



# A PROTOTYPE DESIGN OF A DEDICATED SMART HOME ENERGY MANAGEMENT SYSTEM

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JEL Category: **M15, O32**

## Abstract

*With the continuous rise of electrical energy costs for heating, cooling, and ventilation and the increasing number of energy-consuming home appliances, designing a cost-effective efficient residential electric energy management system has become crucial. This paper presents a prototype simulated design of a Smart Home Energy Management System (SHEMS), dedicated to the management of residential electrical energy according to the user-preassigned comfort requirements and cost criteria. All planted sensors and home appliances are controlled by one master microcontroller. The Proteus Software ISIS was used for all simulation results. The proposed application collects information from sensors to control the required home appliances by switching them ON or OFF based on a specified design algorithm. The sensors' assigned values and home appliance status are stored in a main database. The proposed design also allows home appliances to be monitored and controlled remotely via the Internet. Simulated results are given for a two-room residential home.*

**Keywords:** Smart home, home automation, remote controlling, system management, Web applications, Proteus ISIS

## 1 INTRODUCTION

With a Smart home energy monitor, you can save money and ensure that your home has the most efficient energy use possible. Nowadays it is of great importance to lower power consumption because of environmental concerns and energy

costs. A system to achieve this goal can substantially reduce the users' responsibility for action. Therefore, greater comfort can be reached while at the same time contributing to environmental protection (Kofler & Kastner, 2010). For the next few decades, the two major problems concerning energy are the greenhouse effect and the depletion of petrol resources especially the energy provided by oil and gas. Therefore, the need for another resource of energy such as wind or solar became a very important aspect. The role

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of a smart home dedicated to power management is to adjust the power consumption of the available power resources taking into consideration user comfort criteria. A smart home energy management system must reach a compromise between the priorities of the user in terms of comfort and cost while satisfying technological constraints (Golzar & Tajozakerin, 2010). On the other hand, due to the significant development of the Internet and computer technology, the Internet became a substantial element as a medium used in home automation systems, providing many features ranging from efficient use of energy to increase comfort (Gu, Diao, Liu & Zhang, 2011), (Bos, Chmielewski, Hoepman, & Nguyen, 2007). Along with the mobile phone's popularization and the radio control technology's maturity, getting information about home status based on GSM network service and wireless communication via SMS message is to become a proper choice, because it gets rid of the fetter of wires, and meets the application need conveniently with a lower cost (Yang, Zhang, & Sun, 2010). Intelligent home system design has become one of the favorite current research topics

for the scientific community worldwide. This paper will present the design and development of simulation algorithms for a residential home automation controlling system.

## 2 PROPOSED SMART HOME ENERGY MANAGEMENT SYSTEM (SHEMS)

The general architecture of a designed control system is shown in Fig. 1. The home can be monitored via a PC which is connected to the controllers through a serial port (RS232) as well as a home-based web server that can be accessed from anywhere in the world after logging in successfully. This architecture has been adapted with modifications from the work done by (Golzar & Tajozakerin, 2010). Many improvements were added to the original architecture. The auxiliary controller is added for security purposes. The GSM network has been added to the architecture because it is a proper choice and meets the system's needs at a lower cost. The GSM network can also send information to homeowners about their home status via SMS message.

