Communication Architecture of Solar Energy Monitoring Systems for Telecommunication Objects

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***Abstract*—The sources of energy supply for telecommunication stations are territorially distributed facilities with a multi-level management hierarchy and a large number of structural units. Monitoring them is one of the pressing issues, the main challenge of which is to develop an effective communication architecture for the monitoring system. This article analyzes the communication architecture of solar power supply monitoring, based on the analysis, a new architecture is developed that differs from the communication architecture of other monitoring systems. In this communication architecture, wireless sensor networks, which are considered cost-effective and practical in the application of solar power supply sources for remote monitoring systems, are analyzed. One of the leading directions in this field as a basic wireless sensor technology for monitoring system communication architecture is the development of recommendations for the use of ZigBee technology based on the IEEE 802.15.4 standard.**

Keywords—monitoring levels, communication architecture, wired and wireless network, WSN, WiMAX, Wi-Fi, Bluetooth, ZigBee, comparison analyses.

I. Introduction

It places strict requirements on supply sources in the power supply of modern electronic devices of telecommunication facilities. The power supply sources produced in recent years consist of sensors and various control devices that monitor and control the reliable and quality power supply of telecommunication devices. Computing systems, communication devices and systems, power supply sources, which are an integral part of measuring instruments, determine their performance, resource consumption and a number of other technical and economic indicators [1].

Today, the growing demand for energy resources is leading to an expansion of the scope of research on renewable energy. In particular, work is underway to make extensive use of renewable solar energy sources in the uninterrupted power supply of telecommunications systems. In order to increase the efficiency of the energy supply, ways to apply this system in all areas are being developed. At the same time, high efficiency is achieved through the use of such resources in the field of communications [1], [2].

Currently, smart power systems are used to provide telecommunications equipment with stable and quality energy. This, in turn, leads to the solution of many problems, including remote monitoring, data transmission and receiving system, energy quality and consumption control, increasing energy demand, reliability and security [3].

Existing telecommunication facilities Remote monitoring of power supply sources is not an optimal solution for real-time monitoring of power supply sources. Existing systems have several technical limitations [4], [5]. The main reasons for this are:

- the use of fiber-optic technology in remote monitoring systems is not always advisable, as telecommunications facilities are often located in areas far from the monitoring center, in deserts, mountains, forests and plains.
- telecommunication facilities should implement a system of monitoring of energy sources in a fast, real-time data transmission, fault detection and diagnostics-oriented prevention system. This requires a secure and reliable connection to prevent serious malfunctions and interruptions.
- it is essential to store the monitored parameters on a local monitoring center server (database). The collection of this data allows the study and prediction of faults and their duration.

Due to this, the creation of a new communication architecture and the design of the network in the remote monitoring of power supply sources are the solution to the identified problems.

II. Data Transmission Networks of Remote Monitoring Systems

Special attention should be paid to the communication infrastructure in the system of remote monitoring of telecommunication facilities power supply sources, because the communication network is as important as the electrical infrastructure itself, and faults in the communication network cause a very high percentage of major faults in the power system [1], [3], [6]. There are three levels for a solar panel remote monitoring system: Station Level, Network Level, and Application Level (Fig. 1).

Station Level: Solar panels communicate directly with other solar panels to increase electricity generation, use, and service life, and share the information obtained.

