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IOT ENERGY METER APPLICABLE IN SMART BUILDINGS

Aleksandar Žorić[1], Nikola Žorić[1], Muhamed Bejtović[1]
[1]*Faculty of technical sciences – University of Priština*

Abstract

This paper describes a modern solution for energy efficiency increasing in residential buildings. The solution is based on IoT (Internet of Things), offering the possibility of remote control of electrical energy consumption as well as the monitoring of electrical parameters in real time as: voltage, current, power factor, active and reactive power, active energy and total costs. Owing to the smart mobile devices, the user becomes aware of the consumption of electricity and prices at any time and thereby be motivated to save. The proposed solution offers the possibility of collecting data relating to electrical quantities in the real time. This feature allows the user to analyze the consumption of electricity over a long period of time, e.g. one month, and thereby a possibility of change in consumer habits.

Described solution do not disturb the existing system for electrical energy measuring and do not request important modifications of existing electrical infrastructure in the residential building.

Keywords: IoT, active energy, power factor, smart building, cloud server, WiFi.

INTRODUCTION

Working on this topic is focused on the using of IoT (*Internet of Things*) applications in smart buildings [1], [2]. In a traditional residential housing scenario, tenants use home electrical appliances and periodically pay for their electricity consumption to the distributor. When the consumer is aware of the consumption, it has been proven that he then strives to save energy, which is the interest of both the user and the manufacturer/distributor. The IoT system designed for these purposes uses sensors and built-in systems for electricity consumption monitoring and control, providing the user with a constant insight into the condition and cost of consumed energy, and warning the user in the case of over-consumption. A relatively new concept used in such an approach to designing is IoT [1], [2], [8]. Internet of Things (IoT) is a new concept that connects physical objects to the Internet, changing the way of people view to the environment and how they interact with objects in it: from interconnecting people to people to interconecting people to objects - things and things to things, IoT plays a major role in this transformation of the Internet. With this, IoT can also be defined as a network of objects with unique identities associated with the Internet [2], [3].

The serious limiting factor of the proposed concept is, however, the price of the end system, because the costs of the complete system remain high for the users. The most expensive component for initial setup of the system for monitoring and managing of electricity consumption is on the access point side and Internet connection, while the costs for hardware system and data storage have become cheaper. This is also a major factor that prevents the application of such systems to a greater extent. The aim of this paper was to partially bridge this gap and build the ultimate smart building system with a reduction in total costs and without affecting the functionality of existing systems.

Owing to the large and varied offer of integrated components of the described systems and services on the market, the price of the realized system is relatively small compared to the opportunities and savings that can be achieved by its application.

The realized system, by its capabilities and performance, far outperforms the current, obsolete, or even more modern measuring devices for the consumption of electricity.

OVERVIEW OF THE SMART BUILDING

In modern systems of sophisticated smart buildings, the essential role belongs to automatic control systems. Supervision and automatic control of technical systems in smart buildings is of crucial importance in order to achieve projected conditions in exploitation.

By developing various technologies that are used in smart building systems, the concept of smart buildings has attracted increasing attention for the past twenty years [5]. In this regard, many definitions of smart buildings have been proposed, which, due to the development of technology, have been changed over the time. It is almost impossible to formulate a unique, standard definition of smart buildings, which, however, is of vital importance for a clear idea of terminology, not necessarily necessary. Different approaches to smart building definitions can still be grouped into three categories:

1. Performance-based definitions
2. Service-based definitions
3. System-based definitions

SYSTEM DESCRIPTION

Proposed system is designed to create the better user friendly way of interacting with real world devices. The information of the device to user and commands from user to the device is carried out in following steps:

- Collecting data of the electronic device and transmitting it over the Internet to the cloud server using NodeMCU WiFi module [6].
- Storing of data into the cloud server to maintain the record of data.
- Represent the transmitted data using the cloud server's interface.
- Control the appliances from same interface.

HARDWARE IMPLEMENTATION

The complete system is implemented on the base of only two subsystems: NodeMCU WiFi platform [6] and PZEM004 multifunctional energy meter. NodeMCU is one of the many open source IoT's, based on the well-known ESP8266EX WiFi SoC (System on Chip), the product of Espressif Systems [6]. The platform was created shortly after the appearance of the ESP8266EX WiFi SoC at the end of 2013, precisely, in October 2014. ESP8266EX SoC integrates 32-bit microcontroller unit (MCU) Tensilica's L106 Diamond, which has extremely low power consumption with a maximum clock speed of up to 160 MHz. In addition to the MCU, compact design integrates the hardware TCP/IP stack for adding WiFi functionality, SRAM (50 kB) and ROM memories and standard digital peripheral interfaces, RTCs, antenna switches, RF electronics, power amplifiers, low noise amplifiers, filters and power management modules - all in one small housing.