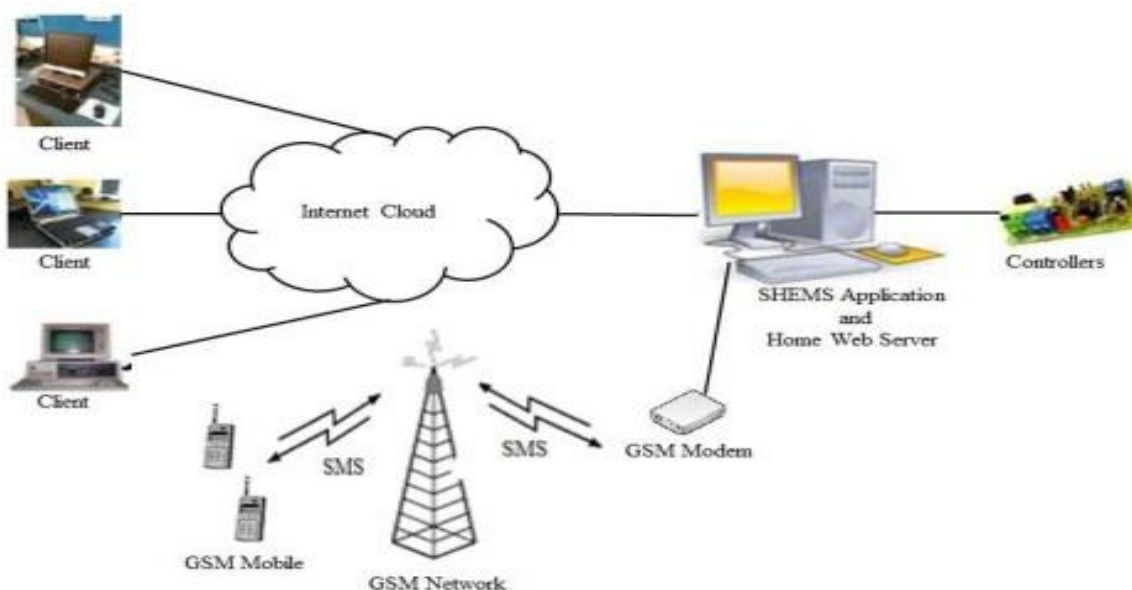


Fig.1 General Architecture of the Proposed SHEMS

### 2.1 Design components

ATmega32: This microcontroller has been used due to the availability of built-in ADC pins. It is programmed by WinAVR software because of its simplicity and ease of use (Atmel Corporation, 2003).

Motion Sensor: This Passive Infra-Red (PIR) pyroelectric device detects motion by measuring changes in the infrared levels emitted by surrounding objects. It is used to determine the presence of occupants inside their premises (Al-Arif, M.R., Kadir, Morshed, Ferdous, Alarm, &

Haque,2011), (Texas Advanced Optoelectronic Corporation, 2007).

Temperature Sensor: The LM35 is a precision integrated-circuit temperature sensor, with an output voltage linearly proportional to the Celsius temperature and can be used to measure the temperature (Al-Arif, M.R., Kadir, Morshed, Ferdous, Alarm, & Haque,2011), (Parallax Inc., 2005).

Light Sensor: This TSL251RD family of sensors converts light intensity into voltage. These devices simplify the design by integrating a photodiode and a trans-impedance amplifier on a single monolithic IC. This family provides a linear output voltage that is proportional to the light intensity (National Semiconductor, 2013).

Door Sensor: The door sensor is a magnetically operated reed switch. This type of switch is chosen since it is easier to accommodate the loose mechanical tolerances of the door movement. The magnet is placed on the door and is close to the reed switch when the door is fully closed the signal is grounded. When the door opens, the magnet moves away from the switch, the switch is opened and a high signal is detected (Atmega Editor, 2012).

Charge sensor: This sensor is used to measure the charge of solar cell batteries. A 12 V sealed lead-acid battery provides different voltages depending on its state of charge. The output has a voltage of 12.6 V when "Full" and 11.6 V when "Empty". The battery's charge state can be

measured using a voltage divider circuit because the maximum voltage of the microcontroller input pins is 5 V (Pavlov, 2017).

Keypads, LCDs, Relays, and many other devices are also used to build the hardware. Simulation tools using Proteus ISIS software are also used to simulate the circuit (Proteus, 2020). The software is used to draw schematics and simulate the circuits in real-time. The simulation allows for human access during run time, thus providing real-time simulation.

## 2.2 Hardware subsystem

The hardware architecture of the proposed SHEMS is composed of two microcontrollers; a central controller and an auxiliary controller, selected from the AVR family (ATmega32), (Atmel Corporation, 2003).

The Central controller: The basic idea of the central controller is derived from the work done by (Golzar & Tajozakerin, 2010). It consists of a microcontroller (ATmega32), a graphical LCD, several sensors of different types; several on/off actuators (relays), and a COM port (RS232), see Fig. 2. The digital sensors are connected directly to the port of the microcontroller whereas the analog sensors are connected to the internal A/D circuit which converts their analog readings to digital. The essential function of the central controller is to read sensor values, send them to the SHEMS, and receive data to turn on/off the actuator from the SHEMS application based on the algorithms and readings on the sensors.

