APPLICATION OF AUTOMATIC MONITORING AND CONTROL SYSTEMS FOR RELIABILITY OF POWER TRANSMISSION LINES

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Abstract

The main aspects of the use of automatic monitoring and control systems in order to increase the reliability of power lines are considered. The article highlights modern technologies and techniques that make it possible to quickly identify and prevent possible emergency situations on power transmission lines. The advantages of automated systems compared to traditional monitoring and control methods are discussed, and examples of research and practical applications of such systems are presented. The results obtained can be useful for energy specialists and engineers involved in the design, operation and maintenance of power transmission lines, as well as for developers and manufacturers of automated monitoring and control systems.

Keywords: power lines, sensors, monitoring, automatic control

I. Introduction

The reliability of power transmission lines (PTLs) plays a key role in ensuring the stable operation of energy systems. Power transmission lines are the main channel for transmitting electricity from generating sources to end consumers, and their reliability directly affects the continuity of power supply. Failures or malfunctions in power transmission lines can lead to power outages, which have serious consequences for both industry and residential areas, including loss of production, financial losses and even threats to human life and health.

Moreover, modern energy systems are becoming increasingly complex and integrated, with an increasing share of distributed generation, including renewable energy sources such as solar and wind power. In this context, the reliability of transmission lines becomes even more critical, since even small power outages can have a cascading effect on the operation of the entire energy system. Therefore, ensuring the reliability of power lines is an essential condition for ensuring stable and safe operation of energy systems as a whole. Online monitoring and automatic control, which are provided by ASMU systems, are becoming necessary tools for the timely identification and elimination of possible problems on power lines, which helps to increase their reliability and ensures the efficient functioning of the entire energy system [1-3].

In recent years, there has been a significant increase in interest in automated monitoring and control systems (ASMU) in various fields, including energy. This increase in interest is due to several factors. Firstly, with the development of technology and the introduction of the Internet of Things (IoT) concept, it has become possible to create more efficient and intelligent monitoring systems that are capable of continuously collecting and analyzing equipment condition data in real time. This allows operators to quickly respond to any anomalies and prevent possible accidents.

Secondly, the desire to improve the efficiency and reliability of technical systems also stimulates interest in ASMU. Automated monitoring and control systems make it possible to optimize maintenance and repair processes, reduce personnel and resource costs, and also increase the service life of equipment due to timely detection and elimination of faults.

Finally, the growing need for security and reliability of critical infrastructures such as power systems is also driving demand for ASMUs. Automated monitoring and control systems provide a higher level of control and protection, which helps prevent incidents and minimize their consequences.

Thus, automated monitoring and control systems are becoming an integral part of modern technical infrastructure, ensuring continuous operation and increased reliability of various technical systems, including energy ones.

II. Formulation of the problem

ASMUs (automatic monitoring and control systems) are an important component of modern energy systems, providing continuous monitoring and control of power transmission lines (PTLs). The technical characteristics and capabilities of ASMU include the use of various types of sensors and sensors, such as temperature, humidity, pressure, vibration and others, to continuously collect data on the condition of power transmission line equipment. This data is transmitted to a central control center via data networks such as the Internet, cellular or satellite communications, ensuring a rapid response to any changes or faults.

In addition, ASMUs are equipped with high-performance controllers and management software capable of analyzing sensor data and making appropriate decisions in real time. This allows monitoring and control systems to automatically respond to changes in the technical condition of power lines, preventing possible emergency situations and ensuring the uninterrupted operation of the energy system. In addition, ASMUs integrate with other control and automation systems to optimize the operation of the entire energy system and increase its efficiency.

Finally, one of the important characteristics of ASMUs is their data analytics and diagnostic capabilities. Using machine learning and data analytics techniques, ASMUs are able to identify hidden patterns, predict possible failures and determine the causes of failures based on the analysis of collected data. This allows operators of monitoring and control systems to make informed decisions on the maintenance and repair of power lines, minimizing the risk of emergency situations and ensuring stable operation of the energy system.

The use of automated monitoring and control systems (ASMU) is a key solution for increasing the reliability of power transmission lines (PTLs) and ensuring the safety of energy systems in general. The main benefits of ASMU for power line reliability include:

Firstly, increasing the efficiency and effectiveness of diagnostics and detection of possible faults or anomalies in the operation of power lines. ASMUs are capable of continuously monitoring the condition of equipment and automatically identifying any deviations from normal operation, which allows you to quickly respond to potential threats and prevent possible emergency situations.

Secondly, optimization of planned and emergency maintenance of power lines. ASMUs make it possible to carry out preventive maintenance and repair of equipment at more optimal time intervals based on real data about its condition, which reduces the likelihood of failures and increases the service life of power lines [4].