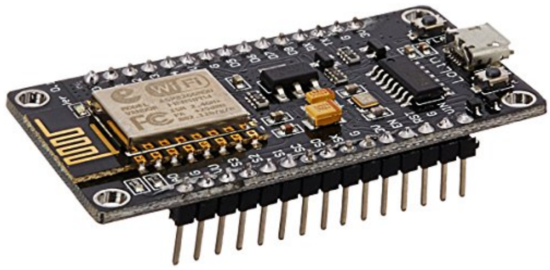

Fig. 1. *The NodeMCU IoT development platform.*

The NodeMCU development platform, Figure 1, is primarily intended for the development of IoT applications, but it can also be used as a general purpose 32-bit MCU development kit. Beside the ESP8266EX SoC, this platform consists of an integrated USB to TTL UART converter - CH340G, fixed voltage regulator from 5 V to 3V3, micro USB port and few passive components. QSPI (*Quick SPI*) flash programming memory is added as an external unit. The 12 I/O lines of this platform are available to the user.

One of the leading and most popular software development environment for the various ESP8266 modules and development boards, including NodeMCU, is ESP8266 Core for the Arduino IDE. Arduino IDE is a free software development environment that includes a rich set of libraries in the C/C++ language. Although programming in the Arduino IDE is not exactly the same as general programming in the C/C++ language, due to the usual differences in embedded software (limited memory and processor power), the programming base is the C/C++ language.

The PZEM004 module is a commercial product of PeaceFair Electronics [4], based on the SoC system SD3004. This module represents a multifunctional digital meter of the effective values of voltage, current, active power and consumed active electricity. It uses real-time clock (RTC) integrated in the SoC system SD3004 for active energy measurement and the TTL-UART serial communication port for communication with other devices.

Fig. 2. *PZEM004 module with a split current transformer as a current sensor.*

In addition with this module, the manufacturer also supplies a split current transformer as a current sensor. Figure 2. shows the appearance of the module.

According to the manufacturer's specification, the current transformer is designed for effective currents up to 100 A with a transformation ratio of 1 : 1000. The mains voltage, in the effective range of 80 - 260 V, is directly supplied to the input port of the module while the active power is in the range of 0 - 22 kW.

Optically isolated serial TTL port requires external power supply of 5 V, but with a slight modification of the value of two resistors can be made functional to a lower voltage of 3V3. On the top side of the PCB of module is there a built-in the button for reset of the accumulated energy. Achieved value of consumed energy is automatically stored in the module's EEPROM memory in the case of a power outage.

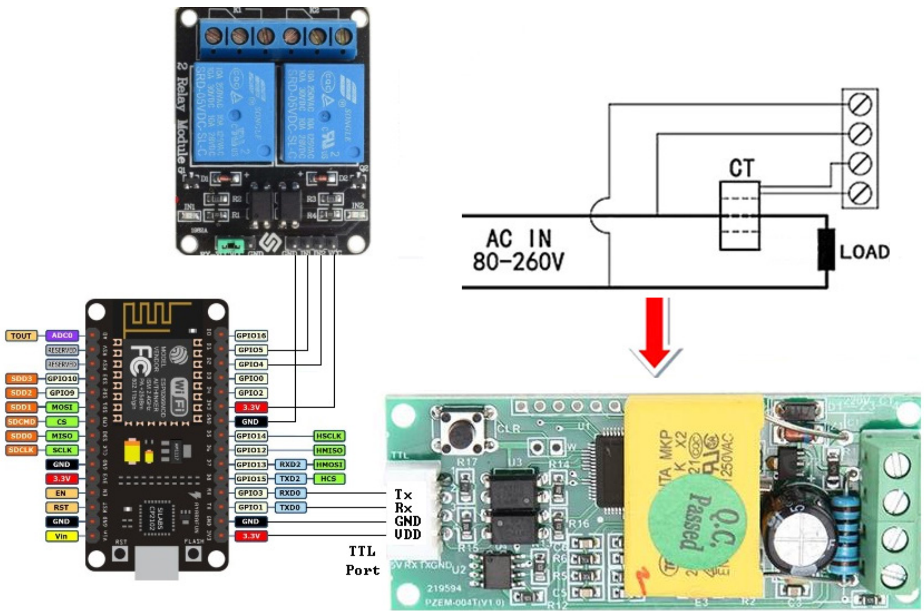

Fig. 3. *The hardware of the realized IoT system for the monitoring and control of electricity consumption.*