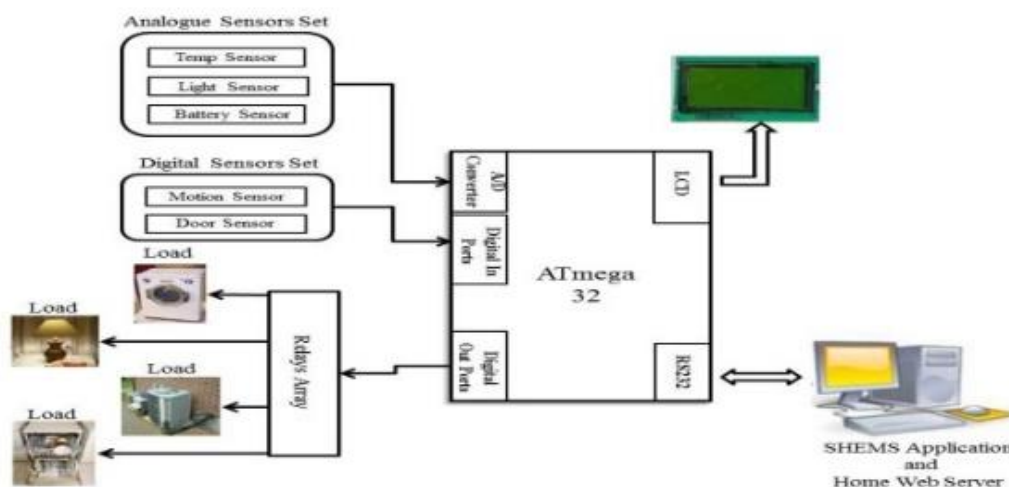


Fig. 2 General Architecture of the Central Controller

The auxiliary controller: It consists of a microcontroller (ATmega32), a graphical LCD, a keypad, and a COM port (RS232) to construct the auxiliary controller as shown in Fig. 3. The main goal of the auxiliary controller is to give authority to the homeowner to enter the home by pressing password via the keypad on the controller when the security is enabled in the home.

application system, a website running on the home-based web server, a SQL Server based database, and an SMS server. SHEMS application collects information from sensors and turns on/off home appliances based on proposed algorithms. SQL Server is necessary to build several tables for the SHEMS system, each one for a specific purpose.

### 2.3 Software subsystem

The proposed SHEMS software subsystem architecture is illustrated in Fig. 4. It consists of an

