GPRS-Based Electrical Energy Monitoring System

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Abstract—**Energy efficiency in buildings and facilities has become an important part of the efforts for reducing environmental pollution. In order to develop strategies for efficient allocation of energy resources aimed at reducing power consumption, certain electrical quantities needed for analysis must be measured and monitored. In this paper, we propose a low-cost architecture of the remote electrical energy monitoring system based on GPRS communication.**

Keywords-energy efficiency; electrical energy measurement; GPRS; monitoring system

I. INTRODUCTION

Nowadays, energy efficient buildings and facilities for industrial, commercial and residential consumers are becoming increasingly important part of the efforts for reducing the carbon emission and environmental pollution. The price of the electrical energy is constantly rising due to the limited availability of fossil fuels. There are many national and international research studies and strategies aimed at increasing the energy efficiency of buildings and facilities. Some of these studies (e.g. [1] and [2]) have shown that 40% of energy consumption in Europe is related to buildings. Energy Efficiency Action Plan (EEAP) predicted that the biggest potential for energy savings is found in residential (about 27%) and commercial (about 30%) buildings [1]. Also, there are studies that propose methods and strategies for improving energy efficiency in buildings [3].

In order to address issues mentioned above, in 2008, European Union adopted 20/20/20 plan, which defines energy and climate policies (greenhouse gas reduction by 20%, energy consumption reduction or energy efficiency improvement by 20%, and 20% of energy obtained from renewable energy sources) to be implemented by 2020. The review of 20/20/20 plan and its impacts is given in [4].

The motivation of this work is to develop a low-cost system for remote monitoring of certain electrical quantities (voltage, current, power, etc.) and events (power down, power up, etc.). The goal is collect information about the power consumption from several (as many as possible) industrial, commercial and residential consumers in order to make analysis of collected data, and suggest methods and strategies for reducing energy consumption (or improving energy efficiency) in buildings and facilities. In literature, many solutions for wireless electrical energy monitoring (see [5]-[9]) are proposed and described. Some of them ([8] and [9]) are solution based on GPRS (General Packet Radio Service) communication. However, none of those monitoring platforms is suitable for analysis of energy consumption of both residential and industrial (or commercial) consumer types.

The paper is organized as follows. In Section II, the architecture of the implemented system is described. Section III presents measurement results with discussion, while Section IV contains some concluding remarks.

II. DESCRIPTION OF THE SYSTEM

The architecture of the implemented system is shown in Fig. 1. Microcontroller based monitoring unit is responsible for communication with the electricity meter and for initialization and control of the GPRS/GSM modem. Monitoring unit communicates with the remote web server over the wireless link based on GPRS communication. Application on the web server is responsible for interpretation of the data provided by each monitoring unit. Electrical quantities, needed for energy consumption analysis, are sent periodically to the web server with configurable period. Monitoring unit can also be asynchronously configured using the SMS (Short Message Service) service that is commonly available in GSM network.

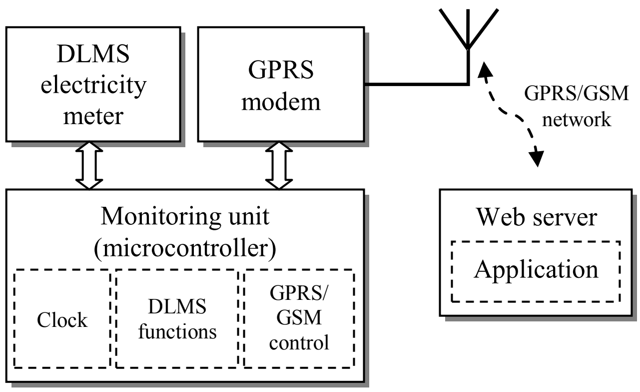

Figure 1. Architecture of the system.

A. *Monitoring Unit*

The realized system is shown in Fig. 2. Monitoring unit is implemented using PIC24FJ64GA002 microcontroller. As an electricity meter, MET410-E34N-I05 from "Mikroelektronika" was used. As a GPRS modem, we have used SIM900 module.

Monitoring unit is responsible for DLMS and GPRS/GSM, as well as clock functions in the system.

