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Remotely Controlled Smart Metering for the Smart Home

Szabo Z. *,* Marcoň P. *,*** Roubal Z. *,*** Zezulka F. **,*** Veselý I. **,*** Saidl O. *** Lahodny L. ***

** Dept. of Theoretical and Experimental Electrical Engineering, Brno University of Technology, Czech Republic (e-mail: szaboz/macron/roubalz@feec.vutbr.cz).*
*** Department of Control and Instrumentation, Brno University of Technology, Czech Republic (e-mail: zezulka/veselyi@feec.vutbr.cz).*
**** Centre for Research and Utilization of Renewable Energy, Brno University of Technology, Czech Republic (e-mail: zezulka/veselyi/szaboz/macron/sajdl@feec.vutbr.cz).*

Abstract: The paper describes the design and management of smart sockets that are wirelessly controlled by a central unit. Each socket has an integrated sensor designed to measure the current consumption of the device; if necessary, this sensor can remotely disconnect the unit plugged in a concrete socket from the AC network. The final section of the article presents selected results from the relevant testing cycles.

Keywords: Smart metering, Controlled sockets, Home automation, Measuring power consumption.

1. INTRODUCTION

At present, the application of different tariffs during the day is envisaged to facilitate effective offtake of surplus electrical energy. In the past, the relevant time period was fixed, and the electricity meter consisted in a clock that flipped the tariff. Current electricity meters are operated via Ripple Control Receivers (RCR); the values measured by a meter at regular intervals are deducted by an employee of the distributor, and the data thus obtained are then used to process customer electricity bills.

Smart metering is a new concept within power measurement and constitutes a part of the smart grid, resulting in remote two-way communication between the measuring equipment and the data-central. This configuration enables us not only to collect the data from the consumption measurement but also to evaluate and manage the connection and disconnection of the measuring points. In this context and in conjunction with the principles of the intelligent home, it is also possible to inform the customer about the actual consumption, together with providing him or her with the perspectively lower energy-related expenditure. These factors will eventually facilitate the choice from a wide range of tariffs, thus reducing the cost of consumed energy at an even faster pace.

Another advantage offered by state-of-the-art smart meters consists in that the consumption is measured continuously, and the device stores the data in its memory. The meters evaluate and record even the "quality of supply", an indicator affected by overvoltage, undervoltage, or deviations from the desired frequency. In the future, the obtained data are to be transmitted without human intervention into a relevant data center to ensure better technical and network management for the purchase of electricity. Such communication will be also instrumental towards quick energy supply restoration in disturbances or even towards the so-called island operation; this latter concept, upon any interruption of major lines, ensures the connection of a concrete smaller region directly to local sources with balanced power and supply [1].

1.1 The Present and the Future of Smart Metering

In recent years, several problems occurred worldwide as regards the currently functioning networks; the difficulties were mostly related to electricity distribution. For this reason, Italy, as a pioneer within smart metering, launched a pilot project titled *Smart Metering* in the year of 2000. In Italy, the main impulse for the widespread conversion from mere measurement to advanced management was a major blackout in 2003; today, more than 30 million smart measuring points are installed in Italian homes.

Within the EU, massive implementation of the discussed technology is required by the European Directive-based project Grid4EU. It is expected in this framework that, by 2020, smart meters will have been installed in 80% of the distribution network; interestingly, 35 million meters are to be thus installed in France, 30 million in the UK, and 13 million in Spain. The last mentioned country has planned to install the devices by 2018.

In the Czech Republic, two of the largest electricity distributor, CEZ and E.ON, also intend to perform the installation of smart meters on a wide basis. Currently, a pilot project focused on smart metering is being executed; this project includes approximately 40,000 consumption points. At this stage, the system is testing the remote readings of consumed energy, together with monitoring the balance between the energy consumed and produced for the grid. Importantly, the energy supplied back to grid is generated by photovoltaic plants in individual homes, constituting a recent and much favored trend. Further, the technology could enable us to reduce unauthorized energy consumption [1].