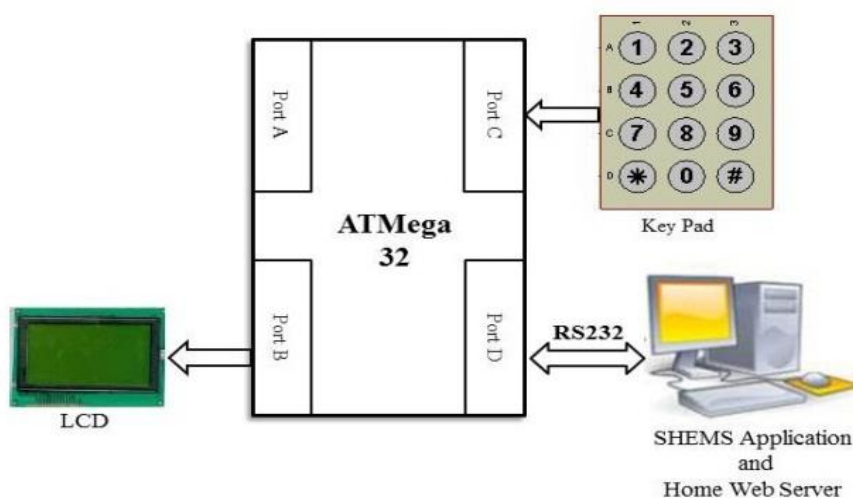


Fig. 3 General Architecture of the Auxiliary Controller

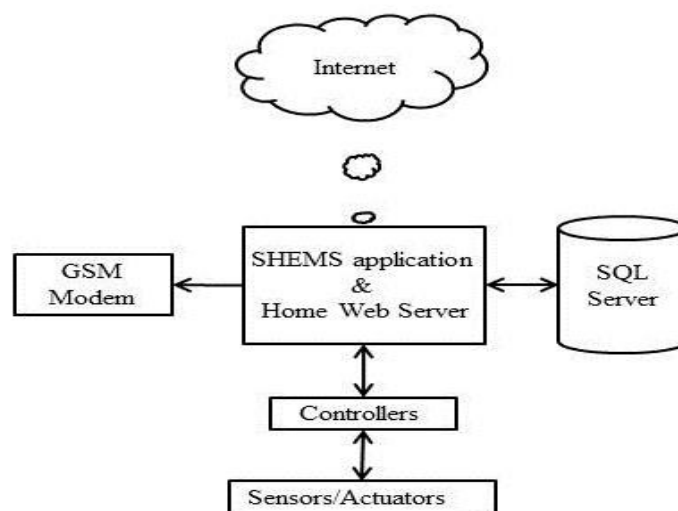


Fig. 4 Proposed SHEMS Software Architecture

## 2.4 Home Appliances connection

The home appliances are grouped into two categories based on power consumption. High power consumption appliances like air conditioners and low power consumption appliances like light bulbs. They are also classified into three categories based on how frequently they are used; continuous, frequent, or occasional. The first group is continuously used throughout the day; they need the power to always be on, like a refrigerator. The second group is used frequently throughout the day like TV and PC. The last group is used occasionally like a hair dryer. A consumer shows concern about the power usage that is frequently used, see Table 1.

Table 1. Appliances category based on usage

Type of use	Appliance
Continuous	Refrigerator, telephone, water purifier, etc.
Frequent	TV, Personal Computer, washing machine, cooker, light, dishwasher, air conditioner, fan, etc.
Occasional	Microwave Oven, electric oven, hair dryer, video game console, etc.

The automation of home appliances will be applied to frequently used groups. Low-power consumption appliances are connected to solar cell power and home electric power supply via relays which exchange between them based on the state of the charge of the solar cell battery which is monitored by a charge sensor. High-power consumption appliances connect to a home electric power supply only.

## 3 SHEMS SCENARIO

Three modes are applied in SHEMS which depend on several factors according to the power management, the inhabitant's existence, and the inhabitant's desire to control the home appliances.

### 3.1 Computer-based mode

This mode is applied when the motion sensors detect movements in the rooms of the home. The

information about the home environment is taken directly from sensors and then sent serially via RS232 to the home server. The information which is collected from the sensor is stored in database tables. Database tables are updated with every reading of the sensors set. The decision is taken based on developing algorithms.

### 3.2 Leaving mode

This mode is applied when the inhabitants leave home and motion sensors detect there is no one in the home and the door sensor is closed. When leaving mode is activated, home appliances will be turned off and the internet enables the remote control. The homeowner may be interested to turn on the air conditioner to make the home at a suitable temperature. In this mode also, if someone tries to enter the home without entering the password via the keypad of the auxiliary controller, the home server remains on leave mode, and an alarm message is sent to the homeowner.

### 3.3 Manual mode

In this mode, home appliances can be controlled by the homeowner regardless of the sensor's value and algorithms as an option to make it more comfortable. In addition, the homeowner can take voluntary actions to reduce home consumption by turning off appliances, lights, etc.

## 4 IMPLEMENTATION OF SHEMS

The SHEMS programs are implemented by applying the proposed algorithms and modes that were explained. These are achieved by using Visual Basic, ASP. Net Web Site and SQL Server Management Studio. The central and auxiliary controllers are both simulated using the Proteus Software ISIS.

### 4.1 Central controller

The central controller is composed of five parts and simulated using Proteus ISIS, see Fig. 5. These parts are the microcontroller (ATmega32), sensors attached to port A, relays attached to port B, LCD attached to port C and COM port attached to port D.

