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The Monitoring and Control Processes of a Renewable Energy Management System

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Abstract

This paper presents the monitoring and control processes as an important part of a renewable energy management system. The main purpose of the work is to build a management system for a commercial consumer (hydroponic greenhouse) that uses solar and biomass energy and to present the monitoring and control processes of this system. The proposed method is to use a micro-controller for the measuring of electrical and non-electrical parameters of the system, to process the data and to adapt a control process to the technological flux. The monitoring and control processes are implemented locally with USB-Serial connections to a PC, or from a web application. This approach leads to an easy management of new or existing systems by following and optimizing the technical processes and by obtaining energy efficiency.

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Keywords: renewable energy; solar power; photovoltaic panel; energy management; microcontroller; web application;

Nomenclature

RES	renewable energy sources
MOSFET	metal–oxide–semiconductor field-effect transistor
PV	photovoltaic
PWM	pulse width modulation

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1. Introduction

In the field of renewable energy management, some tools and components are necessary in order to determine the overall management of a system to work and run properly. The main idea of the paper is to present the methodology and implementation of the monitoring [8] and control processes of an electrical commercial consumer-system that uses renewable energy sources [9], in an off grid power network configuration. The most important part in developing a management system is represented by the information gathering about the existing and ongoing system. To study and model the management system of a power consumer with a defined technological process, the power consumption of the technological process is needed. This requested power depends on the technological process levels and on the RES availability.

The main problems are represented by the diversity of the multiple types of needed information (electrical parameters such as: current, voltage, battery state, PV parameters etc., and technological parameters of the power consumer system such as: temperature, light level, humidity, etc.) processing different data from different sensors or from other sources, by the data used locally or remote to the monitor the system and to control the hardware equipments (electrical consumers) for technological process and by the PV system battery management [1,2].

The proposed solution to solve the above issues is represented by the use of a dedicated embedded microcontroller system. The system is composed by one or by multiple microcontrollers for the entire hardware and software system management. The electrical measurements and the information gathering is performed by using the analog input ports for the monitored parameters and the control of the electrical consumers and battery charging is performed by using the digital and analog PWM wave outputs for driving power electronics, like high power relays and MOSFETs. The used methods and equipments are: a microcontroller development board (ATmega328), dedicated sensors for measuring the system parameters, an communication Ethernet shield for the web server, hosted and generated by the microcontroller, a html type web application with the purpose of illustrating the measured voltage, amperage, the power consumption and the PV charger state in real time and the property to switch on-off electrical loads from the distance.

2. Electrical system, monitoring and control equipments overview

The commercial consumer system is represented by a hydroponic greenhouse, powered only by renewable energy. The consumer is off grid and the only viable solution to power the consumers was to find suitable renewable energy sources, for both electrical and heat necessities. The electrical system is mainly based on a DC network for safety and other technological reasons. PV system [11] is used to power the electrical consumers and also battery banks for the energy storage are considered [2]. The PV-battery-consumer management [1] solution is detailed in chapter 3 of the paper. As mentioned before, the proposed approach to solve a number of tasks such as electrical measurements is to use a microcontroller development board. The main reason is to experiment, modify and improve the existing electric circuit. The development board used in the experiments is an Arduino board, with a ATmega328 microcontroller. The main advantages of the Arduino board are represented by the tested and reliable construction, with standard pin in/out configuration, communication through USB, his own boot loader and the Arduino IDE programming software [5]. Beside of these characteristics, it also has a large range of compatible modules: sensors, displays, high power shields for electric motors, wired and wireless communication shields and as a support for hardware and software it has a community forum. The electrical circuit is built around this development board using breadboards, where the different kind of sensors and secondary electrical circuits are placed. The breadboard contains: the DC sensor, the ACS712 integrated circuit (see Fig. 1), the Hall effect based sensor, the resistive voltage divider circuit for the voltage measurement circuit and the power electronics for the PV battery charging and also the electrical load controller circuit [4]. The communication with the network is realized through the Ethernet shield module (see Fig. 2), compatible with the Arduino development board and it has a dedicated library with the communication functions in the IDE [6]. The Ethernet shield is a modular device that can be attached on the development board. In this case the Ethernet shield connects to a router and it is programmed in the header file to have a local IP address and a unique MAC address on the network [6]. The web application is a generated HTML script, which offers the information under a HTML page, and as the control over the internet for different electrical loads, an address string read method is used.

