Monitoring of Parameters of Power Plants Based on Renewable Energy Sources

A. A. Berestinov(✉), D. V. Korobatov, and A. Z. Kulganatov

South Ural State University (National Research University), 76, Lenin Ave, Chelyabinsk 454080, Russia
berestinov.ru@mail.ru

Abstract. In recent decades, due to the depletion of minerals, renewable energy sources are gaining more and more popularity. In some countries, energy production from renewable sources already reaches more than 50% of total energy production. Monitoring the state of operation of renewable energy equipment is a critical task. Monitoring the parameters of power plants with renewable energy sources is an integral part of the entire operation of a power plant. This is an accounting of generated, consumed or lost electricity. And also, it is monitoring the technical condition of renewable energy equipment. In the article, the authors have developed a prototype device for monitoring the parameters of power plants with renewable energy sources. The block diagram of the device operation has been developed. A user interface has been developed where the energy indicators of a power plant with renewable energy sources will be displayed. The economic feasibility of a device for monitoring the parameters of power plants with renewable energy sources is considered. The principle of operation of the MQTT data transfer protocol is considered, the main advantages of the data transfer protocol, as well as the main disadvantages, are noted.

Keywords: MQTT · Renewable energy · ESP32 · HMI · IoT · Monitoring

1 Introduction

The operating and maintenance costs of the wind farms, as well as spare parts, are estimated at 10–15% of the wind farm's total revenue. Repairs and maintenance requiring the use of cranes result in additional costs due to the lack of cranes and the need for optimal weather conditions to operate. Maintenance optimization can be realized through condition monitoring and early fault diagnosis. 40% of induction generator failures are associated with bearings, 38% with the stator and 10% with the rotor [1]. Condition monitoring technologies such as vibration and surge analysis can detect some of these problems. There is growing interest in using generator current and power signals to detect generator faults.

The generator can meet the electricity needs of the modern era, and the types and characteristics of generators differ depending on its use, location and economy. Moreover, the role of the engine is inevitable in the real operations of any industry. In addition, it is

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an integral part of processes such as power generation, oil and gas production, cement production, food processing and the fertilizer sector. Its use varies by industry, with motor ratings ranging from a few watts to megawatts depending on the nature of the job. In large industries, heavy duty generators and motors must operate at high loads [2]. Therefore, to manage the non-stop operation of engines and generators, we need reliable monitoring systems. Due to the continuous use of motors and generators, wear on parts is common and needs to be addressed. Predicting and preventing massive equipment failures is a vital need in today's industry. The question now arises: how can we track or anticipate malfunctions? The first basic rule is to take a proactive approach to maintenance. Preventive maintenance includes physical examination and periodic maintenance to identify any damaged or defective parts. Accordingly, non-compliant parts will be replaced before serious damage occurs. This is a little risky because periodic maintenance is scheduled according to the specified times, but over time the condition of the generator and engine continues to deteriorate.

Condition monitoring is progress in learning about the health, safety and performance of generators and engines where reliable, continuous and efficient operation is required. There are two types of monitoring systems: the first is offline monitoring, and the second is online monitoring [3]. In this monitoring method, various parameters are measured, transmitted and monitored at a control station where the operator is aware of the operating conditions of the generator and engine.

With the advancement of technology, smart systems are increasingly being used. These systems enable technicians, administrators and managers to monitor and control device performance from a safe distance. The monitoring system is very important when working with three-phase systems; some users and companies use smart monitoring software. These programs are installed on the user's smartphone or company computers so that employers can make decisions in the event of an error.

Thus, we are considering and offering promising solutions to some difficult issues for the renewable energy sector, namely monitoring of energy indicators and parameters.

2 Block Diagram

The Internet of Things refers to any object (or "thing") that can be connected to the network - from factory equipment and cars to mobile devices and smart watches. However, today the Internet of Things is usually understood as connected objects equipped with sensors, software and other technologies that allow them to exchange data with other "things". Traditionally, the connection was mainly via Wi-Fi, but today 5G and other types of network platforms are increasingly coping with large data sets, providing high speed and reliability [4].