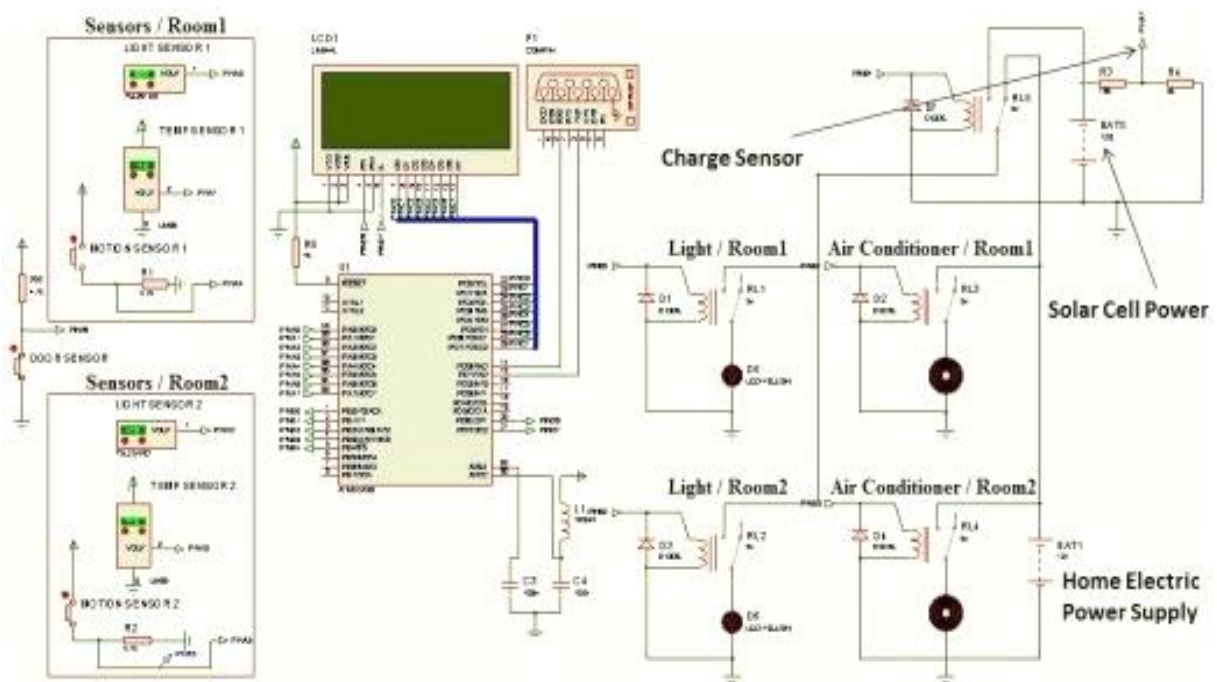


Fig. 5 Simulation of the Central Controller Circuit

#### 4.2 Auxiliary controller

As shown in Fig. 6, the auxiliary controller is composed of four parts. These parts are tested and simulated by using Proteus ISIS. These parts

are the microcontroller ATmega32, Keypad which is attached to port C, LCD which is attached to port A and COM port which is attached to port B.