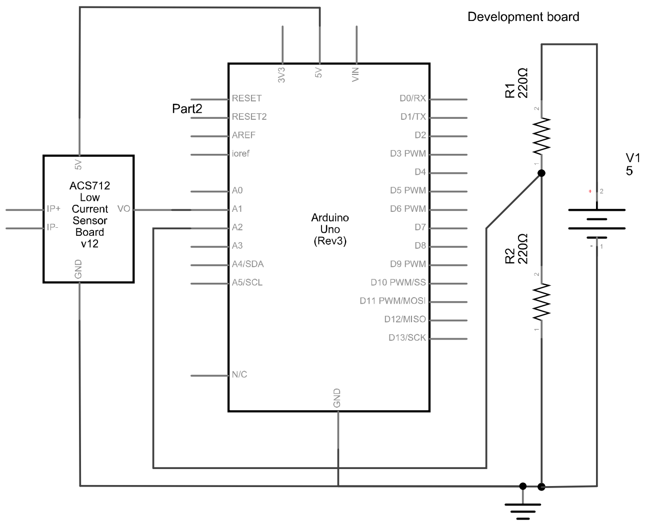

Fig. 1. Schematics of the current and voltage measurements with the Arduino (ATmega328) development board

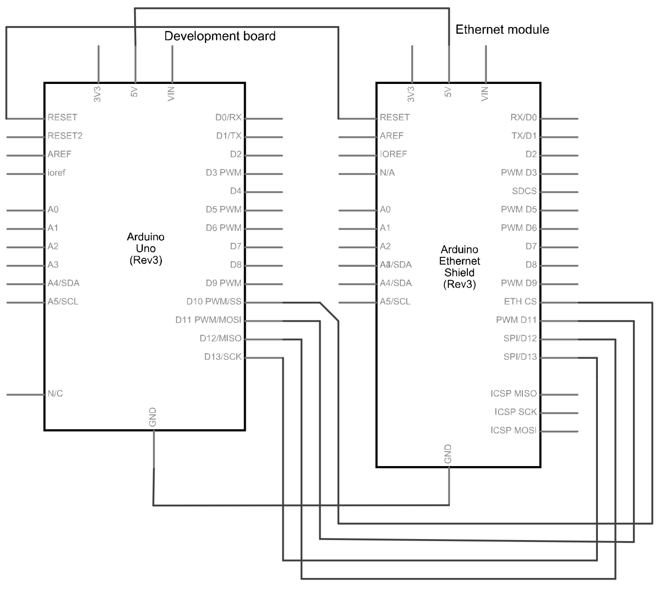

Fig. 2. Ethernet shield (W5100) and Arduino connection schematic

3. Monitoring and control processes implementation

The presented electrical schemes are conceived in the range of low voltage and currents. The circuits were implemented for study and experimental purposes and it represents real physical models, only in low powered scale.

As seen in Fig. 3, the schematic of the electric circuit for the monitoring and control processes that contains the PV panel 5V, as a power source, the capacitor filter, the voltage measurement point for the PV panel beeing the A2 analog input port of the microcontroller, where the analog measurements have a 10 bit resolution (0-1023) on the analog input port, from a 0-5V range is presented. The used function to read the analog measurements is analogRead(A2). Another important part of the circuit is the battery, a 3.7V LiPo with internal limiter and charge controller. The battery voltage and the charging level are monitored through the A0 point.

