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Development of a smart electricity meter for households based on existing infrastructure.

To cite this article: I N Perekalskiy and S E Kokin 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **510** 022006

Development of a smart electricity meter for households based on existing infrastructure.

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Abstract. Following the universal introduction of information technologies in the electric power industry, it became necessary to create a more perfect measuring infrastructure that would reduce theft of electricity and implement new concepts such as demand response and the P2P market. Existing meters are able to solve the problem of reducing theft, but they do not yet support the functions of P2P trading. This article proposes the development of a smart metering device based on ESP 8266 controller for detection and control of electrical energy and remote turning off or turning on the consumer supply. The meter will be able to exchange information with the cloud platform in real time and provide information about the decline in the quality of electrical energy. It is proposed to use Wi-Fi (main) and GSM (reserve) communication channels.

1. Introduction

According to the Center for Economic Research of the Institute for Globalization and Social Movements, in 2011 the theft of electricity accounted for more than 60% of the total losses in the low-voltage network (3.7 billion kWh), and the damage in monetary terms exceeded 7.25 billion rubles. In the central regions of Russia in 2012 alone, facts of theft of electricity in the amount of 150 million kWh were revealed. [1] [2]. The installation of “smart meters” can solve the problem.

Unlike their analogue old models, “smart meters” will automatically transmit current readings and the mode of electricity consumption to the power company, give a signal about an accident in the network, or about unauthorized interference. Also, they are able to remotely control the load, and will provide for the implementation of the concept of demand management in low-voltage networks. Such meters several times reduce the number of disputes and disagreements between consumers, sales and retail company, and minimize losses. By installing smart meters, theft of electricity will be excluded, which means it will increase the reliability and quality of power supply to consumers.

In this research, the concept of creating a smart meter devise based on the ESP8266 chip with the function of data exchange with the cloud platform using a GSM module or an available Wi-Fi channel is proposed. It is planned that the system is mainly aimed at the needs of the consumer and will allow the consumer to remotely receive information about the consumed electricity and to implement remote control. It is assumed that the implemented measuring system will become the first step towards development a paradigm for the future of energy industry, this paradigm being based on the implementation of the P2P (peer-to-peer) concept of the market. This structure is the exact opposite of a traditional system with centralized management and planning. It provides for each member of the network to become not only a consumer of energy, but also its supplier. In this case, energy will be traded directly between participants, without the participation of intermediaries, using smart meters and adaptive settlement algorithms that interact in real time.

The proposed system consists of the following: a digital energy meter based on the ESP8266 chip, a GSM modem. It is planned to install the device next to an existing energy meter. In this case, parallel operation of the existing meter will be ensured without violating the integrity of the main circuits from the meter to the power supply. Measurements will be carried out using voltage sensors and current sensors. The smart meter will have a built-in relay that will be controlled by the microcontroller and will turn on and off the power supply of household loads. The entire module is powered directly from the measured power network.

2. Existing electric power metering.

2.1 Traditional system

A traditional electric energy metering system consists of a meter of electric energy that displays the consumed kilowatt hours, continuously measuring the instantaneous voltage (in volts) and current (in amperes) [3]. The main types of electricity meters are: electromechanical induction meter and electronic meter. In an electromechanical induction meter, the total number of aluminum disk rotations is directly proportional to the power consumption.

Electronic meters show power consumption, cos, reactive power on a digital LCD or LED display, and are also able to send energy consumption data to the communication network.

In addition to measuring energy consumption, electronic meters can read other parameters of the load and power, such as instantaneous and maximum load levels, voltage, power factor, reactive power, etc [3].

According to normative documentation, electricity meters are installed on electric poles of overhead high-voltage lines - 0.4kV. Every month, readings are transmitted to the retail company, moreover, verification of the correctness of the readings is carried out by specially assigned persons - meter readers, who have free access to metering devices.

Disadvantages of the existing energy metering system:

- Human error cannot be avoided for the manual meter reading.
- Cross checking or recheck of human readers for energy utilization is not always in place.
- High chance of stealing, bribery, misuse, especially during events.
- Possibility to falsify the readings on the photos of energy meters using photo editor software.
- Larger number of meter reading employees means extra expenses for the company, both for hiring and for travel expenses
- If energy meter is installed inside the house, this may lead to non-checking of readings for the reasons of no access to the meter (the house being locked).
- The consumer does not have instant data on his regular usage of energy.
- The consumer may fail to receive his energy bill by the due date.
- In the event of an emergency, the consumer will not be receive an alert. Therefore, no remedial action will be taken. This is especially true in country houses, where a power outage can disable the entire climate control system.

