of amps during normal operation, while currents flowing through the transmission line are only a few amps or even close to zero during no-load operation. In order to ensure stable power supply to the back end under the condition of large fluctuation range of the transmission line current, the wire energy-receiving device also needs to solve the following problems:

- 1) There is a magnetic saturation problem in the energizing coil, and it is necessary to prevent the energizing coil from working in the deep saturation region to avoid inevitable damage to the power supply device;

- 2) Try to increase the energy-receiving efficiency of the energy-carrying coil, and increase the output power as much as possible when the current of the power transmission line is small;
- 3) When the current of the transmission line is too large, the excess energy should be treated or vented to ensure the safety and stability of the back-end circuit;
- 4) When the transmission line is unloaded, the power supply unit should have no power supply dead zone.

4.2. Photocell Energy Supply

Photocell powered power supply technology is widely used in overhead transmission line monitoring devices. However, the reliability and support capabilities of solar power as a system for generating electricity need to be improved. Another important component in the solar cell power supply system is the battery. The battery inevitably loses energy when it is charged and discharged, and its performance is greatly affected by temperature. At present, the problems in the application of photocells are as follows:

- 1) The overall conversion efficiency of the solar cell power supply system and the solar panel power generation efficiency are low, and the controller charging efficiency needs to be improved;
- 2) The battery capacity is greatly affected by the temperature. In order to ensure the power supply of the equipment under low temperature conditions, the power supply equipment is too heavy.

4.3. Capacitor Voltage Division Energy Supply

The high-voltage line capacitor and the voltage transformer are connected in series to directly extract energy from the high-voltage wire, and the insulator string as the insulation support of the over-voltage of the transmission line is connected in parallel with the line capacitor and the voltage transformer. The method can obtain stable energy output and realize reliable power supply to the transmission line tower monitoring equipment. However, the capacitor charging device is highly susceptible to external influences and damage due to long-term exposure to the natural environment. At present, the research on high-potential energy-taking technology based on capacitor voltage division faces the following problems:

- 1) The capacitive voltage divider is connected to the transmission line in parallel. From the perspective of system operation safety, it puts forward higher reliability requirements;
- 2) The secondary circuit components are on the high potential side, which is resistant to various types of overvoltage conditions of the line and a very harsh electromagnetic environment. Therefore, the requirements for overvoltage protection, electromagnetic shielding and insulation coordination are more severe;
- 3) The power supply obtained by the existing capacitive voltage divider is too small to meet the application of high power sensor.

4.4. Laser Energy Supply

The laser energy supply system is a photoelectric energy transmission system that is applied to the ultimate goal of safe and reliable power supply in extremely harsh environments such as high voltage and strong electromagnetic interference. Due to the inherent insulation and light weight of the optical fiber, the laser energy supply system is more and more widely used in power systems, especially photoelectric current transformers. However, as a basis for long-term operation of the equipment, the power supply system has higher requirements for reliability. The two important problems existing in laser power supply are as follows:

- 1) Due to factors such as the working life of the device, the long-term stability of the entire system is difficult to guarantee;
- 2) The energy conversion efficiency is low due to limitations of optoelectronic devices, energy transmission fibers, and the like.

5. Summary and Prospect of Self-powered Technology

Based on the above analysis, the main advantages and disadvantages of self-powered technology are shown in Table 1:

Table. 1 Self-powered technology advantages and disadvantages

Method to realize	Relative transmission distance	Advantage	Disadvantage
CT Energy Supply	1 mm~1 m	High energy conversion rate, direct and convenient power-off mode, low cost, stable energy supply	Short transmission distance, current dead zone
Photocell Energy Supply	1 cm~10 m	No pollution, no greenhouse gas emissions	Limited output energy, susceptible to external conditions, low photoelectric conversion rate
Capacitor Voltage Division Energy Supply	1 cm~10 m	Limited output power	No electrical isolation, there are certain safety hazards and poor reliability
Laser Energy Supply	10 m~100 km	High output accuracy, safe and reliable, stable energy supply	Low photoelectric conversion rate, high cost, short working life of hardware

At present, in the self-power supply mode of power equipment, CT power utilization is the most practical and has broad application prospects. Compared with capacitor voltage division energy extraction and laser energy supply mode, CT power is more direct, large output power and high energy conversion rate. In the field of high voltage transmission and distribution, it is mainly used for power system online monitoring, line inspection robots and other power [5]. Equipment, in the field of smart grid, mainly used in outdoor intelligent switchgear, transmission and distribution monitoring power supply, power wireless temperature measurement system. The power supply of photocell uses sunlight as an energy source and is not affected by the form of power equipment. The advantages of power supply in overhead transmission line monitoring devices are obvious. Capacitor voltage divider energy supply can obtain different voltage output by adjusting the size of the capacitor to obtain the required power, which will be more widely used in digital substations, ring network cabinets and other power equipment [6]. The laser energy supply technology isolates the high and low potential sides through the non-conductive optical fiber, and can safely measure the power bus parameters on the high voltage side on the ground. On the other hand, there is no safety hazard of open circuit on the low voltage side, and the insulation cost is greatly reduced, which has obvious advantages in power supply for the high voltage side monitoring equipment.

6. Conclusion

In summary, although the existing self-powered modes have their own characteristics and application scope, they also have a relatively complete theoretical system support. However, some key technologies need to be further studied. For example, the CT energy transmission distance is short and there is a dead zone. The laser energy supply and the photoelectric conversion efficiency of the photocell are low, and the capacitor voltage division energy supply is easy to generate safety problems due to no electrical isolation. So far, self-powered transmission methods with long transmission distance, large output power, safety and stability have not been developed at home and abroad. With the development of smart grid, self-powered technology has great application prospects in power

system electrical equipment because of its advantages of not requiring independent power supply and strong applicability. If the self-powered technology has further innovation in theory and technology, it will have important practical significance.

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