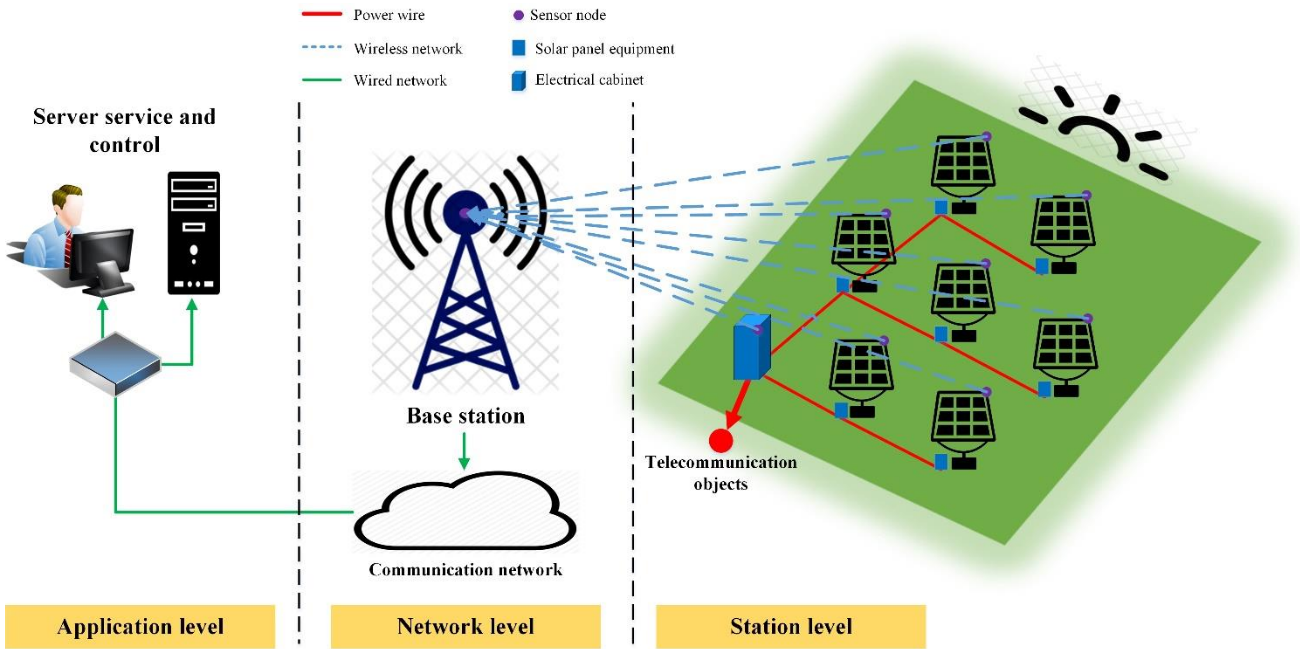

Fig. 1. Remote monitoring system levels of Solar Power Station.

Network Level: Supports reliable communication between the solar station and the main network. This level must be reliable, large-scale, and fast, and satisfy a wide range of service quality (QoS) for a variety of applications.

Application level: Assists monitoring center operators to perform basic functions of monitoring, analysis and control.

Typically, the communication infrastructure of a solar panel remote monitoring system is a switching-based architecture, each solar panel is equipped with an Ethernet switch, and optical fiber or Ethernet cables are used to connect between the solar panels. Disadvantages of conventional solar station architecture include [7], [8]:

- Low reliability, failure of the solar panel switch can prevent the remaining panels from being connected to the monitoring center;

- High cost, the cost of switches is very expensive, and an independent network of switches and communication lines incurs additional costs;

- Difficulty in providing real-time monitoring and control when all solar panels share traffic over a single physical line.

To solve the above-mentioned problems, it is necessary to take into account the advantages of the latest technologies and services for existing power systems in order to make power grids more efficient, reliable, scalable, scalable and secure. It is also important to take into account the latest advances in communication technologies and protocols that have not been previously considered when designing a new communication architecture for next-generation solar stations.

The design of the remote monitoring system and communication infrastructure should be designed to provide the highest level of access to the monitoring system and appropriate control and protection devices, taking into account the overall durability of the system. The main requirements of the design are:

- Environmental problems: solar energy sources are exposed to extreme environmental conditions, including high pollution, salt, humidity and sudden changes in temperature. Devices must be specially designed to be resistant to corrosion and high humidity.

- Backup: The communication network of the solar power supply monitoring system must always maintain reliable operation in the event of a breakdown at some point. All important network devices, such as switches or routers, must be backed up.

- Self-recovery: The solar power supply monitoring system should be able to quickly recover itself in the event of a network outage.

IEC 61724-1: 2017 does not set any specific communication network requirements for the energy source monitoring system [9]. Solar panel monitoring system should take into account important communication characteristics such as security and QoS when designing a communication network. QoS solar panel monitoring system is one of the important parameters of communication network evaluation. It determines network properties (e.g. bandwidth, standby time, packet loss, etc.). Table 1 shows the communication time requirements for different types of message monitoring systems based on IEC 61850 [10] [11].