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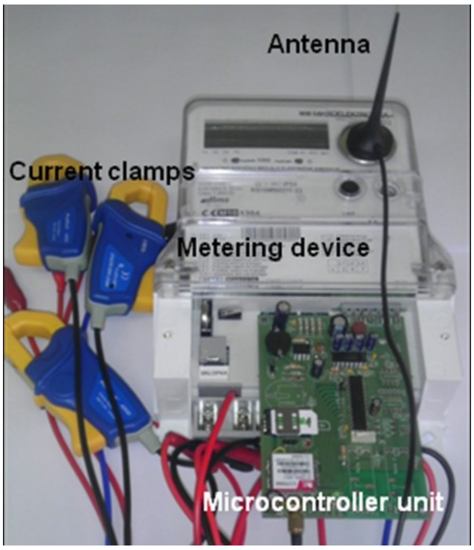

Figure 2. Realized system.

B. GPRS Communication Module

GPRS modem is responsible for communication with the remote web server that runs specially developed web-based application, which is accessible by the standard web browser and presents the results to the end user for the analysis. In order to minimize the cost of the system, we have used pull communication model. The advantages and possible application areas of this model are presented in [10]. The usage of pull communication model eliminates the need of public IP address for the monitoring system, which reduces the total cost of the system. Data and configuration parameters are exchanged between monitoring unit and web-based application by using HTTP-POST method. Several monitoring units can access the web server at a time. Configuration parameters can also be changed on demand for each monitoring unit by using SMS service.

C. DLMS/COSEM Metering Device

The DLMS/COSEM is a set of standards for electricity metering. This specification is published as an open standard within IEC 62056 specification [11]. DLMS, which stands for Device Language Message Specification, is a generalized concept for abstract modeling of object-related services, communication entities and protocols which was developed and maintained by DLMS User Association [12]. COSEM (COmpanion Specification for Energy Metering) defines a number of standard interface classes, called objects that, when instantiated, contain attributes and methods to describe some required functionality. It also describes metering specific objects based on OBIS (OBject Identification System) codes for use with (x)DLMS. xDLMS is an extension to DLMS and describes how to access attributes and methods of COSEM objects. More information about DLMS/COSEM and comparison with other smart metering communication standards can be found in [13].

DLMS/COSEM communication model is shown in Fig. 3. As can be from Fig. 3, DLMS/COSEM specification covers four ISO/OSI communication layers. Physical layer defines several standards for data exchange. In our system, we have used RS-232 standard since it is suitable for implementation in microcontroller environment. On data link layer, we have used HDLC (High-level Data Link Control) since it is the only protocol that can be used with RS-232 protocol. Application layer implements an interface to the data object model of the COSEM.

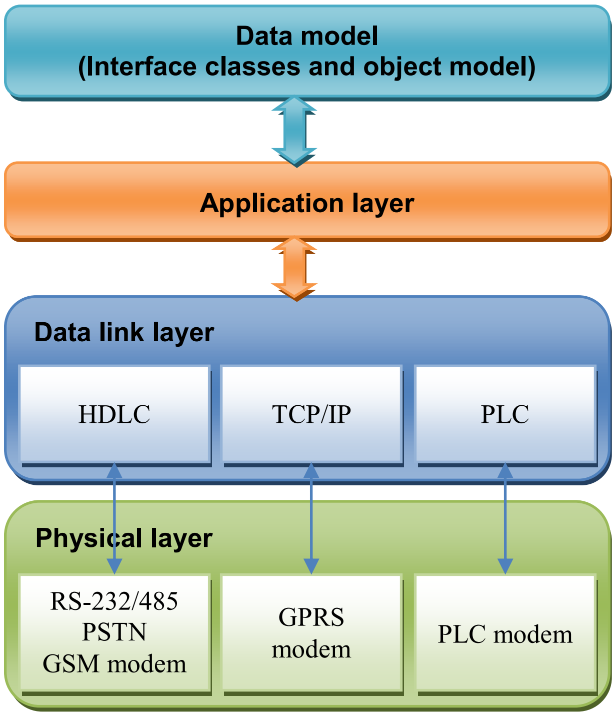

Figure 3. DLMS/COSEM communication model.

In DLMS, everything is considered to be an object with corresponding interface class. Special object type, known as *profile*, is used for non-volatile storage of predefined electricity objects and/or specific events. There are many profiles defined in DLMS standard that have specific purpose. For logging the electrical quantities, we have used *load profile*, and for detecting events (such as power down, power up, overvoltage, etc.) *quality profile* was used.

