GSM-based Control and Data Collection System

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***Abstract*—The original automated system for centralized data collection and management of spatially separated objects based on a GSM channel is described. The developed system with the use of modern element base for the first time realizes simultaneously the measurement of a set of electrical parameters of remote electrical loads, collection of information and control of operating modes of remote objects from a single center.**

Keywords—Data collection, control system, sensors, microcontroller, software, GSM channel, GPRS

I. Introduction

The task of operational remote control and data collection in a single dispatch center is a classic task in the development of automation systems. The purpose of this work is to develop a specialized control system and data collection from spatially separated objects based on a GSM communication channel.

Data transmission technologies using the GSM channel are widely used to solve various problems of creating data acquisition and control systems. The amount of publications on this topic includes a lot of articles, among them [1-5]. The specificity of the GSM channel, the range of tasks to be solved and the use of various electronic components and ready-made modules determine the multivariance of the systems being developed. So, in [1], along with GPRS connection, SMS communication is used to receive data from the periphery and to set the operating modes of the system, which is an additional advantage of the functionality of the system as a whole. The article [2] describes the basic principles embedded in GSM networks for packet data transmission, as well as the main functions of the Wavecom modem. The article [3] describes the main methods of data transmission in GSM networks with detailed technical characteristics. The work [4] describes in detail a system for collecting information from housing and communal services facilities based on ready-made equipment and ready-made software products. The work [5] describes a system for remote control of air conditioners based on the use of a set of communication channels: GPRS, LORA, Wi-Fi, LAN.

Such an abundance of publications on this topic not only does not diminish, but confirms the relevance and necessity of original developments, which allow taking into account all the features and needs of a particular production and individual wishes of the customer. Also important is the operational technical support of the system being implemented, the possibility of its modernization as it is used in real production conditions, as well as the attractiveness of the price of the complete system for the customer.

In accordance with the stated purpose, the authors had to solve the following tasks:

1) to make a choice of the data transmission method using the GSM channel;
2) to develop hardware and software parts of peripheral devices based on GSM modems;
3) to implement the collection of information from sensors in peripheral devices;
4) to develop a protocol for interaction (a set of commands) of the peripheral nodes of the system and the central server;
5) to develop central server software.

A specific application task for the application of the system was the collection of data on energy consumption and control of street lighting objects in the city (illumination of buildings).

II. Choice of Data Transfer Technology

In our previous works, we used PLC technology to organize a data transmission network within one or several spaces (buildings, railcars) [6, 7]. In the case of remotely spaced points located on one open compact area (within a few hundred meters), we used wireless technologies to organize local radio communication [8]. This task is distinguished, firstly, by a large spatial spread (urban development). Accordingly, a transition to the use of cellular communication infrastructure (GSM technology) is necessary and possible.

When using GSM technology, data can be transmitted in three main ways [9]:

- usage of the short message service (SMS);
- usage of the voice channel CSD (Circuit Switched Data);
- usage of the packet data transmission GPRS (General Packet Radio Service).

Data transmission via SMS is practically not suitable for transmitting large amounts of data. The main advantages of SMS are ease of use and relatively low cost of services. The significant disadvantages include the non-guaranteed timely delivery of the message, as well as a small number of characters in it (160 characters of the Latin alphabet and numbers). These circumstances impose significant restrictions on the use of SMS as the main data transmission service, for example, in systems of continuous monitoring of objects (telemetry).

Data transmission with circuit switched (Circuit Switched Data) allows to organize the exchange of data of any volume between two objects in real time. This mode provides the user with a fixed data transfer rate for the entire communication session. However, the fee is charged regardless of the amount of information transmitted, the connection must be paid for the entire period of connection, including cases when there is no information transmission.

The most effective way to transmit information over GSM is the GPRS technology (General Packet Radio Service). The main advantages of GPRS are due to the fact that it uses packet commutation:

- Information between subscribers of the data transmission network organized in this way can be transmitted directly via the Internet.

- Data from one subscriber can be transmitted not continuously, but in separate time intervals. Accordingly, the time intervals can be distributed among all subscribers of the network.

- Even if the subscriber is not in the receiving or transmitting state, he has constant access to the data transmission network.

- The network resources are allocated to the subscriber only when it really needs them.

