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# MICROCONTROLLER-BASED REMOTE MONITORING OF OVERHEAD POWER LINES

**KHAYRULLAEV ALISHER**

PhD student of Tashkent University of Information Technologies named after Muhammad al-Khwarazmi

**Abctract:**

**Objective.** Due to the technical failure of the line, illegal connections, temperature rise in the cable occurring in the section between the electricity distribution point and the consumer meter of the overhead power lines, a number of difficulties arise in monitoring the energy consumption in the line. There are a number of ways to solve these problems, among which remote monitoring using modern IoT wireless sensors and microcontroller control devices gives effective results. Because this method is the basis of the SG (smart grid), which is widely used in the future. The main goal of this article is to design a monitoring device used in remote monitoring of the condition of low-voltage overhead power lines, classify the structure and characteristics of the sensors used in it, and do a comparative analysis of the modules used in the construction of the data transmission network.

**Methods.** It is not possible to adequately monitor the condition of 0.4-6 kV transmission lines using ASCAE (automated system for control and accounting electricity). These methods can calculate the amount of energy coming out of the distribution transformer and the amount of power passed through the consumer meter. Therefore, this paper proposed a remote monitoring method based on microcontroller control for real-time monitoring of the status of low-voltage overhead power lines.

**Results.** As a result of the research, a remote monitoring device was designed, capable of transmitting the results obtained from voltage, current and temperature sensors in real time from two wireless transmission modules. This device transmits data to the concentrator using ZigBee, and it transmits data to the monitoring center through the GSM module. In addition, the microcontroller control unit in the device takes into account the geographic location of the object and the synchronized time.

**Conclusion.** The system, which is organized using a remote monitoring device, prevents technical failures that may occur in low-voltage overhead power transmission lines, the current parameters of the line (voltage, current, cable temperature, wind speed, phase) and unexpected to the line (the unregistered-illegal connection) provides opportunities to send real-time information about downloads.

**Keywords:** energy, wireless sensors, voltage, current, temperature, ZigBee, ESP32, IoT, smart grid, power, monitoring system.

**Introduction.** Application of modern methods of corporate management, advanced information and communication technologies and automated systems of management, accounting and control into the energy sector, on this basis, increase management efficiency and reduce production costs plays an important role in ensuring the transparency of energy sector organizations and financial activities. Especially in recent times, special attention has been paid to studies aimed at regular monitoring of the condition (freezing of the cable, disconnection, temperature rise, erosion of elements in the line and failure due to external influences) of overhead power transmission lines for transmitting electricity over long distances without losses [1].

Monitoring of energy losses is very important for energy distribution and energy supply companies to achieve economic efficiency. Because the grid length of low-voltage (0.4-6kV) overhead power lines is much larger than other power lines. In addition, the impossibility of real-time remote monitoring of this network (between the distribution station and the consumer meter) requires scientific and practical research in this area. The concept of smart grid (SG) plays a key role in this. The essence of SG is real-time monitoring of the entire energy network with the help of modern IT technologies based on centralized management. The main constituent elements of SG are: internet of things (IoT), sensors, radio modules, web applications and microcontroller control devices [2, 3]. In this article, as an element of the SG concept, a device for remote monitoring of the condition of low-voltage overhead power lines, its structural structure, characteristics and communication tools was given detailed information [4].

The following tasks were defined for remote monitoring of the condition of overhead power lines:

–*sensor selection:* suitable sensors are selected (taking into account the location and availability of the power grid) to measure the monitored parameters, such as voltage, current, power factor and frequency;

–*communication network analysis:* communication network that can transmit data from sensors to the monitoring center is selected for analysis. This can be done using wired or wireless networks, depending on the location and accessibility of the power grid;

–*data analysis:* data analysis tools are used to analyze data collected from sensors and detect any unexpected situation or problems in the power grid;

–*detection of errors and illegal connections:* algorithms are developed to detect situations such as short circuits, overloads and faults in the neutral. This can be done using a combination of sensor data and machine learning algorithms;

–*alerting and reporting:* a system will be implemented to alert and report any problems detected by the monitoring device. This includes sending alerts to maintenance staff or generating reports for management;

**Methods.** Electricity is mainly produced in large power plants that are connected to a single energy system and work together. And the centers of electricity consumers (industrial enterprises, cities, rural settlements, agro-industrial complexes and other consumers) are located at a distance of hundreds or thousands of kilometers from sources of electricity. The following figure shows the elements of the power transmission and distribution system (Figure 1).