In addition, ASMUs provide the ability to automatically control and optimize the operation of power lines in real time depending on changing operating conditions, such as load, weather conditions, etc. This allows for more efficient use of resources and ensures stable power supply in all conditions.

Finally, ASMUs help improve safety and protect transmission lines from external threats such as power outages, cyber-attacks or natural disasters. Automatic monitoring and control systems ensure a quick response to any threats and prevent the possible consequences of such incidents from spreading to other parts of the energy system.

III. Problem solution

When transporting electricity through a specific power transmission line, the permissible current loads are regulated. In this case, current limit values are used that determine the sag of the wires above the critical value. These data are taken for the most extreme conditions, which do not occur in more than 90% of the operating time of power lines [5]. Consequently, there is a resource for transmitting large capacities without violating the regulations. That is, it is possible to transmit additional power (15–30%) almost 90% of the operating time. The presence of a monitoring system allows you to use this additional resource without reducing the reliability regulations. To do this, it is necessary to monitor the current level and temperature of the wires along the entire route and, in accordance with the real state of the line, dynamically adjust the level of transmitted power (Fig. 1).

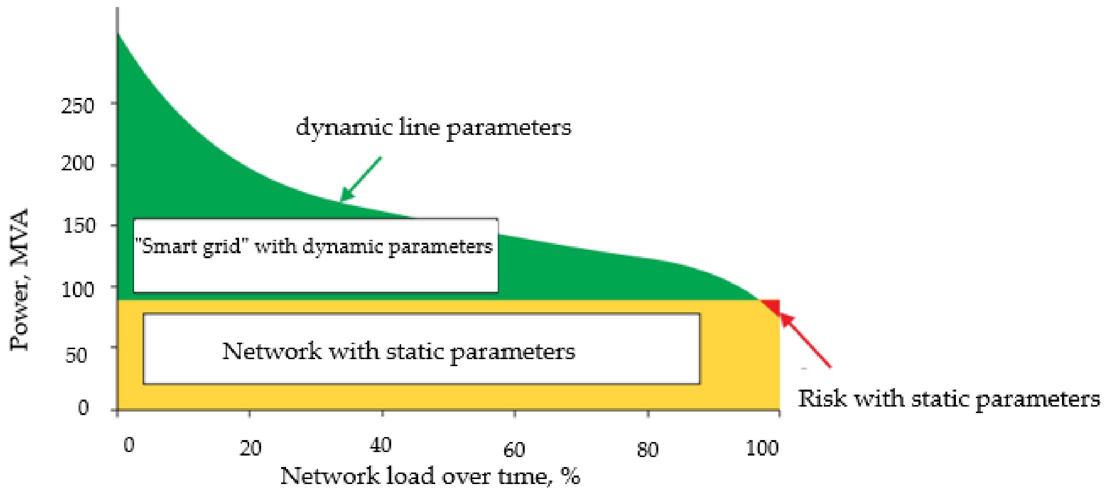

Figure 1: *Efficiency of energy transfer in power transmission lines with static and dynamic parameters*

Telemetric monitoring of power line wire parameters was first proposed more than 40 years ago. The first controlled parameter via a telemetric radio channel was the current in the wire. The appearance of the American patent Remote measuring system [6] dates back to this time ("Systems for remotely measuring current in a wire with transmission of the measured value via a radio channel"). The proposed solution used power to the measuring device from an induction transformer due to the current flowing in the wire. It was measured through a transformer current sensor. The signal modulated the grid circuit of the tube transmitter (Fig. 2). As can be seen in the figure, the current meter used measuring and current transformers to power the lamp circuit (anode and filament circuit). The transmitter is made on a single-tube stage. The AM RF signal is used by modulating the grid current of the transmitter oscillator. In the last 15 years, thanks to the development of information technology, the commercial implementation of power line wire monitoring systems has become possible.