The Q1 MOSFET transistor represents the charge controller for the battery. It is a P channel transistor and it acts like a high side switch. The Q1 transistor driver is the Q3 NPN general purpose transistor with the base commanded through D5, connected to a digital pin. The control can be the ON/OFF type or PWM signal (8bit) through the digital (only PWM pin ports) output function, analogWrite(D5) depending by the PV panel voltage reading and the battery discharge level. If the battery is discharged below a certain admissible level, for example at 3.4V where the nominal voltage is 3.7V and the maximum charged level is 4.2V, and the solar power is available, which means that the PV panel generates around 4.5-5V, then the gate of the Q1 is switched on to open and charge the battery.

The actual switching can be the ON/OFF type of switching, where the gate is open until the battery is charged or PV panel voltage drops, or it can be controlled in PWM, with the analogWrite() function which has a scale of 0-255 values, where the 255 value is the 100% duty cycle. When full charging spec is available, the duty cycle is set around 90-95% and it is in function with the actual battery configuration. The battery supplies power to the electrical consumer (see Fig. 3). represented as a DC motor. The energy metering is in the front of the electrical consumer, in this case in front of the DC motor. The energy metering section is represented by the Hall effect current sensor ACS712. The current sensor has a sensitivity of 185mV/A and a range measuring of 0-5A. The sensor output is connected to the A1 analog input.

The microcontroller energy measurement involves components such as time, current and voltage. The time measurement is performed with the millis() function and converted in seconds. The other two parameters, the voltage and current are obtained by the analog reading of 150 samples over 2 seconds, and then an average value is calculated. The total current is incremented as the total current and the actual current readings sum. With the obtained values, the energy is the product of the current reading and voltage in time.

To control the electrical load, an N channel MOSFET was added into the circuit. The transistor Q2 is a low side switch with the gate controlled by the digital output D6 through a resistor. This part of the circuit is important for the load which is disconnected if the battery discharges beyond the minimal level. The microcontroller also transmits the values, the charging state and the consumer connectivity to the battery through serial data monitor, used for debugging and local monitoring and to a web application over the network.

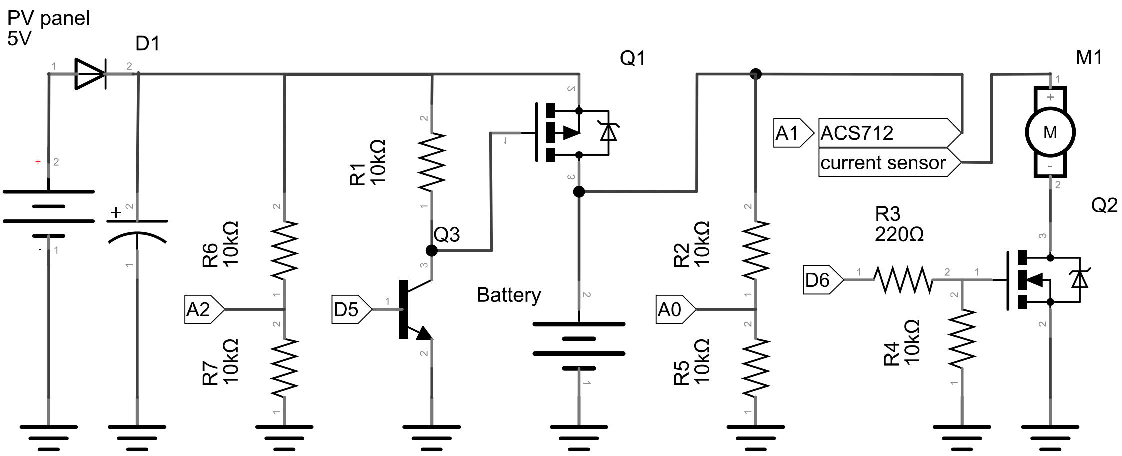

Fig. 3. Schematic of the circuit for monitoring and control of the electrical loads

4. Results

Fig. 4 presents the experimental workstation built for the system study and testing. In this phase, the monitoring and controlling process are done by a web application presented in Fig. 5.

