Renewable Energy Management System for Smart Home

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Abstract

Energy consumption increases day by day as more appliances used in today’s home. Increasing energy demand and limitations of fossil fuels, time to use the renewable resources for energy generation in domestic areas. This paper proposes renewable energy management system architecture for smart homes in which energy consumption and generation simultaneously for efficient energy, minimization of cost and environment friendly. Microcontroller based energy management module with ZigBee is used to control and monitor the energy consumption of smart home. The propose system is used the solar and wind resources as these are not always available, also introduce water resources to generate the electricity. The charge controller, battery bank and battery level monitoring are used to provide stable energy module for smart home. Energy consumption should be minimized by users, can access home energy information through smart devices. The propose system save the limited fossil fuels, generated efficient energy and minimize energy consumption.

Keywords: - Renewable Energy Sources (RES), Renewable Energy Management System (REMS), Charge Controller, Battery Level Monitoring, ZigBee

1. Introduction

Today’s energy crisis becomes global problem for the world. We need to reduce the wastage of electricity in day to day life. But the consumption of electricity increases year to year as more home appliances are installed. So, today’s the energy saving becomes first priority. Because of the limited fossil fuels, these generations have started the use of different ways of electricity generation like using the renewable energy sources. Solar, wind and water sources are easily available anywhere on earth. Renewable Energy Sources (RES) as an important approach to meeting rural energy needs, reducing pollution, and promoting economic development. A Smart Home is a house that uses new technologies to monitor the in-house temperature, out-house climate changes, control and monitor the home appliances and communicates with the worldwide. Smart homes have the potential for increasing energy efficiency, decreasing costs of energy use, decreasing the carbon footprint by including renewable resources, and trans-forming the role of the occupant[1][2][3].This project proposes a novel model of smart homes for rural areas where reaching or 24*7 power supply is one big question till date.

Several projects have proposed to minimize the electricity consumption using Home Energy Management System (HEMS). Efficient HEMS [5], [6] includes the support of automatic and manual scheduling and control of the devices, continuous monitoring and efficient notification. This work considers a device control module to handle networked home appliances; it does not consider the energy generation. A green HEMS that monitors, compares, and controls home appliances has been proposed [7], [8]. It does not consider generation of electricity as using renewable energies. The solar and wind power system are used, energy management systems have been studied to enhance smart home [9] [10] [11]. These works consider only renewable energies, not consider the energy consumption of the home.

This paper presents a design of the smart home energy management system using renewable energy sources. It is associated with user interface, home server, microcontroller interface and Renewable energy management system interface.

The report is organized as follows. Section 2 proposed the architecture of Renewable Energy Management System (REMS). Section 3 shows several hardware implementation and section 4 software implementation in detail and section 5 shows the results of the system. Finally, section 6 conclude and summarize the paper.

2. System Architecture of Renewable Energy Management System for Smart Home

2.1 System Architecture

Fig.1 shows the system architecture of Renewable Energy Management System for smart home which generate energy using RES and minimize the energy consumption using remote access of home appliances. In the energy consumption part, the energy consumption of home appliances is monitored through users mobile to know about the current status of the appliances. The user can see the current status of their home appliances anywhere of the world and control it via graphic user interface (GUI) of the home. In the energy generation, RES used to generate electricity as the solar panel generates DC voltage and the wind and water turbines generates AC voltage. Generated
electricity stored in battery bank, which have controlled by use charge controller module. Charge controller unit maintained the charging voltage, control charging current and protects battery from being overcharged. ARM 9 microcontrollers used to control relay module to control the home appliance.

ARM9 provides various advantages like high performance, very low power consumption, compressive on-chip debug, design flexibility and scalability, optimal price, fast growing support eco-system. ZigBee module provides wireless communication between microcontroller and home server. For home automation, first the user call the home automation web page and select home appliances, which send commands and instructions to server via internet(GPRS, Wi-Fi), where top-level directory of the web application hierarchy is also the document in root of the application. We will place the HTML files and JSP pages that comprise the application’s user interface. When the system administrator deploys the application into an Apache Tomcat server, need to locate a context path to the application. Thus, if the system administrator assigns the application to the context path then a request URI referring to.html will retrieve the index.html file from the document root. User can access the home server which is connected to internet via modem or Wi-Fi. The Home Server connects the hardware module where home appliances are connected. It has application programming, which communicate with user via GPRS and microcontroller through ZigBee. Home server sends command to microcontroller through ZigBee transceiver. Microcontroller get signal and run accordingly to carry out specific operations. ZigBee used to communicate the microcontroller to home server and provide a wireless interface with wide range. Control the relay module as per the user request and command received from home server via ZigBee. Relay is using to switch the appliances, which user sends commands to microcontroller. Proposed system provides the home automation means controlling of appliances can be done remotely. Appliances controlled by relay which is connected to the controller. Battery bank is used to store DC voltage generated by solar, Wind, and water resources. Battery Level Monitoring (BLM) used to monitor the voltage level of battery bank. Charge controller used in the project for following purpose. To maintain the charging voltage, Control the charging current, Protect battery for being overcharged. Proposed system energy generates from Solar, Wind as well as Water resources. Renewable energy sources as solar, wind and water that is used in the project, which used a clean and cost effective that considered to be an opaque medium against harmful reactions to our environment. Solar panel can generate 3w, 6V DC, water turbine 5-10 VAC, wind turbine, 5-10 VAC.