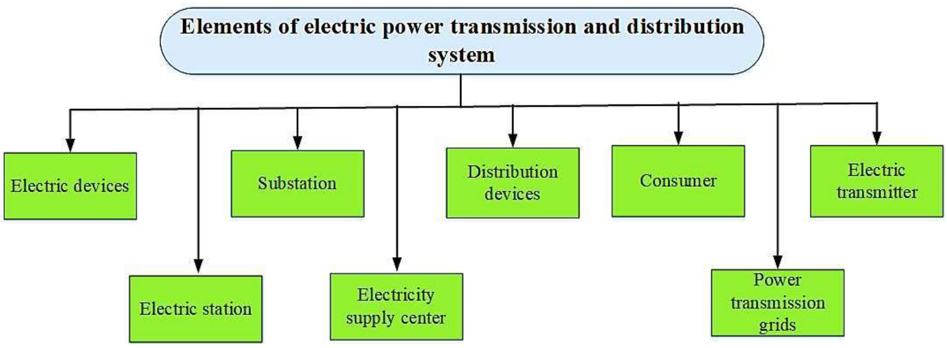



**Figure 1. General elements of the electric power transmission and distribution system**

In total, there are more than 240,000 km of power transmission lines in our republic, of which:

- 500 kV networks - more than 2000 km
- 220 kV networks - more than 5300 km
- 110 kV networks - more than 5600 km
- 35 kV networks - more than 12100 km
- 6-10 kV networks - more than 97100 km;
- 0.4 kV networks - 112370 km [4, 5].

The main cases observed recently in Overhead Power Lines (OPL) are: technical failure and illegal connections to the line. In some cases, the network is shut down by the monitoring center during line maintenance and necessary measures are taken. In this case, the level of energy loss does not exceed the permissible amount. However, in some cases, it is possible to observe energy loss in the line due to several factors, for example, illegal use of energy. Illegal use of electricity is considered to have occurred in the following cases: when it is carried out without a consumption contract, when the metering equipment is bypassed, or when the meter is changed to change the indicators; the main goal is to save money [6].

**Results.** A remote monitoring device and model were developed to overcome the mentioned situations (Fig. 2). This model consists of three parts, each part performs separate functional tasks [7].

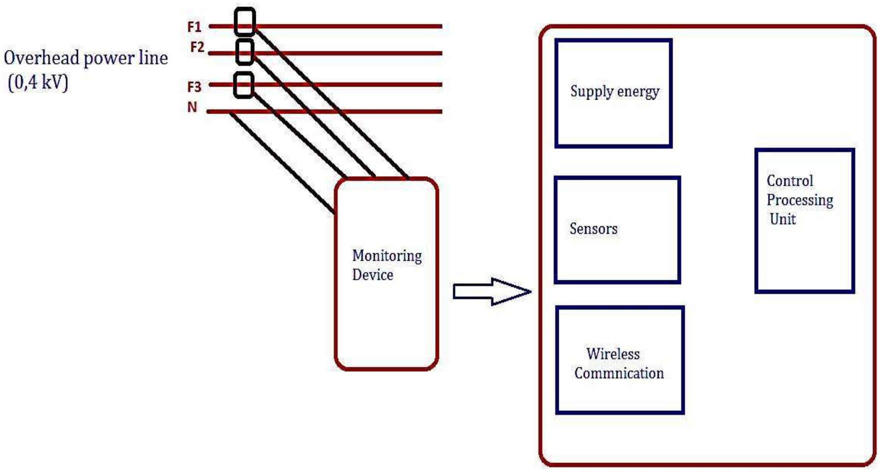



**Figure 2. Remote monitoring system model**

According to this model, each phase of 0.4 kV lines is connected by a monitoring device. Sensors measuring voltage, current, temperature and frequency in the monitoring device calculate the current state of the phases. The received information about the condition through the control unit of the model is sent to the monitoring center using a radio module. In the selection of the used sensors, special attention was paid to the condition of the line, its characteristics, and the reliability indicators of the sensors [8].

There are many supports in the low voltage overhead power grid. In the proposed model, it is assumed that each electric support will be equipped with a monitoring device. Such a monitoring device is equipped with built-in sensors and a microcontroller to monitor the condition of the power line, analyze the power quality, and control the use of electricity.

*ESP* (Espressif Systems*)* *32 SIM7000G module.* In order to further develop IoT and expand its field of application, robust, low-cost and low-power solutions for IoT devices are required. Another requirement for an IoT device is to have a small form-factor; the smaller the size and weight of the device, the wider its field of application [9].

Every IoT device is made up of a microcontroller (μC) and a wireless transferring module (typically WiFi), or a combination of both. Many various kinds of modules and μC are already accessible through the market and are widely used in the construction and creation of IoT devices.