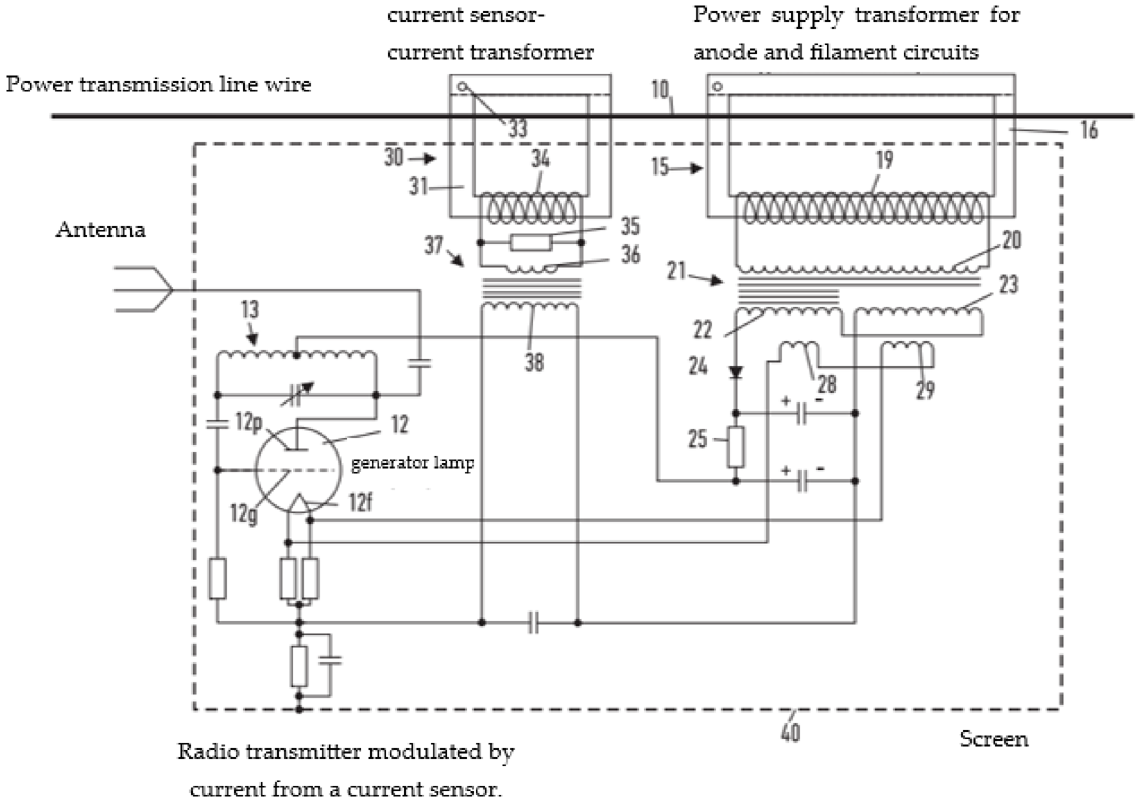

Figure 2: *Circuit diagram of a remote current meter with a radio channel*

Currently, various monitoring systems for overhead power lines are widely used throughout the world, providing the system operator with detailed information about the current state of overhead cable power supply networks. The monitoring system consists of a network of measuring units connected through a communication channel with equipment at the control center. Measuring units are distributed along the power line route and mounted on supports or directly on high-voltage wires. Figure 3 shows the structure of the transmission line capacity monitoring system.

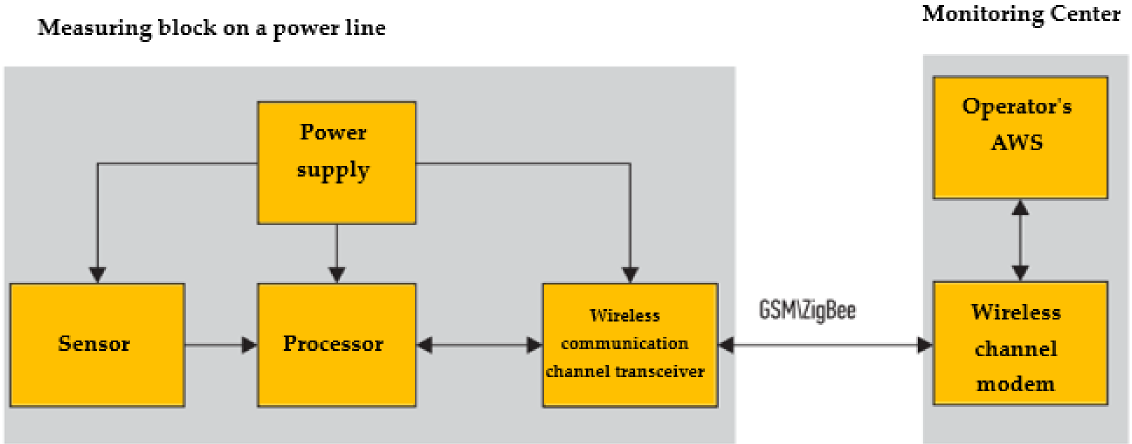

Figure 3: *Power line wire monitoring system*

Control rooms are located at the nodes of energy redistribution networks. Currently, they usually use SCADA systems that provide processing and interpretation of data received from measuring units (Fig. 4).