2.2 Software Architecture

Fig. 2 shows the software architecture of the proposed system. Home Server is a centralized controller and user interface for a smart home system. It also provides a simple Web browser for information and guidance from the Internet. Internet technologies such as TCP/IP, HTML, JavaScript, Web Server and Cipher Security are ported into the embedded home server which is controlled and monitored with HTML interface from both in side home and out from home via the Internet. Property and status of appliances are expressed with their structure by HTML and JavaScript, whose description capability is excellent. Database (MySQL) is a popular choice of database for use in web applications, and is a central component of the widely used LAMP open source web application software stack (and other 'AMP' stacks). LAMP is an acronym for "Linux, Apache, MySQL, and Perl/PHP/Python." Free-software-open source projects that require a full-featured database management system often use MySQL. Windows XP is an operating system. An operating system (OS) is software that manages computer hardware and software resources and provides common services for computer programs. The operating system is an essential component of the system software in a computer system.
Application programs need an operating system to function. Web Application programs are used to control appliances in a house. Application service providers can monitor/control appliances remotely and can develop various application services for home users with network access techniques using HTML and JavaScript. A Graphic User Interface (GUI) web application created, so the user can easily access the home server status. We built the web application to monitor the appliances status and the power consumption. The user can have their secured login id and password which provide security profile to home users. The users can create own login id and password in registration window. The On/Off control of home appliances can be done in home web window.

3. Hardware Design

Process to develop a Renewable Energy Management System for Smart Homes involves both Hardware and Software developments. Hardware development needs to implement the proposed system a module to module with following methods.

- It is a renewable energy generation model. First, It is necessary to select the energy generation source as solar, wind and water energy system, a 6V battery need to store the generated energy, a charge controller need to control the battery charging, a battery level monitor need to monitor the status of battery charger all implemented first and simulate properly.
- ARM -9 microcontrollers is selected due to extremely low power consumption and on the basis of I/O requirement, memory requirement, execution time and communication protocol. A relay module is connected to the controller to switch the home appliances. A light and a fan are connected to relay module. This is implemented in mbed and compiled the code and imported on microcontroller.
- ZigBee Module is selected to provide wireless communication between home servers to the microcontroller for wide range. ZigBee communication implemented with microcontroller using mbed development tool and with home server to plug with USB.
- Integration of all components is done with the help of the specification.

3.1 Microcontroller Module

Microcontroller interfacing module, in which select a ARM 9 FRDM-KL25Z microcontroller as shown in fig. 4 is an ultra-low-cost development platform for Kinetis L Series KL1x (KL14/15) and KL2x (KL24/25) MCUs built on ARM® Cortex™-M0+ processor. Features include easy access to MCU I/O, battery-ready, low-power operation, a standard factor with expansion board options and a built-in debug interface for flash programming and run-control. Microcontroller module receives controlling command through ZigBee and takes decision to switch ON/OFF the relay module circuit unit. Fig. 3 and 4 show the interfacing and hardware of microcontroller.
This module has a relay unit as shown in fig. 5, which requires +6 VDC for its proper operation. This unit provides switching of home appliances connected to the pin of relay. The BC547 transistor is used as an electronic switch to pull down the voltage of coil to the ground. This helps in closing the circuit between the power supply and the ground through the coil. The switching of transistor is done by applying nearly 6V on its base through the resistor which limits the current. A relay is a simple electromechanical switch made up of an electromagnet and a set of contacts using SPST (Single Pole Single Throw) Type Relay. It will be used to switch ON OR OFF the electrical path between two contacts.