These include Xbee, WhizFi, and various Arduino boards. However, the majority of current devices are either too expensive or too large in terms of weight and dimensions. Furthermore, a very small number of modules are open-source devices with no performance constraints. Espressif Systems released the ESP32 QFN48 chip in September of 2016, replacing the older ESP8266 μC.

The ESP32 is a sophisticated microcontroller with Wi-Fi and Bluetooth® that has been constructed to be the best choice for IoT devices [10]. This module is the primary control module of the proposed monitoring device, and it is utilized for protecting the device's connection with the sensors, and it also serves to receive and monitor data from the sensors. The ESP32 is a low-cost, low-power system-on-chip microcontroller series with a highly integrated structure powered by a dual-core Tensilica Xtensa LX6 microprocessor. This module also includes LTE (4G), GPS and GPRS elements. With this module, it is possible to receive SMS service, location and time using GPS, Internet connection using SIM card data plan (a data plan refers to a data quota in a telecommunications or data hosting contract) [11, 12].

Table 1.

**Classification of microcontrollers for designing IoT devices [13]**

| Chip (module) | ESP32 (ESP–WROOM-32) | ESP8266 (ESP8266-12E) | CC32 (CC3220MODSF) | Xbee (XB2B-WFPS-001) |
|---|---|---|---|---|
| Details | | | | |
| CPU | Tensilica Xtensa LX6 32 bit Dual-Core at 160/240 MHz | Tensilica LX106 32 bit at 80 MHz (up to 160 MHz) | ARM Cortex-M4 at 80 MHz | N/A |
| SRAM | 520 KB | 36 KB available | 256 KB | N/A |
| FLASH | 2MB (max. 64MB) | 4MB (max. 16MB) | 1MB (max. 32MB) | N/A |
| Voltage | 2.2V to 3.6V | 3.0V to 3.6V | 2.3V to 3.6V | 3.14V to 3.46V |
| Operating | Current 80 mA average | 80 mA average | N/A | N/A |
| Programmable | Free (C, C++, Lua, etc.) | Free (C, C++, Lua, etc.) | C (SimpleLink SDK) | AT and API commands |
| Open source | Yes | No | No | No |
| Connectivity | | | | |
| Wi-Fi | 802.11 b/g/n | 802.11 b/g/n | 802.11 b/g/n | 802.11 b/g/n |
| Bluetooth® | 4.2 BR/EDR + BLE | - | - | - |

| | | | | |
|---|---|---|---|---|
| UART | 3 | 2 | 2 | 1 |
| I/O: | | | | |
| GPIO | 32 | 17 | 21 | 10 |
| SPI | 4 | 2 | 1 | 1 |
| I2C | 2 | 1 | 1 | - |
| PWM | 8 | - | 6 | - |
| ADC | 18 (12-bit) | 1 (10-bit) | 4 (12-bit) | 4 (12-bit) |
| DAC | 2 (8-bit) | - | - | - |
| Size | 25.5 x 18.0 x 2.8 mm | 24.0 x 16.0 x 3.0 mm | 20.5 x 17.5 x 2.5 mm | 24.0 x 22.0 x 3.0 mm |
| Price | 114,529 sum | 71,542 sum | 228,936 sum | 329,183sum |

The table below contains information about the four modules and C used to create IoT devices. Actually, there is a wide range of elements and microcontrollers for IoT, but the majority of them have issues with size, performance, and cost. In comparison to other microcontrollers, the ESP32 QFN48 is an extremely small element, measuring only 5x5mm. For more sophisticated tasks, the ESP32 is a better choice [14].

*Voltage sensor*. A ZMPT101V sensor manufactured by Qingxian Zeming Langxi Electronic was used to measure the line current voltage. When using this sensor, an additional resistance element is not required in the connection of contacts.

Table 2.

**Technical characteristics of the voltage sensor**

| Voltage area , V | Insulation voltage,V | Current , mA | Supply voltage, V | Power indicator | Size, mm | Weight, gramm |
|---|---|---|---|---|---|---|
| 0 - 1000 | 4000 | 2 | 4÷12 | LED | 50 x 19 x 23 | 25 |

*Current sensor.* The SCT024TS-D sensor was used to measure the line current. This sensor has a silicone coating, easy to install, it can measure the current value of AC lines with a frequency of 50Hz-1000Hz, a voltage of up to 720V, a range of 100A-300A . This device is highly durable and does not lose its ability to work at temperatures up to -25 $^0$C~60$^0$C.