In IoT and IIoT, sensors are used to collect information from different devices: smart bracelets, machine tools, cars. They can measure different physical parameters: from air temperature to the level of infrared radiation. To do this, sensors are equipped with sensitive elements, for example, photosensitive diodes or metal plates that change properties depending on the environment.

To transmit information to a regular server or cloud, where it will be processed and used further, the sensors are equipped with a transmitting module. In IoT, it is usually a wireless communication module, for example: Bluetooth, NFC, RF or Wi-Fi. Sometimes several sensors are connected to one transmitting module. Any sensors collect analog data. Such data is continuous it can be represented as a winding line, a continuous flow of information. It is not possible to transmit such data via cable or wireless communication first the signal must be converted into digital data. Digital data is a sequence of zeros and ones. To convert analog data to digital, a continuous analog line must be divided into several separate sections, and each section must be assigned a specific value.

Analog data can also be transmitted, for example, by radio. But computers only work with digital data, so they still have to be converted to digital. And it is better to do this before transmission in order to use more modern and faster communication channels. Simple analog sensors do not know how to convert a signal. To get information from them in digital form, we need a scale where digital values correspond to analog values.

2.1 Description of the Block Diagram

The developed block diagram of the device is shown in Fig. 1. The explanation is given below.

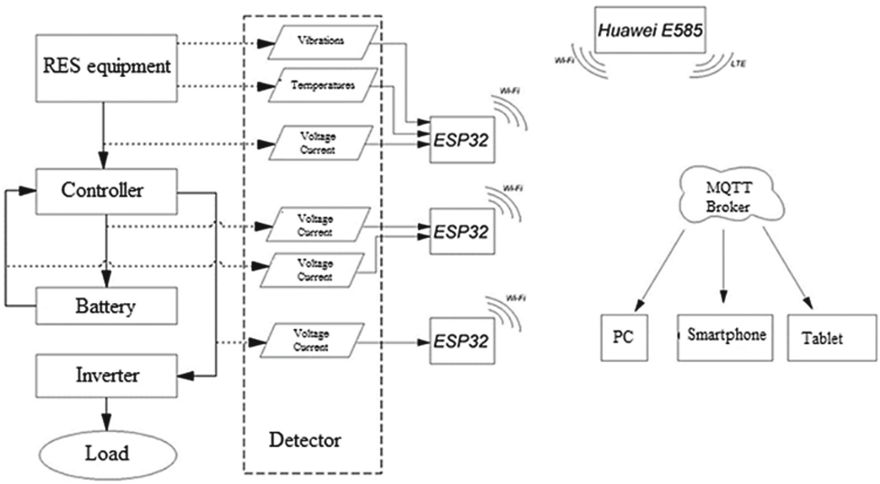


Fig. 1. Block diagram

"Renewable energy equipment" refers to wind turbines, solar panels, etc. The controller, battery and inverter are traditionally used equipment. We will measure voltage and current at each section. Then the received values from the sensors will be converted into a digital signal and sent to the MQTT Broker. A mini WiFi router was also providedin the absence of a stationary WiFi router next to the microcontrollers.

This block diagram shows sensors for monitoring parameters such as vibration, temperature of the RES installation itself, as well as voltage and current sensors in individual sections. Modernization and improvement of this scheme is possible due to the flexibility and mobility of sensors. For specific conditions of use of the monitoring device, it is possible to determine the optimal parameters of the device relative to renewable energy equipment. Today, the microelectronics market offers a large number of sensor options for various purposes.

In this chapter, a block diagram of the operation of a device for monitoring the parameters of renewable energy equipment was developed. Various modes of operation of the device are taken into account both with a fixed WiFi router and equipped with a mini WiFirouter.

3 Advantages of ESP32

ESP 32 is a device that is perfectly used in IoT technologies today, the company Expression Systems is engaged in production, the popularity of the microcontroller is growing due to its low cost, wide availability spector and a wide range of features. The core of the microcontroller system is a dual-core Extensa LX6 microprocessor with a frequency of 240 MHz, which provides significantly low energy consumption. The microcontroller is equipped with 520 kbytes of static random access memory and 448 kbytes of programmable permanent storage device. The board is equipped with both a Wi-Fi module and a Bluetooth module to meet a rich range of Internet of Things use cases [5].