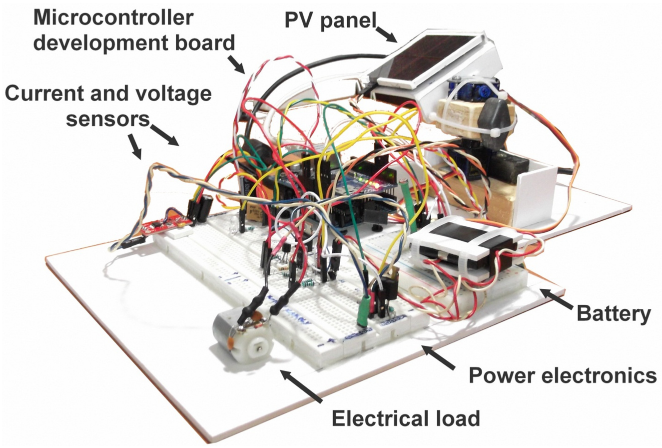

Fig. 4. Experimental stand containing: the microcontroller board, the Ethernet shield, the PV panel and the breadboards with power electronic components and sensors

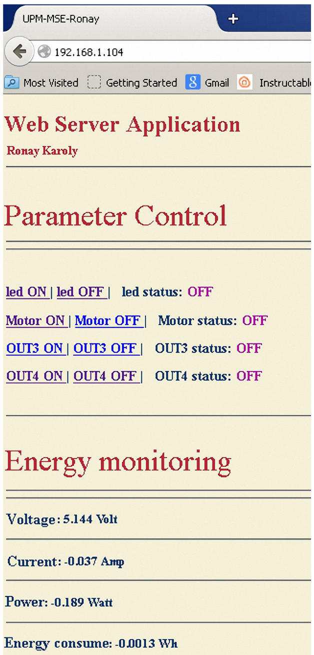

Fig. 5. Web application presented in internet browser

The web application can be accessed in the local network by typing the address given in the software. In this example, the address is 192.168.1.104. and it can be accessed from the internet, through a port needed for the local address in the router to obtain the WAN IP address. For example, in the 5.15.9.2XX:50006 address the last five digits represent the open port for the internal address. The sequence */?L1=0* at the end of the address represents the string that controls the L1 switch in the program, in this case a digital output and a LED for testing. The application reads the string and then executes the task. *L1=0* means that the output is low and *L1=1*, the output is at a high value and the LED is on. Also, the electrical load, in this case the DC motor, can be turned on and off from the web application and gets the status of the current state. The control can be done manually as described or automatically. Only the status symbol changes the feature to switch from auto to manual mode in the application. The next section is the monitoring one, where the PV panel voltage, battery voltage, battery status, the current used in the circuit, the actual power and the energy consumed can be seen. This mainly covers the parameters discussed and presented in the previous sections. The bottom of the application page shows the temperature and light level measurements. It can also be accessed by a mobile phone at an automatically page refresh rate of 5 seconds.

5. Conclusions and future developments

The paper presents the implementation, methods and obtained results of a software and hardware educational tool developed for a renewable energy management system. The monitoring and control processes represent an essential part in the energy management systems and the obtained experimental stand contains the necessary components of a functional model. The objectives were: the control through the internet browser of the electrical power consumers and the monitoring of their behavior and of other system parameters such as the state of the battery, the system temperature or the light level.

The experiment involving the development boards and breadboards was successful as the main circuit changed often, as the work was progressing and the changes were easily performed. The communication between the server part and the client was successful, but in the future it has to be optimized as sensors and other devices are attached. Also a future development is represented by a database for the web application, and a new user friendly type of interface, for a better understanding of problems. The database can also be included as a part of the management system and will contain more information regarding the system properties and functionalities.

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