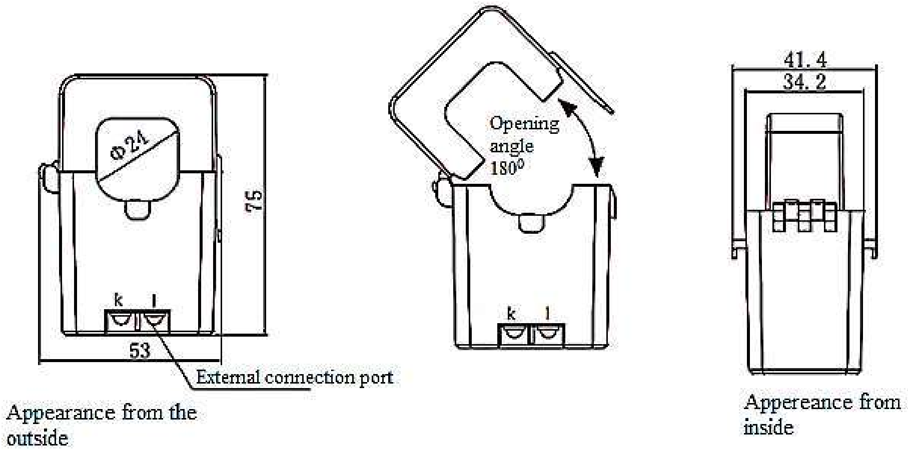



**Figure 3. Schematic diagram of the current sensor**

According to the proposed model, voltage and current sensors (IoT sensors) monitor the secondary current, voltage and load current of the distribution transformer. The entire power sent from the distribution transformer is monitored by an energy sensor. In the system, backup of communication channels is carried out, which implies the transmission of data bypassing the defective device not only within one phase wire, but also through devices on neighboring phase wires. The data collection module can be replaced by another depending on the monitoring tasks [15].

**Discussions.** Data received from modular devices are collected in the permanent and additional memory of the concentrator. The collected data is sent to the monitoring brand using radio transmission modules and displayed on the computer of the monitoring center through the web interface. The large number of bases in data transmission can cause problems and prevent information from being received at the right time. Therefore, *ZigBee* module is used to act as a repeater. Since the ZigBee module consumes little power, it can work for several months even on a normal battery. Below is the circuit diagram of ZigBee module and ESP32 SIM700 microcontroller [16].

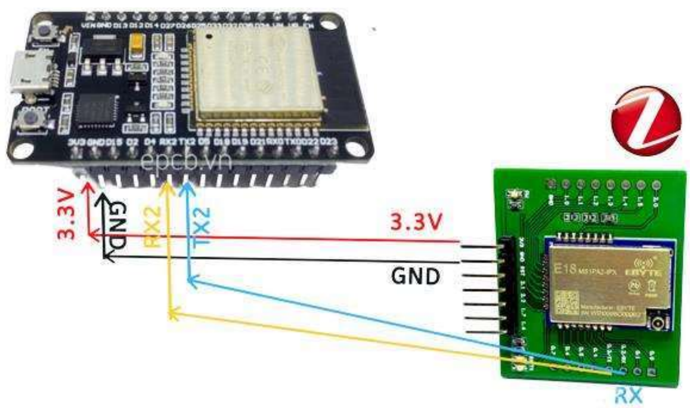



**Figure 4. ZigBee module and ESP 32 SIM700 connection diagram**

According to quality of service (QoS) indicators, ZigBee modules can be divided into 2 types: external (used in an open facility) and internal (used indoors). The following ZigBee modules were compared in terms of packet delivery ratio (PDR), current and energy consumption, network lifetime, delay and throughput [17].

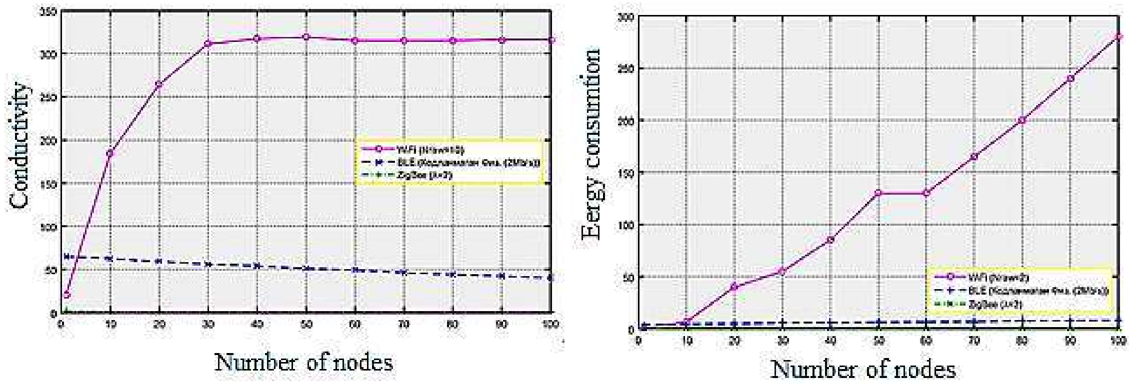
Table 3.