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1.2 The Requirements

The major demands placed on smart metering include, above all, the power measurement and collection of information related to energy consumption. Power measurement is performed in the actual outlets, and we can thus control the power consumption of individual appliances. The measured consumption data are recorded and transmitted to a control unit. The unit then collects information from all outlets paired with it; if required, the unit is able to disconnect any appliance plugged in. Due to the controller being connected to the Internet via Ethernet, the system is capable of displaying information to consumers via a computer or smart phone.

2. THE MEASURING UNIT

To calculate the consumed active power, the following formula is used:

$$P = U.I.\cos(\varphi). \quad (1)$$

The equation shows the necessity to know the consumed current, voltage, and power factor. The measurements are carried out directly in the socket, and thus the consumption of the device plugged into the socket is measured immediately. The second variable that affects power measurement is voltage. The rated voltage in the Czech Republic is 230 V. This voltage can vary (according to the Czech National Standard) with a tolerance of ± 10%, depending on the supply point or on the distance from the kiosk substation. The voltage may therefore oscillate between 207 and 253V. The range of such changes may vary too, depending on the place of consumption; this variation, and also that of the calculated effective power, may amount to as much as 20%.

The last quantity influencing the discussed power measurement consists in the power factor, or the cosine of the phase shift between the current and the voltage; this quantity is, however, neglected in measuring power consumption within the home. Equation (1) for this measurement is simplified to apparent power.

2.1 The Block Diagram

The figures below show the block diagram of the system. Fig. 1 represents the control unit in its simplest possible form; Fig. 2 then presents the basic block diagram of a remotely controlled socket with an ammeter.

The system uses an Arduino development board. Supplying the board and all the components is ensured by an inverter with 5V output DC voltage. The input/output pins are used for simple signalling operation. The last three important peripherals are connected via the serial interface.

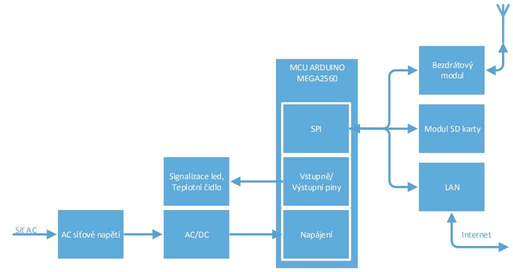

Fig. 1. The block diagram of the control unit.

The first element thus connected is an SD card module, which serves as the data storage; the second one consists in a wireless transmitter/receiver communicating with the outlets; and the third one embodies a unit for communication via the Internet.

The basis of the outlet module is again an Arduino development kit (yet a significantly smaller version in this case). Similarly to the previously mentioned application, this kit is fed by a voltage converter, whose input is connected to the main supply. Output pins are used to control the bistable relay, where a switch phases the voltage from the input to the output of the socket. To these contacts, an ammeter is connected in series to measure the current flow. The value of the measured current is then passed to the input pins of a microcontroller. As in the case of the control unit, a serial bus is employed to connect the wireless communication module.

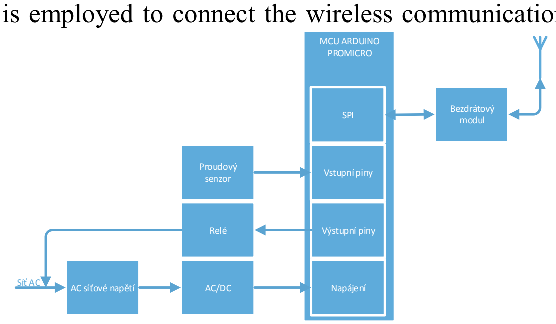

Fig. 2. The block diagram of the outlets.

Fig. 3 indicates the wiring of the outlets. The module is powered via terminals X1 and X3 designed for the neutral and phase lines, respectively; these terminals are connected to the voltage converter AC1 supplying the entire control system and the current measurement circuit. The current is measured by the circuit IC3 ACS712 between the terminals IP + and IP-. The circuit, according to the current, generates an output voltage Vout on the terminals, and this voltage is applied to the analog input A0. The phase voltage from the output terminal IP- circuit ACS712 is connected to the relay REL1. In the event of switching the phase voltage, the relay switches to the terminal X2.