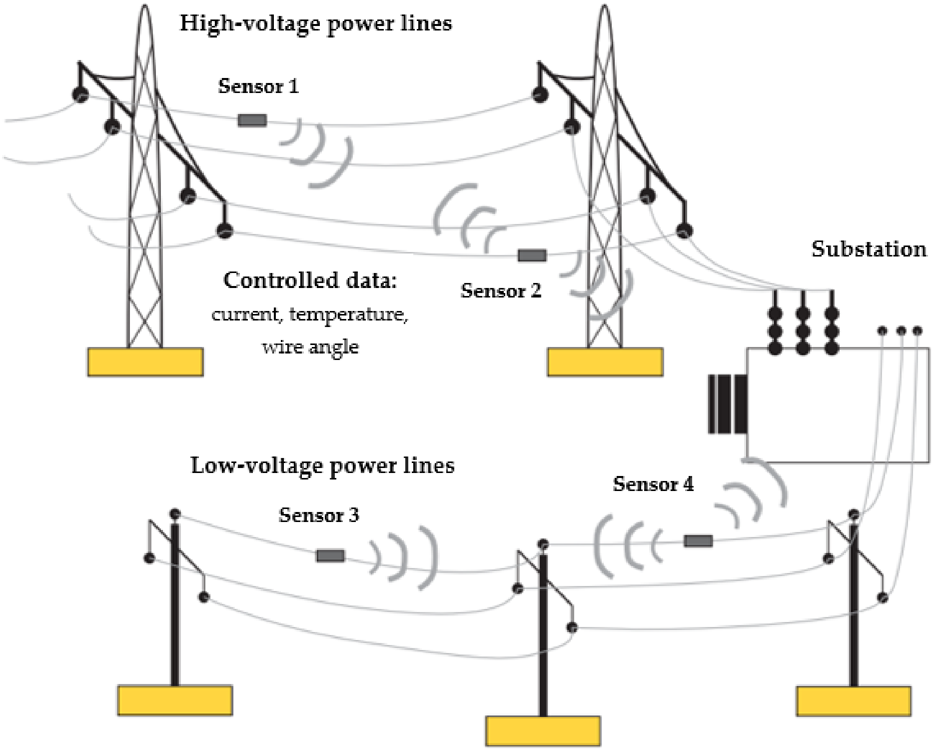

Figure 4: *Structure of the measuring unit and monitoring center*

The measuring unit includes the following basic components:
- a group of sensors for measuring the main current parameters of the wire line;
- processor module for processing measured data;
- data transmission system;
- autonomous power module.

Depending on the functional purpose, various types of sensors can be used in monitoring systems:
- for measuring current in a wire;
- temperature of the wire in the span;
- mechanical stress of the wire at suspension points (strain gauges);
- for measuring attenuation in optical fibers of ground wires or phase wires;
- to measure critical sag;
- climatic conditions (weather station);
- vibration characteristics of wires (accelerometers). Current measurement is carried out using a non-contact method, for which sensors based on the Hall effect or Rogowski coil are used.

Currently, wireless communication channels are mainly used to transmit data in overhead line monitoring systems - these are GSM or ISM radio modems operating at frequencies of 434, 868 MHz and 2.4 GHz. GSM modems have been used in the market of automated process control systems for more than ten years, including for data transmission in monitoring systems. The first models had limited capabilities for transmitting SMS messages and data in analog mode. The operation of such devices in analog modem mode provides a data transfer speed of only 9.5 kbaud, and payment is made in accordance with the time spent on the network. The GPRS system implements packet switching throughout the entire communication channel, significantly optimizing data transmission services in GSM networks. It establishes connections almost instantly, utilizes network resources, and occupies bandwidth only when data is actually being transmitted, ensuring extremely efficient use of available bandwidth. GPRS provides a multipoint transmission service (multicast) between a specific network provider and a group of mobile subscribers with GPRS terminals. GPRS requires traffic payment, which is charged only for the volume of transmitted and received information, and not for the time the modem is in the receiving/transmitting state. To transfer data from the measuring modules to the monitoring system server, a wireless network created on the basis of xBee radio modems from Digi can be used. Currently, transceivers are produced at frequencies of 868 MHz and 2.4 GHz. Transceivers provide a line-of-sight data transmission range of up to 4 km. Based on a network of ZigBee transceivers with a backbone topology, it is possible to organize relay data transmission over the network between meters to the monitoring system data server. The direction of transmission in the transmission network along power lines is always set towards the server. To increase reliability, it is possible to alternatively bypass the problematic node that blocks communication along the chain.

IV. Conclusions

In conclusion, the application of automatic monitoring and control systems (ASMU) is an important step to ensure the reliability of power transmission lines (PTLs) and improve the efficiency of energy systems in general. ASMUs provide the ability to continuously monitor the condition of equipment, automatically identify and eliminate faults, optimize the operation of power lines and analyze data to predict possible failures. These systems play a key role in ensuring a stable and safe power supply, as well as reducing the cost of maintaining and repairing power lines.

However, further development of ASMU requires efforts to improve monitoring and data analytics technologies, as well as the creation of standards and regulations to ensure compatibility and interoperability of various monitoring and management systems. In the future, the development of ASMU will be aimed at improving automation and artificial intelligence, which will improve the efficiency and reliability of energy systems, ensuring stable and uninterrupted power supply in any conditions.

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