2.2 Proposed System

A smart meter works with an Internet data collection platform, there is no need to read readings from the front panel of the meter. The smart meter uses a Wi-Fi channel as a communication channel. If the Wi-Fi channel is unavailable, the GSM channel will be used. The advantages of such metering device in comparison with a traditional meter include:

- New smart energy meters send precise readings on a regular interval in sequence about customer's energy usage to utility (Electricity) provider. So the bills will be proper, and the labour cost for taking the readings in consumer residential areas will be reduced;
- If the consumer does not pay the energy bill in time, the utility provider can remotely disconnect the service (line) of a particular consumer and after payment, the provision of service to the consumer

can be renewed. So sending a specially designated employee to the consumer's premises to cut off the energy from the network or to reconnect it can be avoided;

- We have introduced a lever switch to detect tampering attempts. Should anyone try to open the meter, the cover button will be released, and the meter will send the information to the service provider;
- If the quality of electricity decreases, a message will be sent to the energy supplier, and in the case of a decrease in excess of permissible standards, the consumer will be automatically turned off. Thus, consumer appliances will be protected from damage. The supplier will not have to reimburse the costs to the consumer if the quality decline was due to his fault;
- New meters provide for the opportunity to implement the Demand response concept: Demand management in which the energy supplier, in agreement with the consumer, can turn off non-critical loads such as street lighting, ventilation system, etc.

A smart meter consists of a digital energy meter, an ESP8266 microcontroller [4], a GSM modem [5]. Measuring elements, which are represented by the Non-Invasive AC Current Sensor "SCT-013-030 [6], are connected to the mains phase. Voltage sensor ZMPT101B [7] is connected to the power supply line. The ESP8266 module is powered from the power supply line by a AC/DC converter. The ESP8266 module collects data from the current and voltage sensors. The high voltage relays are connected in series with the load and are controlled by the ESP8266. Based on a command from the network provider or the consumer, the load from the power supply line can be disconnected.

3. System architecture

The architecture of the Smart meter based on ESP8266, GSM is shown in Figure *1*. Energy consumption is calculated using the Metering block (unit) and ESP8266. The energy meter includes the following components: LCD, ESP8266, GSM modem, 2 relays, 2 measurement units. The first is designed to account for electricity from an external electrical network; the second is designed to account for electricity from an internal network of households with connected renewable energy sources, an exterior electrical network, etc.

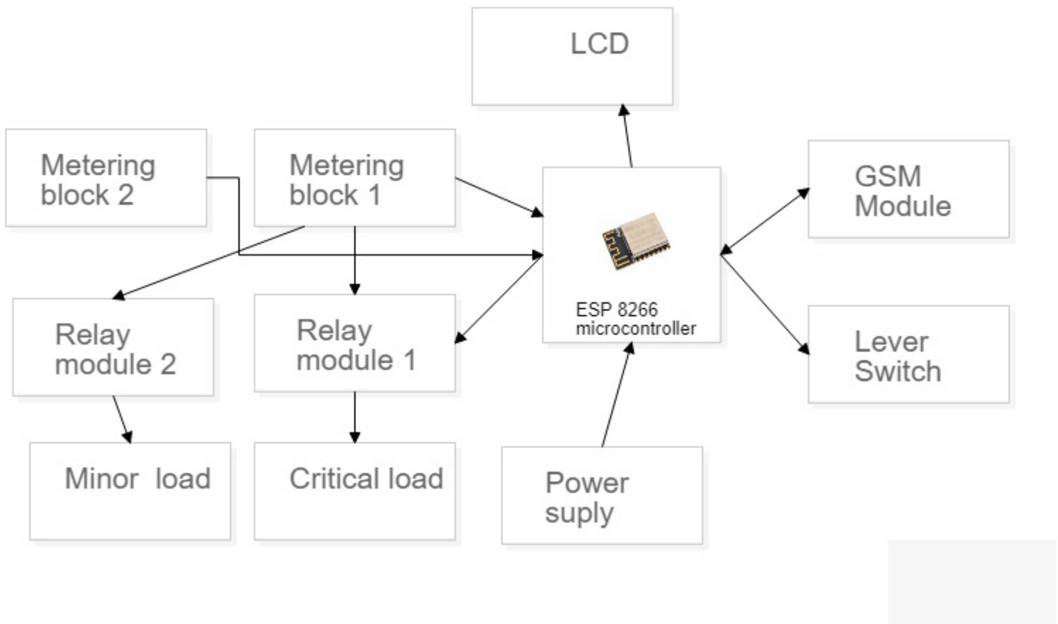

Figure 1. Architecture of the Smart Meter.

3.1 Voltage transformer or potential transformer

The voltage sensor ZMPT101B is used as a measuring voltage element. The voltage sensor consists of the following: a transformer, which provides for the electrical isolation of metering circuits from power

IOP Conf. Series: Earth and Environmental Science **510** (2020) 022006 doi:10.1088/1755-1315/510/2/022006

circuits, and a key-click filter that eliminates interference from the power supply. It connects directly to high voltage circuits. The transformer has appropriate protection and can be directly connected to the power supply line without additional elements.

3.2 Current transformer
The current transformer is connected according to a special circuit considered in [6]. Data from the transformer is read using the ESP8266.