**Technical specifications of popular ZigBee modules [18]**

| ZigBee Module | Transmitter | Programmable memory | Programmable CPU Clock | Number of chanels | Receiver sensitivity | Tx power | Current Tx and Rx |
|---|---|---|---|---|---|---|---|
| XBee S2C | Silicon Labs EM357 SoC | 32 KB Flash/ 2 KB RAM | Up to 50.33 MHz | 16 | −100 dBm/ −102 dBm (boost mode) | 3.1 mW (+5 dBm)/ 6.3 mW (+8 dBm) boost mode | Tx: 33 mA @ 3.3 VDC/ 45 mA boost mode Rx: 28 mA @ 3.3 VDC/ 31 mA boost mode |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| XBee-Pro S2C | Silicon Labs EM357 SoC | 32 KB Flash/ 2 KB RAM | Up to 50.33 MHz | 15 | −101 dBm | 63 mW (+18 dBm) | Tx: 120 mA @ 3.3 VDC Rx: 31 mA @ 3.3 VDC |
| XBee S2D | Silicon Labs EM3587 Soc | N/A | N/A | 15 | −100 dBm/ −102 dBm (boost mode) | 3.1 mW (+5 dBm)/ 6.3 mW (+8 dBm) boost mode | Tx: 33 mA @ 3.3 VDC/ 45 mA boost mode Rx: 28 mA @ 3.3 VDC/ 31 mA boost mode |
| XBee 3 | Silicon Labs EFR32MG SoC | 1 MB/128 KB RAM | - | 16 | −103 dBm normal mode | +8 dBm | Tx: 40 mA @ 8 dBm Rx: 17 mA |
| XBee 3 Pro | Silicon Labs EFR32MG SoC | 1 MB/128 KB RAM | - | 16 | −103 dBm normal mode | +19 dBm | Tx: 135 mA @ 19 dBm Rx: 17 mA |

ZigBee is also a wireless network technology based on the IEEE 802.15.4 specification, which includes a set of high-level communication protocols. This technology, called ZigBee, is designed to be simpler and cheaper than other wireless personal networks, such as Bluetooth or Wi-Fi. When choosing network technologies, special attention is paid to their transmission capacity and energy efficiency [19-20].



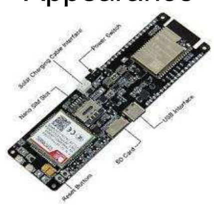

a) b)

**Figure 5. Graphs comparing WiFi, Bluetooth, and ZigBee wireless network standards in terms of throughput (a) and energy efficiency (b)**

In general, the appearance and characteristics of the main components of the monitoring device are detailed in the table below.

Table 4

**Device elements**

| T/r | Name of element | Appearance |
|---|---|---|
| 1 | LILYGO TTGO T-SIM7000G Module ESP32-WROVER-B |  |

| | | |
|---|---|---|
| 2 | DS1820 Stainless Steel Package Waterproof DS18b20 Temperature Black Probe Temperature Sensor 18B20 Fit For Arduino |  |
| 3 | ZMPT101B Active Single Phase Voltage |  |
| 4 | Split Core Current Transformer SCT024TS-D Rated Input 100A, 150A, 200A, 250A, 300A Output 1V/3V/5V DC 50-60HZ 2% |  |
| 5 | CC2592 PA ZigBee module 16 Mb RM yadro 2,4 GHz |  |

**Conclusion.** Remote monitoring of low-voltage (0.4 kV) OPL situations uses sensors that are suitable for the specific environment and conditions of the transmission line, if the temperature in the transmission line is too high, then the sensor we choose must withstand these temperatures. In addition, taking into account the power consumption of the device, low-power sensors, an Arduino board and a ZigBee module were selected. To minimize power consumption and increase device battery life, a wireless protocol specially designed for low-power devices such as ZigBee is used.

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# CONTENTS

## PRIMARY PROCESSING OF COTTON, TEXTILE AND LIGHT INDUSTRY



## GROWING, STORAGE, PROCESSING AND AGRICULTURAL PRODUCTS AND FOOD TECHNOLOGIES