III. RESULTS AND DISCUSSION

The realized system was installed in the real environment for about 20 days (Fig. 4). The sampling period for storing data in *load profile* was set to be 5 minutes. Data were sent to server every hour. During the defined period, we have noticed no erratic behavior in the system. In order to assess accuracy of our system, we have also installed a professional power quality analyser (Metrel PowerQ4).

Implemented electrical energy monitoring system was configured to store the following quantities: instantaneous effective value of voltages and currents for three phases, power factors for three phases, and total active energy. Active, reactive and apparent power values are then derived from the measured quantities on the server side by the application. The results are then presented to the end user in graphical and table format. Also, there is support to export data in excel format for further analysis.

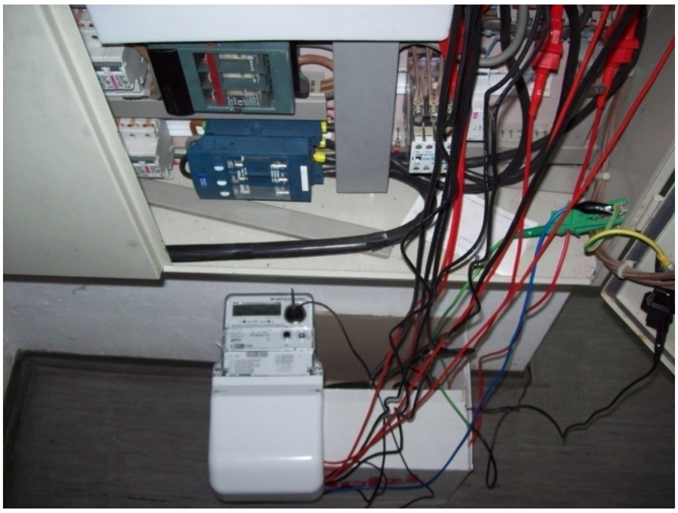

Figure 4. System in operational state on site.

In Fig. 5, active power, measured by our monitoring system and Metrel, is shown. Only period of four characteristic days (two working days, Saturday and Sunday) is presented in this figure. Other measurements are similar.

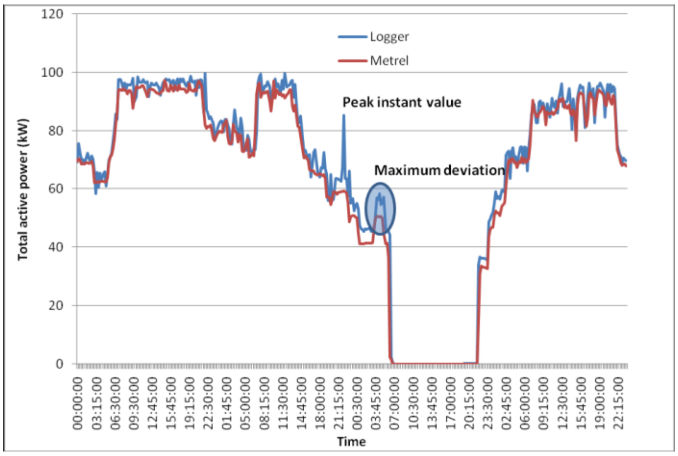

Figure 5. Active power measured by realized monitoring system and Metrel.

As can be seen, the values measured by our monitoring system are close to those obtained by a professional power quality analyser. Maximum deviation is about 10%, which is acceptable for purposes of qualitative analysis of energy consumption. One can also note a peak instant value in Fig. 5. This peak originates from the different measurement methods used by the Metrel and the electricity meter. Namely, Metrel measures the value of the active power that is averaged on the 15 minutes interval, while electricity meter measures the instant effective value of current and voltage, as well as instant value of the power factor that are used for active power calculation. As a result, we get the peak instant value of the active power that does not occur long enough to reflect the average active power measured by Metrel. We have confirmed this by analyzing the measured values around the peak.

IV. Conclusion

Energy efficient buildings and facilities in both industrial and residential sector is gaining the significant attention recently. In order to develop methods and strategies for energy savings in buildings and facilities, we need to measure and analyze certain electrical quantities.

In this paper, a low-cost architecture of a remote monitoring system based on GPRS communication was described and implemented. The system was installed in the real environment during the period of 20 days and we have noticed no erratic behavior during its exploitation. The measurements, compared with a professional power analyser, give promising results.

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