To date, the Internet of Things (IoT), Internet of Energy (IoE) is formed from highly intelligent monitoring and management of electricity consumption in order to identify and optimize energy consumption by monitoring the consumption profile of users using sensor data, which allows the process to be more efficient and economical. And also, IoE is applicable to energy production technologies and, therefore, has various capabilities for the development and application of solutions for energy processes for the production of renewable energy sources (RES), it should also be noted that meteorological fluctuations affect sensors and microcontroller, but not significantly, which can become the basis for the sustainability of optimized electricity production/consumption [6].

The technical characteristics of the microcontroller are summarized in Table 1.

Table 1. Technical ESP32.

Parameter	Value
Processor	Xtensa 32 LX6
Number of cores	2
Processor frequency	160–240 MHz
RAM	520 Kb
ROM	448 Kb
Type of network	WiFi 802.11n
	Bluetooth
Programming language	Lua

(*continued*)

Table 1. (*continued*)

Parameter	Value
	Arduino IDE
Operating temperature	-40 … + 80
Flash memory capacity	4–16 Mb
Food (direct current)	2,2–3,6 V
Average current consumption	80 mA
Dimensions	18x19,2x3,2 mm

Foreign colleagues use the ESP 32 microcontroller in healthcare for remote monitoring of an electrocardiogram with the ability to determine the probability of a normal heart rate, abnormal heart rate and noise.

4 Equipment for Measuring Voltage and Current

Electricity is an extremely important thing in a person's life. Due to the increase in energy consumption, currently reducing energy consumption is an important task in this area. As a result, knowing the state of electrical energy consumption is the first thing to do to solve this problem. When we learn the electrical information of each device, it will help us to know about the consumption of electrical energy at a certain point in time. As a result, you can save up to 20% of energy. In order for this to happen, the first step is to select equipment that can correctly measure energy consumption. One of the most important things in this device is the current sensor, which is used to measure the current flowing through a certain phase.

A current sensor is an equipment that can measure the amount of current flowing and send an output signal in the form of a voltage level to any microcontroller for reverse calculation of the measured current value. To select a current sensor, you need to take into account many criteria, such as budget, measurement accuracy, installation complexity, etc. Today, inexpensive current sensors are on the market, which are very popular in many areas. And also, it is necessary to know the information and characteristics of modern inexpensive current sensors.

4.1 Power Meter Module PZEM-004T

The PZEM-004T module is widely used for monitoring current and voltage consumption. The PZEM-004T outputs the RMS value of voltage and current, and also calculates the active power and total energy consumption over time or total energy consumption. The PAM-004T module is equipped with a current transformer, which is used to convert the effect of the detected magnetic field on the electrical load system into an electrical signal that will be processed by the PZEM-004T module [7, 8].

The cost of this power meter module is 500–600 rubles. The technical characteristics of the PZEM-004T module are summarized in Table 2.

Table 2. Technical characteristics of the SCT 013 current sensor.

Parameter	Value
Operating voltage: - variable	80–260 V
Nominal current	0–100 A
Operating temperature	−25 to +70 °C
Mass	80 g

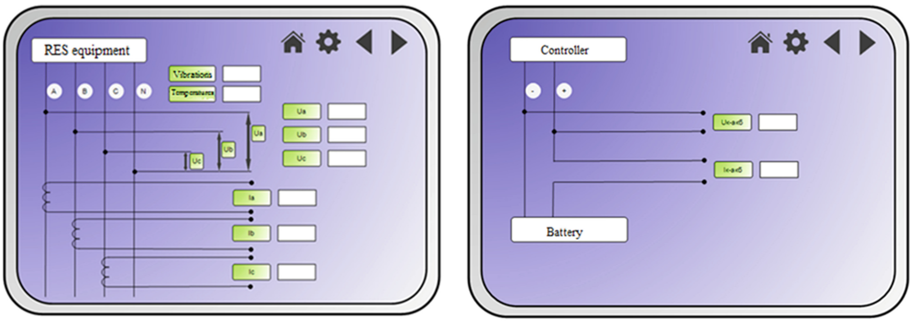
5 Visualization

To date, the development of new technologies, namely software and hardware devices of data collection and monitoring systems are constantly being upgraded. Data collection and monitoring systems have demonstrated trends in data exchange, configuration, unified interfaces and multifunctional auxiliary application software.