As a result, the subscriber does not occupy the physical communication channel constantly, as in the case of CSD, and pays for the services of the communication operator (provider) only for the amount of information actually transferred, and not for the entire session time. At the same time, the subscriber always has a connection to the GPRS network [9].

The above advantages have led to the choice of GPRS as a technology for organizing a data transmission network.

III. Description of the Peripheral Unit

The data collection and control system consists of a set of peripheral units (including GSM modems) with the functions of controlling and measuring the parameters of the power grid and one central server that controls the entire system (Fig. 1).

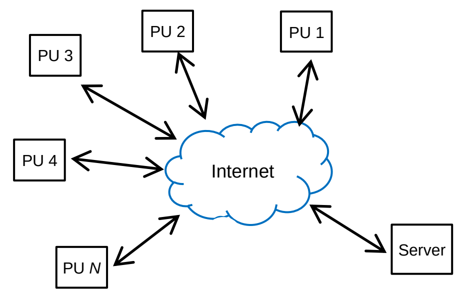

Fig. 1. General system diagram

The block diagram of the peripheral unit (PU) is shown in Fig. 2.

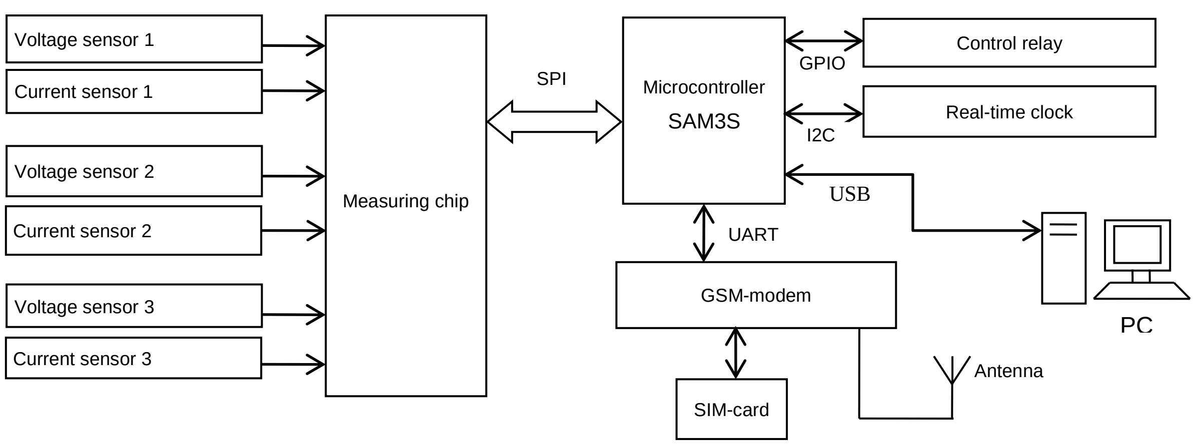

Fig. 2. Block diagram of the peripheral unit

The PU consists of a measuring part and a control part. The control part is implemented on the basis of the SAM3S microcontroller with the Atmel Cortex-M3 architecture [10]. Interaction with the measuring chip occurs through the SPI interface of the SAM3S microcontroller.

The GSM modem is connected to the UART interface of the SAM3S processor. A set of AT-commands is used to perform control instructions and data exchange [11]. When power is applied to the peripheral device, the GSM modem is initialized, the SIM card is checked, the connection to the GSM network is established, the GPRS connection is established and the connection to the server is made using the TCP transport layer protocol.

To simplify interaction with a large number of sensors and chips, the FreeRTOS real-time operating system was used [9], on the basis of which the following software processes (threads) are implemented:

1. The process of interaction with the GSM modem.

2. The process of controlling I/O lines.

3. The process of interaction with measuring chips.

4. The process of interaction with the PC.

Interaction between threads is implemented using the built-in methods of interprocess communication: message queues [12].

The peripheral unit has a queue for sending information packets and checking for successful package delivery. Each information packet is characterized by its own number of attempts to send it successfully. The fact of unsuccessful package delivery is regarded as a loss of communication with the server, after which the reconnection procedure is performed. These actions allow increasing the reliability of communication between the server and the client.

On the basis of the SAM3S controller, a continuous check of communication with the server is implemented, as well as testing the GSM signal level, which allows preventing the loss of communication with the server, or restoring the lost connection in the shortest possible time.