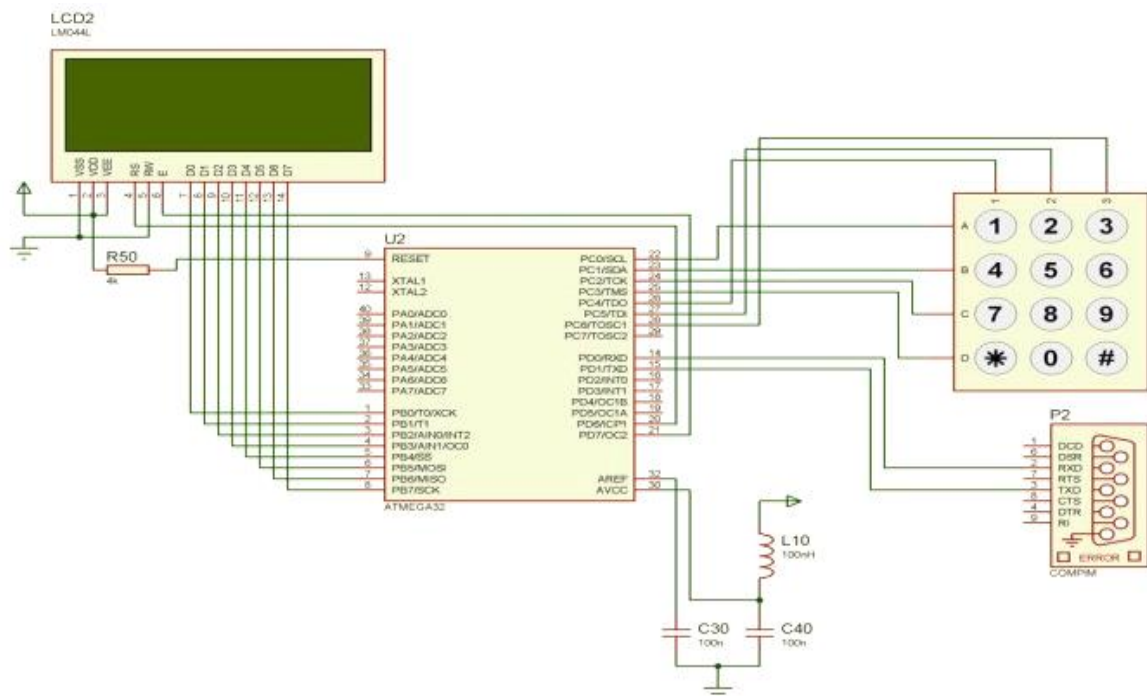


Fig. 6 Simulation of the Auxiliary Controller Circuit

## 5 SHEMS SIMULATION RESULTS

The SHEMS application monitors and controls the central and auxiliary controllers and manages the database and SMS server.

### 5.1 Main form of SHEMS

The main form of the SHEMS application has buttons to control and view information about the system. A panel in the main form is the control panel used to connect with the central controller, see Fig. 7.



Fig. 7 Main Form of SHEMS Application

### 5.2 Room setting form

The SHEMS application in this work is designed for a house with two rooms with two home appliances in each (air conditioner and light). Therefore, a room setting form controls home appliances in two rooms. The room setting form

represents manual mode. Each device has the following three states: (i) ON used to turn on the device regardless of home environment; (ii) OFF used to turn off the device regardless of home environment; (iii) AUTO the device turns on/off based on data received by sensors, see Fig. 8.



Fig. 8 Room Setting Form of SHEMS Application

### 5.3 System information form

This form displays all information about sensor readings, home appliances state, the solar cell

battery state, the state of charge (charging or discharging), and the total power consumption at that time, see Fig. 9.

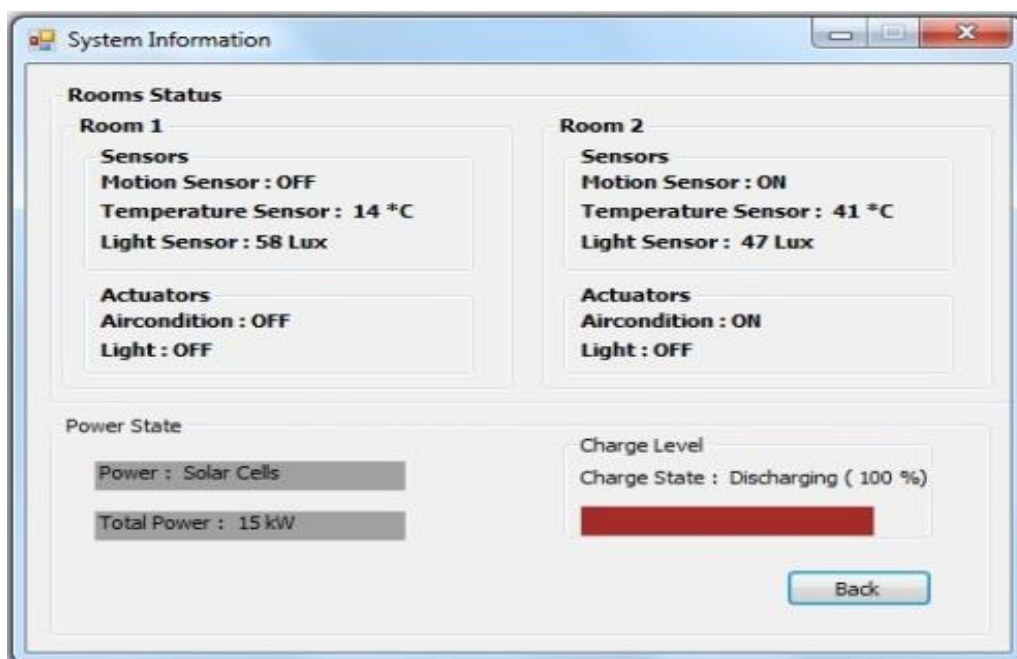


Fig. 9 System Information Form of SHEMS Application

### 5.4 SMS server form

This form is responsible for sending an alarm SMS message when someone attempts to enter the home without inputting the password of the auxiliary controller. This is done by entering the

phone number that will receive an SMS message. The serial port must be selected to connect to the modem, and finally, the connect button must be clicked. A further option is to specify the number of SMS messages that can be sent during security system penetration, see Fig. 10.