Currently, production processes are visualized and controlled using special components of the human-machine interface (HMI) [9]. These devices are usually located in fixed locations on the production floor. This creates significant limitations in terms of portability and extensibility [10]. Smartphones (tablets) represent an interesting additional HMI solution. Smartphones are a universal solution that enables engineers to access energy and technological data occurring in various processes of the devices (for example, sensor values) from anywhere in the field. And also, the software on smartphones can be easily expanded to provide additional functions, such as access to company services, Internet resources or interaction with Internet of Things devices installed in an industrial network [11].

5.1 Interface

Figure 2 show screenshots of the visualization. Extensive visualization is developed for specific renewable energy equipment.



a) b)

Fig. 2. (a) Interface 1, (b)Interface 2.

In this section, a user interface has been developed for monitoring parameters in the renewable energy sector. The interface can be adjusted and adjusted according to the user's(operator's) wishes, can be supplemented with various schedules, etc. [12].

6 Data Transfer Protocol

For Internet of Things (IoT) devices, an Internet connection is a kind of requirement. An Internet connection allows devices to work with each other and with server services. The main network protocol of the Internet is TCP/IP. Built on top of the TCP/IP stack, MQTT (Message Queue Telemetry Transmission) has become the standard for IoT communication. MQTT can also run on SSL/TLS, which is a secure protocol built on TCP/IP to ensure that all data between devices is encrypted and protected [13]. MQTT (Message Queuing Telemetry Transport) a protocol for transmitting a sequence of messages with telemetry data, that is, information from temperature, humidity, light sensors, etc. The protocol that uses the publish/subscribe communication pattern is used for machine-to-machine communication (M2M). MQTT was proposed in 1999. Andy Standford-Clark as a protocol that would serve to transmit data on the state of the oil and gas pipeline in real time. The development was carried out by IBM for a new pipeline of the largest American oil company ConocoPhillips. As part of the creation of a dispatching control and data collection system (SCADA), it was necessary to ensure the guaranteed collection of a variety of information: the condition of pumps, bearing temperature, flow rate, valve condition, tank levels, etc. [14].

6.1 How Does MQTT Work?

The communication system built on MQTT consists of a publisher server, a broker server and one or more clients. The publisher does not require any settings for the number or location of subscribers receiving messages. In addition, subscribers do not need to configure for a specific publisher. There may be several brokers in the system distributing messages. MQTT provides a way to create a hierarchy of communication channels a kind of branch with leaves. Whenever the publisher has new data to distribute to customers, the message is accompanied by a delivery control note. Higher-level clients can receive each message, while lower-level clients can receive messages related to only one or two basic channels "branching off" at the bottom of the hierarchy. This facilitates the exchange of information ranging in size from two bytes to 256 megabytes [15]. Any data published or received by the MQTT broker will be encoded in binary format, since MQTT is a binary protocol. This means that to get the original content, you need to interpret the message. MQTT brokers can sometimes accumulate messages related to channels that do not have current subscribers. In this case, the messages will either be discarded or saved, depending on the instructions in the control message. This is useful in cases where new subscribers may need the most recently recorded data point, instead of waiting for the next dispatch. It is noteworthy that MQTT transmits security credentials in plain text, otherwise authentication or security features are not supported. This is where the SSL framework comes into play, helping to protect the transmitted information from interception or other forgery. In addition, in MQTT, you can use Ably authentication on tokens if you do not want to disclose your API key to the actual MQTT client at all (in the case of MQTT without SSL, tokens are required to prevent the transfer of API keys in plain text) [16, 17].

7 Conclusion

A block diagram of the operation of a device for monitoring the parameters of power plants with renewable energy sources has been developed. A user interface has been developed for displaying information on various devices, for example, on a smartphone, tablet, laptop or personal computer. The principle of operation of the MQTT data transfer protocol is considered, the main advantages of the data transfer protocol, as well as the main disadvantages, are noted. Based on the results of the work done, we can say that monitoring the parameters of power plants with renewable energy sources is an integral part of the entire process of the power plant operation. This is an accounting of generated, consumed or lost electricity. And also, it is monitoring the technical condition of renewable energy equipment.

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