The process of controlling the I/O lines is responsible for controlling the external relay, as well as for displaying the current state of the operating mode with the LED indicators of the peripheral unit.

The packet structure in the information protocol between the processor and the measuring chips has the following form:

1. Preamble – 1 byte.
2. The device address – 1 byte.
3. The command number – 1 byte.
4. Data – up to 28 bytes.

The measuring part of the device is implemented on a single polyphase energy meter chip manufactured by ATMEL [13]. Current and voltage sensors are connected to the polyphase meter to measure all parameters of the power grid (current, voltage, active power, reactive power, full power, power factor, frequency) – in total three pairs of sensors for each of the three electrical phases. During programming, current and voltage measurements are calibrated, as a result an accuracy with an error of no more than 0.5% is achieved.

A real-time clock is also connected to the SAM3S central processor via the I2C interface. The hardware clock has its own calendar, as well as the function of a programmable "alarm clock" that realizes scheduled control function.

The schedule can contain up to 1000 events, which can be annual, monthly, daily and one-time. Events are stored in the non-volatile memory of the SAM3S processor, while only 32 bits (one memory cell) are used to store one event.

The interaction of the peripheral unit with a personal computer (PC) is performed via the USB interface. With the help of a PC the initial configuration and testing of the peripheral unit is run (GPRS access point assignment, number of server IP address and port, as well as switching on/off the relay, reading the power grid parameters, setting the schedule, setting the date and time, etc.).

IV. Server software

The general control of the system is performed by the central server. The server software is written in C++ for the Windows family of operating systems.

This software allows to control and download data from all remote peripheral units, as well as view and analyze the received data.

Data exchange with peripheral units is performed via the Internet. For the correct operation of the server, it is necessary to allocate an external IP address and a TCP port on which this application will be launched. Network exchange is implemented using the socket library.

When a new client (peripheral unit) is connected to the server, its authorization procedure takes place, which consists in verifying the client's unique key. After successful authorization, the client logs in, otherwise it is disabled.

The server software constantly checks the communication of the central server with all clients. If the client is idle for three hours, it is disconnected from the data transmission network.

The interaction of the server and clients is performed through a developed protocol (a set of commands) and occurs according to the "request–response" principle: each server request is followed by a response from the peripheral unit [6, 7].

The information package of the data transmission network has the following structure:

1. Preamble – 1 byte.
2. The unique key (address) - 15 bytes.
3. The command number - 1 byte.
4. Data – up to 32 bytes.

Although the communication in the system, thanks to the use of sockets, is based on the "point-to-point" (peer-to-peer) principle, each packet contains the device address (modem IMEI) for additional verification of the correctness of the addressee and sender and primary protection against unauthorized access. On the basis of the described protocol, 30 different control and data collection commands are implemented.

As well as on peripheral units, a queue of packets for sending is implemented on the server. Moreover, in this case, the queue supports packet priorities, and its own individual queue is created for each connected client. The highest priority is given to the commands for controlling and configuring the device, the lowest priority is given to commands for receiving debugging information, since they are the least important and a delay in the delivery of such a package will not affect the functioning of the system.

The graphical interface of the server application allows to perform the following functions of the dispatcher:

• Viewing the parameters of the power grid in real time from any peripheral unit for any selected phase or sum of phases;

• Manual switching on/off of the relay of the selected peripheral unit;

• Displaying the operating time of each peripheral unit in the switched-on state of the control relay;

• Maintaining an archive and viewing statistics (of energy consumption, of load current and of voltage in the supplied power grid) separately for each remote unit in the form of a set of graphs with the ability to group data by hours, by days and by months;

• Configuration of each peripheral unit: setting the date and time, setting the statistics collection interval, setting the number of connected phases, setting current and voltage thresholds;

• Setting a schedule for each peripheral unit: saving events to memory, reading events from memory, clearing the schedule;

• Server configuration: port configuration, polling interval settings, etc.

A screenshot of the server application window with an open tab for displaying statistics of the collected parameters is shown in Fig. 3.

The appearance of the peripheral unit is shown in Fig. 4.