Figure 3 shows the complete hardware of the system with two channel relay actuator for appliances control. Of course, number of relay channels can be larger than two, because there are a large number of available I/O lines. The system is powered via the USB port of the NodeMCU platform, while DC power of the PZEM004 module is obtained from the AC main voltage.

As can be seen in the Figure 3, UART0 interface of the NodeMCU platform is used for establishing the serial communication with PZEM004 module. An addressable serial protocol of the PZEM004 module is described in [4]. TTL UART port of the PZEM004 module is pre-adjusted for the 3V3 voltage, which is the NodeMCU platform operating voltage.

Also, the relays have been declared for a voltage of 5 V. The test has established that the relays normally operate at a voltage of 3V3 and therefore the entire relay module is connected to the stabilized output voltage of the NodeMCU platform.

NODEMCU PROGRAMMING

As mentioned in the previous section, the Arduino IDE is used for NodeMCU programming. For communicating with the NodeMCU platform, a remote cloud server - Blynk [7] was used. The selected server allows the development of iOS and Android applications on the appropriate mobile devices or tablet PCs, but not under the Windows environment. Establishing communication between the NodeMCU and the Blynk cloud server is enabled thanks to the ESP8266WiFi.h and BlynkSimpleEsp8266.h system libraries [8], used in the application.

A simple data transfer between the NodeMCU platform and the PZEM004 module was realized with the help of the dedicated PZEM004T.h library with built-in functions for sending the commands and receiving the module responses. For correct communication, the serial transfer rate must be set to 9600 baud.

The application firmware, written in the Arduino IDE [9], contains inclusive libraries, a global variables declaration part, a setup() function for initialization and resources configuration which is executed only once, a loop() function that is cyclically executed, and the dedicated functions of the cloud server.

BLYNK ANDROID APPLICATION

Blynk was designed for develop IoT applications that can control remote hardware via the Internet [7]. Showing data from sensors, data storage, visualization and many other features are enabled by Blynk applications that support more than 400 hardware development systems. There are three main components of the Blynk platform:

- Blynk application that allows creation of user-oriented graphical interface using different, ready-made graphic objects (widgets).
- Blynk server, responsible for communicating mobile device and hardware. It can even be installed on a PC or Raspberry Pi system, and thus create a private, local cloud server.
- Blynk libraries available for the most popular hardware development systems that allow communication with the server and the processing of incoming and outgoing commands.

The Blynk application should be installed on iOS or Android platforms such as a smartphone or tablet. Upon installation, the user creates a new account for keeping and accessing the project from multiple devices and from anywhere. At the same time, the account also represents a security measure for the protection of user projects.

The digital dashboard where we built a graphic interface for our project is shown in Figure 4.

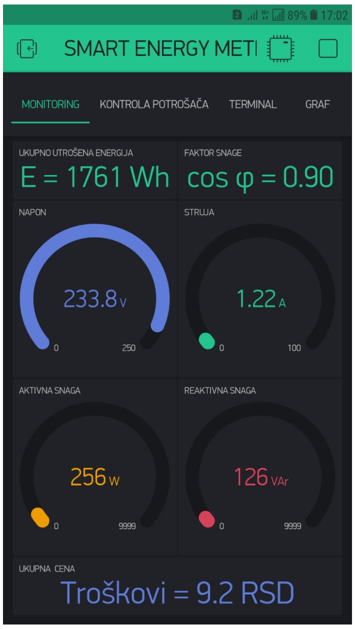

Fig. 4. *'Monitoring' tab of digital dashboard.*

As can be seen, effective values of voltage and current, active and reactive power, as well as energy, power factor and costs are presented on the tab '**Monitoring**'. Some of them are presented as widgets and other as LCD displays. Sampling rate in the real time amounts 5s.

Figure 5 shows the review of tab '**Appliances control**'. A user can control of energy consumption by turn-on or off individual loads. The LEDs near the switches provide a safe feedback to the user on turning on or off the load.