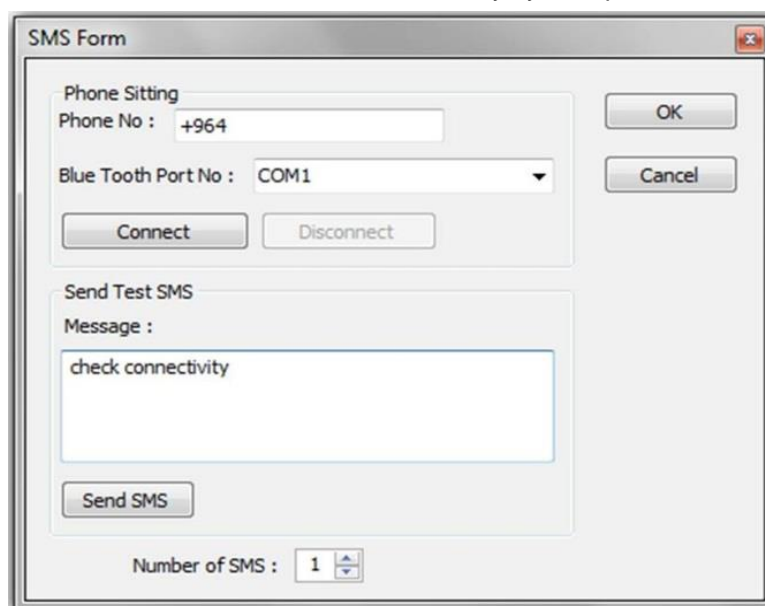


Fig. 10 SMS Server Form of SHEMS Application

## 6 SMART HOME CONTROL WEB PAGE

The SHEMS system collects useful data from sensors about the home environment and stores them in a database that can be used by the Smart Home Control Web page. The website is designed to allow the homeowner to see the home status and to be able to control home appliances remotely.

### 6.1 Home Page

The homeowner must have a username and password to enter the home page of the smart home control web page, see Fig. 11. The home page contains all the necessary information which is updated continuously about sensors, home appliances, and power state, see Fig. 12.