3.3 Relay module
SSR solid state relays are used to turn on and off power loads, which allows to turn the load on and off only at the point where the sine wave of the current passes zero passage. Thus, the pulse current and impulse noise during switching are reduced. However, the relays should be protected against overvoltage, overcurrent and rise of temperature. [8]. SSR is a fully electronic relay [9]. As contacts, power transistors, high-power thyristor or triacs are used. The control circuits from the power circuits are isolated using an optocoupler [5]. However, during installation, they must be mounted on radiators in order to avoid damage to the power switch in case of excessive loads.

3.4 Microcontroller ESP8266
ESP8266 is a multifunctional microcontroller that supports the IEEE802.11 b / g / n standard, a protocol stack of TCP / IP. It has a built-in 32-bit low-power MCU, a built-in 10-bit ADC, 2.4 GHz Wi-Fi, UART support [4]. Communication between the module and the cloud platform is executed via a built-in Wi-Fi module. When the Wi-Fi network is not available, it will automatically switch to the GSM channel. This constitutes a reserve channel, and the likelihood of not getting readings is reduced. To communicate the meter via GSM, the GSM / GPRS Module is used [5]. The GSM / GPRS module is used to send SMS, make calls, and exchange data via GPRS. In our case, it is used to send SMS with the readings of the meter.

4. The Implementation of the Solution.
The suggested solution was tested on a real prototype.

The proposed data transmission system consists of the ESP826 microcontroller with the connected GSM module.

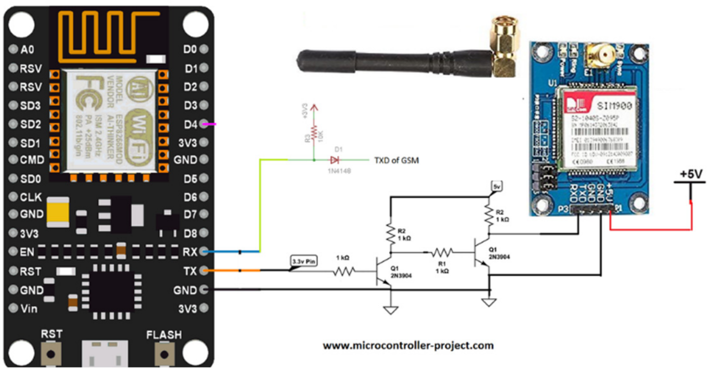

Figure 2. Connection circuit of ESP8266 to GSM module.

Data is received on the ESP8266 from energy metering units installed on the power circuit consisting of a current and voltage transformer.

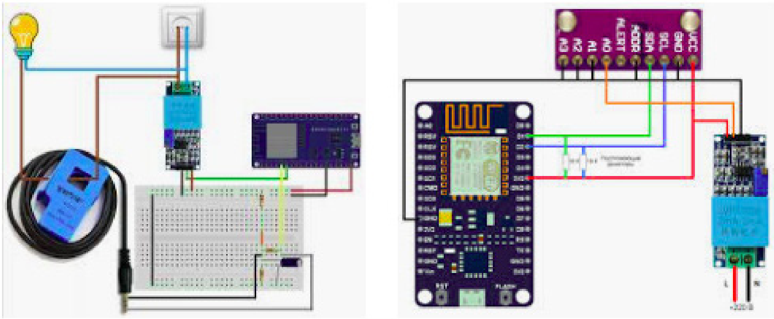

Figure 3. Scheme of the measurement unit.

Current measurements are made by a removable sensor SCT-013-030, which can be installed on a phase wire without breaking the circuit. Voltage is measured by a voltage sensor. Data is continuously sent to the ESP8266 board where it is processed and multiplied by the transformation coefficient of the installed current and voltage sensors. The algorithm calculates the energy in kW / h and sends the data to the cloud storage on the Internet. If the Wi-Fi network is not available, the readings are sent using the GSM modem. Thus, redundancy of communication channels is achieved. Remote control of the relay is executed by sending commands to the ESP8266 using the available Wi-Fi or GSM channels. The meter ensures independent metering of energy that is received from a neighbouring household with renewable energy sources. For this, a separate measuring module is provided in the meter. Switching between power circuits is carried out by a relay at the command of the ESP8266 controller. At this stage, this is the first step towards implementing the “P2P energy market concept”. The smart meter offers the ability to connect 2 types of load, the main (critical) and non-critical, which is not critical for the functioning of the household. At this stage, it is planned to implement the concept of “demand response”. Load shedding at the request of the network operator to smooth the load schedule with subsequent reward to the consumer who agreed to such shedding.

5. Conclusion

This research examined the concept of a smart meter that will provide for the timely and reliable sending of the readings to the energy supply company. The reliability of data transmission is ensured by 2 alternative communication channels using either GSM technology or a Wi-Fi network. An intelligent metering device will reduce the possibility of theft of electricity, and will allow to reduce the cost of subscriber service controls used to take readings. Additional metering systems will provide for the implementation of the P2P market concept, when the energy from renewable energy sources can be transferred to neighboring households (of course, in experimental mode). A built-in connectivity for two types of load will allow the consumers to participate in “demand trading” upon implementation of the Demand response concept in networks.

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