The '**Terminal**' tab serves to set the limit of the active power by moving the slider. In case of exceeding the limit power, the user receives an audible and textual warning about the date and time of the overrun, as well as the current limit power.

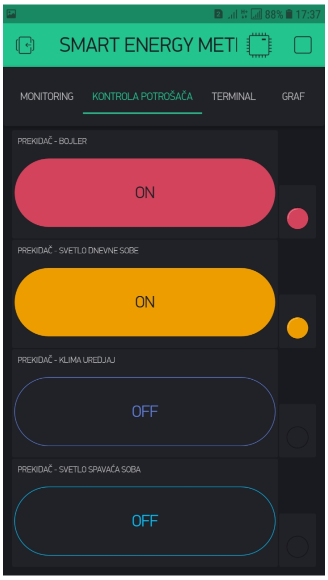

Fig. 5. *'Appliances control' tab of digital dashboard.*

The message text remains permanently written in the terminal window, see Figure 6.

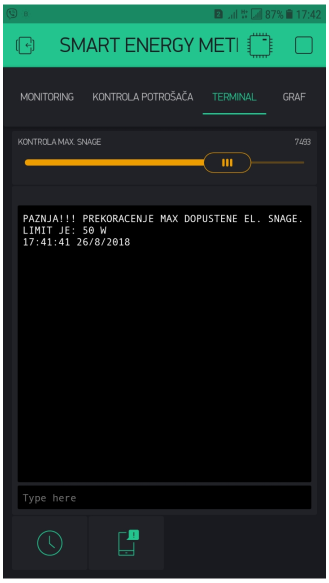

Fig. 6. *'Terminal' tab of digital dashboard.*

Finally, the '**Graph**' tab represents the waveforms of voltage, current, active power and energy consumption in the long time of monitoring. The discrete values of the waveforms of quantities are stored on the Blynk cloud server and can be downloaded to the user's email as CSV files.

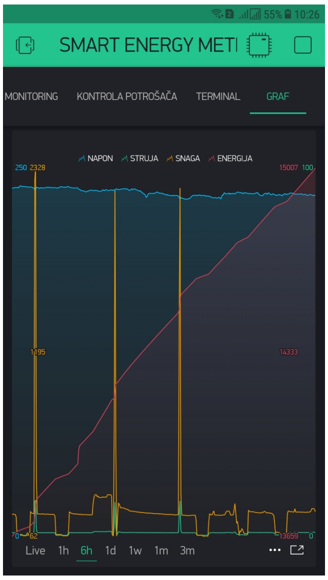

Fig. 7. *'Graph' tab of digital dashboard.*

The application created on a mobile device provides a constant insight into the actual values of electrical quantities of importance for the electricity in a residential or business facility.

The data acquisition in real time is enabled by using the 'SuperChart' widget, which besides the visualization of waveforms also provides for the storage of discrete values of measured quantities, as well as time and date data in Unix format on the Blynk server [7].

The negligible self-consumption of the proposed system will not increase the cost of managing and using the system.

CONCLUSION

The main goal of this paper was the experimental realization of a smart system for monitoring and managing of electricity in smart buildings. The realized system, by its capabilities and performance, far outperforms the current, obsolete, and even more modern measuring devices for the consumption of electricity. The system was tested in a reasonable time period and did not show any shortcomings that could have been assumed, such as: frequent breakdowns with the server, system reliability, self-consumption, self-sustainability, and the like.

Thanks to the large and varied offer of integrated components of the described system and services on the market, the price of the realized system is relatively small compared to the opportunities and savings that can be achieved by its application.

Installation of the system into existing, classical housing units gives the building an epithet of smart building, since electricity consumption is predictable and controlled by users. Also, the installation of the system requires only minor modifications of the electrical infrastructure on the installation panel with fuses or outside, due to the interruption of consumer circuits controlled by relay switches.

The negligible self-consumption of the system will not increase the cost of managing and using the system.

Further qualitative work on the development of the described system could be gone in the direction of automation, that is, automatic switching on/off of individual consumers at the scheduled time, automatic switching on/off of additional subsystem for repair of power factor in case of its small values and adding functions for separation of tariff zones.

Since the described system is intended for single-phase low-voltage infrastructure, it would also be necessary to consider the possibility of implementing an extended system in three-phase networks.

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