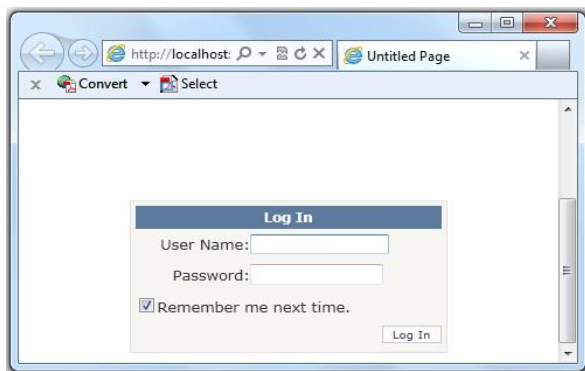


Fig. 11 Login page

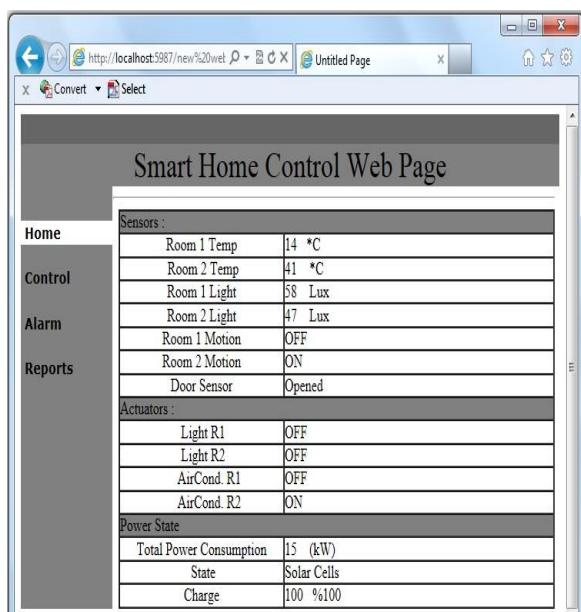


Fig. 12 Home Page of Smart Home Control Web Page

### 6.2 Control Page

On this page, the homeowner can remotely control

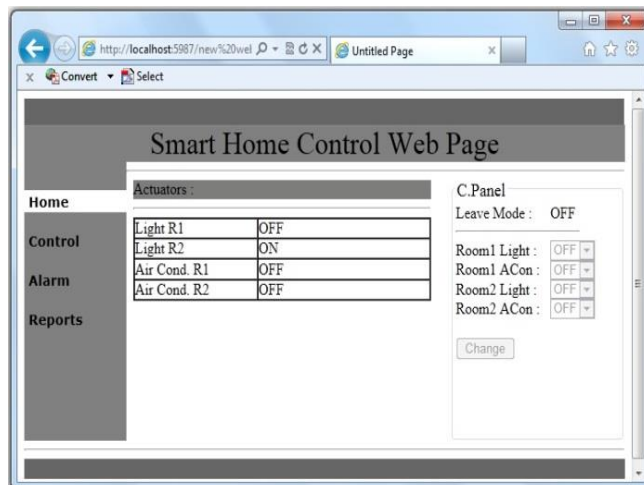


Fig. 13 Control Page of Smart Home Control Web

the home appliances by selecting ON or OFF of specified sensors and then clicking the change button. This is done if the home is in leaving mode else the options of control will be grayed and disabled. Fig. 13 shows the control page of the smart home control web page.

### 6.3 Alarm Page

This page displays information about home



Fig. 14 Alarm Page of Smart Home Control Web Page

security, whether the home is secured or penetrated in a leave mode state. The alarm message which appears on this page differs according to the sensor detection. This page also loads the date and time, see Fig. 14.

## 7 CONCLUSIONS

In general, smart homes are becoming promising technologies for the near future and are based on the principle of requiring the least possible human intervention while maintaining the optimum comfort level and minimum energy consumption.

Therefore, after finishing this prototype design of SHEMS and implementing the proposed algorithms using the Proteus Software ISIS, the following conclusions may be drawn:

- The communication between controllers and the PC is fully textual. Therefore, each packet received from the controller is separated by a

“dot” to enable recognition of the value of each sensor and store them in a database.

- To make a compromise between the priorities of the inhabitants in terms of comfort and energy management, requires the creation of three modes in SHEMS. These are computer-based mode, manual mode, and leaving mode.

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Received for publication: 28.05.2023

Revision received: 07.06.2023

Accepted for publication: 06.07.2023

### **How to cite this article?**

#### Style – **APA Sixth Edition:**

Al-Naima, F. M., & Kareem, H. H. (2023, July 15). A prototype design of a dedicated smart home energy management system. (Z. Cekerevac, Ed.) *MEST Journal*, 11(2), 01-11. doi:10.12709/mest.11.11.02.01

#### Style – **Chicago Sixteenth Edition:**

Al-Naima, Fawzi M., and Hassanain H. Kareem. "A prototype design of a dedicated smart home energy management system." Edited by Zoran Cekerevac. *MEST Journal* (MESTE) 11, no. 2 (July 2023): 01-11.

#### Style – **GOST Name Sort:**

**Al-Naima Fawzi M. and Kareem Hassanain H.** A prototype design of a dedicated smart home energy management system [Journal] // *MEST Journal* / ed. Cekerevac Zoran. - Belgrade – Toronto : MESTE, July 15, 2023. - 2 : Vol. 11. - pp. 01-11.

#### Style – **Harvard Anglia:**

Al-Naima, F. M. & Kareem, H. H., 2023. A prototype design of a dedicated smart home energy management system. *MEST Journal*, 15 July, 11(2), pp. 01-11.

#### Style – **ISO 690 Numerical Reference:**

*A prototype design of a dedicated smart home energy management system.* **Al-Naima, Fawzi M. and Kareem, Hassanain H.** [ed.] Zoran Cekerevac. 2, Belgrade – Toronto : MESTE, July 15, 2023, *MEST Journal*, Vol. 11, pp. 01-11.