Table 1. Requirements for communication time for various messages based on IEC61850

Message type	**Application**	**Latency request (ms)**
1 type	Instant message	3-100
2 type	Average speed	100
3 type	Low speed	500

4 type	Unprocessed data	3-10
5 type	Large file transfer	1000

Two different wired and wireless communication technologies can be used in the local communication of solar panel data, as well as in the connection between solar panels and monitoring centers. To ensure real-time data transmission in the system, as well as to meet the requirements of industrial applications, it is very important to select the best communication network protocols within the solar panel (Table 2) [12], [13], [14], [15].

Table 2. Communication network technologies for monitoring of solar panels

Technology	**Standard / protocol**	**Data transfer rate**	**Coverage area**
Fiber optical	PON WDM SONET/SDH	155 Mbit/s-2.5 Gbit/s 40 Gbit/s 10 Gbit/s	Up to 60 km Up to 100 km Up to 100 km
ZigBee	ZigBee ZigBee Pro	250 Kbit/s 250 Kbit/s	Up to 100 m Up to 1600 m
WLAN	802.11x	2-600 Мбит/с	Up to 100 m
WiMAX	802.16	75 Мбит/с	Up to 50 km
Cellular	GSM GPRS 3G 4G 5G	Up to 14.4 kbit/s Up to 14.4 kbit/s 384 kbit/s -2 Mbit/s Up to 100 Mbit/s Up to 2 Gbit/s	1-10 km

An important task of monitoring systems is to remotely identify and eliminate problems in controlled systems, the purpose of which is to monitor the efficiency of the system and to develop solutions based on the information collected. Typically, this system consists of 3 main components: (1) the main control panel of the system, (2) monitoring and automatic detection of access (using current and voltage, temperature, illumination and other similar sensors) from reference points for the monitored object, and based on them (3) activation of output components (management, database formation, transmission of monitoring data over the Internet) [16].

Signal communication between the above components and devices of the monitoring system is carried out mainly in two ways: by means of wired (wired) or radio signals (wireless). Wired communication is available in two ways, addressable (in packet networks) and conventional wired (in traditional telephone networks) [8], [17]. Located systems provide the exact location of the monitored device on the monitored object (sensor for transmitting data between nodes and from them to other network devices). This system also used an unaddressed wired network (signal transmission from sensors to nodes). In a monitoring system, wireless communication has both targeted and unaddressed signal transmission methods [18], [19].

A comparison of wireless and wired networks is made based on the following key characteristics [12], [16]:

1) Installation - In wired networks, installation is very difficult because the device must be connected to a conductor within a wired network, and no additional components such as a conductor are required in a wireless network. Creating a wired network takes more time than a wireless network.

2) Mobility - The advantage of a wireless network is reflected in the mobility of the devices connected to it. A wired network provides limited mobility only because of a fixed access point, while a wireless network provides a mobile connection and there is no restriction on movement.

3) Node view on the network - All nodes in a wired network are visible to node devices, there are some hidden nodes in wireless networks.

4) Speed and bandwidth - The speed of wired devices is higher than wireless devices. The speed of wired devices can be up to a few 10 Gbit/s, and wireless devices up to 100 Mbit/s.

5) Security - The security of a wired network is better than a wireless network. It can easily affect the security of a wireless network because the process of transmitting the signals takes place over the air.

6) Reliability - The reliability of a wired network is better because if a router in a wireless connection fails, it affects the entire network.

7) Cost - The cost of a wireless network is less for a large area, and wireless network systems are easier to service than wired network systems.

Given the capabilities of this wireless and wired network, building a station-level network of the monitoring system based on wireless network technology will be highly efficient. This underscores the importance of introducing a solar power supply monitoring system at telecommunications facilities.

III. MONITORING SYSTEMS WSN-BASED SOLUTIONS OF DATA TRANSMISSION NETWORKS

In this section, the technologies studied above are compared and the most optimal option for the solar power station monitoring system is selected.

A. WiMAX technology

The WiMAX (IEEE 802.16) standard, like the GSM standard, provides long distance, high throughput in data transmission [20], [21], [22]. But today the demand for it has almost disappeared due to its high cost of installation and maintenance, as well as the availability of standards such as its replacement GSM. Therefore, the use of this technology in WSNs of monitoring systems is not advisable.