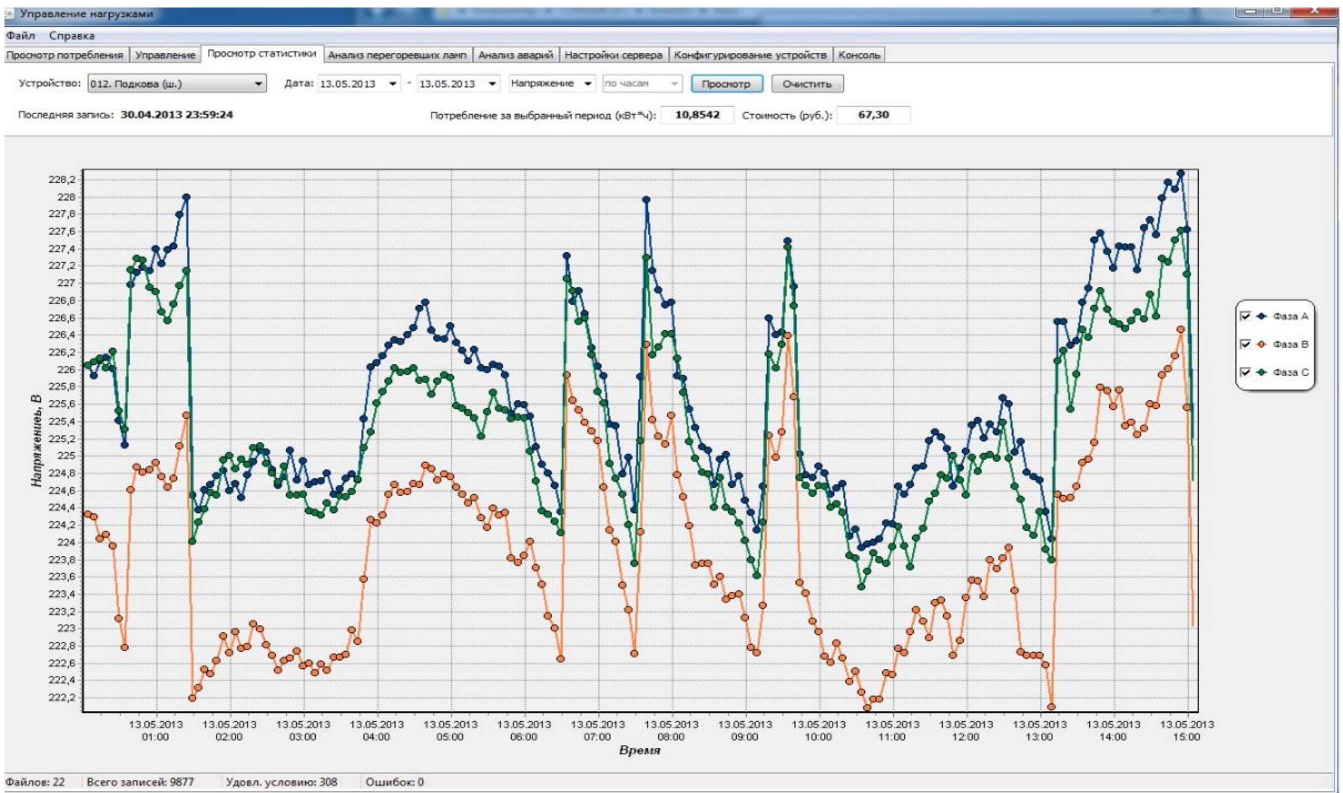

Fig. 3. Server application data view tab

Fig. 4. Appearance of the remote peripheral unit of the system

V. Implementation and Experience of Operating the System

This system is installed in the Kazan Kremlin on 22 objects and allows controlling street lighting, as well as collecting data on energy consumption. The polling of all objects acts simultaneously and takes no more than 30 seconds. The actual data transfer rate is 12 kbit/s. Because of the timely disconnection of loads and constant monitoring of the current consumed, the developed system allows reducing the cost of electricity by 30% for street lighting (illumination of buildings).

A detailed technical description of the system is given in [14]. There are also detailed screenshots of the work of the central server software and instructions for operating the system.

VI. Conclusion

As a result of this work, the original automated system for centralized data collection and management of spatially separated objects based on a GSM channel has been developed which for the first time simultaneously realizes the measurement of a set of electrical parameters of remote electrical loads, collection of information and control of their operation modes from a single center.

In the presented system with a modern element base the hardware and software parts of peripheral and central devices are implemented. The original software has been developed which implements the data exchange protocol in the system and general control from the central dispatching point.

Acknowledgment

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