B. Bluetooth technology

Bluetooth (IEEE 802.15.1) technology requires the coordination of switches to establish a connection between two devices (end and input devices) over a very short distance. Coordinating switches is a complex process, especially when the connection process is time-consuming when a request is sent to the access device by many end nodes at the same time. The slow connection of Bluetooth for 5 seconds makes it difficult to determine the location of limited nodes [8]. For wireless sensor networks, the Bluetooth standard was initially rated as a compatible technology, but it was soon discovered that it had a very complex connection and an expensive price. Later, a new type of Bluetooth technology was developed that solves some problems such as data transfer speed, range and power consumption. However, this also failed to address issues such as data transmission distance and network capacity. In addition, Bluetooth has limited node capacity. It has only point-to-point (single transmitter, single receiver) and Broadcast (single transmitter, multiple receiver) network topologies [23].

C. Wi-Fi technology

The Wi-Fi (IEEE 802.11) standard was originally developed as a technology to replace Ethernet technology when connecting to the Internet or creating wireless local area networks. Long-distance data transmission is not a problem due to the presence of routing feature in Wi-Fi technology, but the problem of power efficiency in it still limits the use of all its capabilities. The latest technologies in this standard are aimed at limiting the inefficient use of power supply in the transmission of analog and digital signals. Wi-Fi technology is suitable for continuous monitoring and high-speed data transmission, which allows them to fully increase their high throughput. Although experts say that Wi-Fi standards for WSNs can provide more bandwidth than conventional WSNs, they are considered to have an extremely complex structure and relatively high energy consumption.

D. ZigBee technology

Finally, the ZigBee (IEEE 802.15.4) standard is a two-channel radio technology that is mainly suitable for automatic control and remote control based on wireless communication [24]. It is a low-cost wireless networking device capable of transmitting at low speeds over relatively short distances, and its small size or lack of infrastructure allows it to be used in WSNs with small size, energy saving, and low-cost solutions. It automatically adapts to the network on which it is installed and is easier to use than other devices [25].

The following table (table 3), compiled using the above analysis and the specifications of wireless network technologies, illustrates the capabilities of these technologies in more detail. The table shows the main technical characteristics of each wireless network technology used in WSNs.

Table 3. Wireless Network Technology Comparison Table

Name / Characteristics	**WiMAX**	**Wi-Fi (802.11)**	**Bluetooth (802.15.1)**	**ZigBee (802.15.4)**
According to the purpose of use	comprehensive voice and data transmission	build a wireless local area network	conductor replacement	monitoring and control
System resource	16MB	1MB	16KB	4-32KB
Energy consumption	High	High	Overage	Low
Throughput	10-100Mb/s	Up to 54Mb/s	720Kb/s	250Kb/s
Transmission distance (m)	40 000	50-100	1-10	≥100
Number of nodes by network size	1	32	2	unlimited
Advantage	existing infrastructure, high communication quality	high speed, flexibility	easy to use, low cost	reliable, low cost, low power consumption

As can be seen from this table, three Wi-Fi, Bluetooth and ZigBee technologies have the highest performance in the organization of local monitoring systems. But it can be seen that the application of ZigBee technology at the station level of the proposed three-tier communication architecture is an effective solution.

IV. Conclusion

The main purpose of the solar power supply monitoring system of telecommunication facilities is to control the parameters for the sources installed at each facility using appropriate sensors, digitize the signals of the monitored parameters and transmit them serially to the monitoring center server via telecommunication channels (radio channel, wired channel). One of the main problems in the design of the monitoring system is the creation of a communication architecture at the level of the solar power plant and the organization of the data transmission network. The main challenges are the development of a communication architecture that provides quality and reliable communication between sensor nodes, as well as the analysis and selection of wireless network technologies for monitoring. The article analyzes wireless network technologies and selects them based on criteria such as network bandwidth, power consumption, number of nodes and its dependence on other parameters, data transmission distance between nodes, network size. As a result of the analysis, it was determined that the ZigBee (802.15.4) standard for the station-level communication architecture of the monitoring system we proposed was the most effective according to the required criteria.

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