Now this module includes the programming for controller and downloading the program in controller. Using ARM mbed which is IoT Device Platform provides the operating system, cloud services, tools and developer system to make the creation and deployment of commercial, standards-based IoT solutions possible at scale [13]. Pins have mapping for relay and ZigBee on the board. Write the code and import in mbed compiler and selected the FRDM-KL25Z as platform from the top right, compiled the code. Creating a program in mbed Compiler as following steps:

1. Step 1 - Open the mbed Compiler.
2. Step 2 - Create a New Program.
3. Step 3 - View the default Program Source Code.
4. Step 4 - Compile and Download the Program.

Downloading program in ARM FRDM-KL25Z as following steps:

1. Step 1 - Save a program binary (.bin) to the FRDM Platform.
2. Step 2 - Press the Reset Button.
3. Step 3 - Hello World!
4. Step 4 - To download a different program.

Program loaded into the board. After reset button on board code will run and now tested the mapping of hardware is working properly. Fig. 7 shows the process flow chart of the controller control the relay and ZigBee. When user select the appliance on GUI page and a start signal sends to web server to home server. Home server sends signal command to microcontroller via ZigBee Transceiver module. Now, microcontroller initializes the input / output and it print hello world. Microcontroller wait for the controlling commands and process the On/Off the appliances as user selected.
3.2 Renewable Energy Management System Module

REMS module includes a charge controller unit. This unit needs to charge lead acid or Ni-Cd battery using solar, wind and water energy power, to maintain the charging voltage, to control the charging current, and to protect battery for being overcharged. Relay RL1 and RL2 and a variable voltage regulator IC LM 317 used to select the energy system when all sources are available at a time. 6 volt DC is available from solar system, water system and wind system to charge the 4.5AH battery bank. Fig. 8 shows the circuit diagram and fig. 9 implemented hardware of the unit. Charging current passed through D1 to the voltage regulator IC LM 317. By adjusting its Adjust pin, output voltage and current can be regulated.

Variable resistor is in between the adjust pin and ground to offer a sufficient output voltage of 6 volts to the battery. Resistor R4 and R8 Restrict the charging current and diode D3 and D4 prevents discharging current from the battery. Transistor Q1 and zener diode (D1, D2, D3, and D4) act as a cut off switch when the battery is full. Normally Q1 is switch to off and battery gets charging current. When the terminal voltage of the battery rises above 6.8 volts and zener diode conducts and provides base current to transistor Q1. It then turns on grounding the output of LM317 to stop charging.

REMS module have a Battery Level Monitor unit, which can be used to monitor the voltage of 6V, 4.5AH battery bank. Fig. 10 and fig.11 shows the circuit diagram and implemented hardware of the unit. LM3914 is very easy to apply as an analog meter circuit. A 1.2V full-scale meter needs only 1 resistor and a single 3V to 15V power in the buffer drives 10 individual comparators to the divider. The non-linearity can thus be held typically to $\frac{1}{2}$%, even over a different temperature range.
This circuit contains adjustable reference and use accurate 10-step voltage divider. The low-bias-current input buffer accepts signals down to ground, or $V_-$, needs no protection against inputs of 35V above or below ground.

Fig. 11 Battery level Monitor Module Hardware Setup

Renewable energy generation unit uses solar, wind and water system to generate electricity to power up the smart home appliances. Fig. 12 shows the renewable energy system used in the system for electricity generation and a battery bank used to stored electricity for further used. Renewable sources as we know not a stable resource to generate constant energy. A battery bank used to store and stabilized the system.

A PV solar cell system as shown in Fig. 12 (a) is a packaged, connected of solar cells. Solar modules use directly light energy (photons) from the sun into electricity using the photovoltaic effect. The modules using wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. When sunlight hits the silicon atoms of the solar cell and loses electrons. When these free electrons are captured electric current will generate and that can be used as electricity. The solar modules were first used in space in 1958. Output of this system having mono crystalline cells 19% efficient, open circuit voltage 7V, 6V peak voltage, 378mA peak current and 2.27W is the peak power capacity. Solar panels electric tolerance is +/- 10% with irradiance of 100 mW/cm2 and absolute air mass of 1.5, at 25 °C, as per cell.

Mini wind energy system as shown in Fig. 12 (b) used to generate electricity around 1.5 to 7 VAC in 8-31 mph wind to 80mA into a ni-cad battery. When fan moved with 8 – 31mph, copper coil induced current to oppose the motion that induced it by Lenz’s Law.

Fig. 12 Renewable Energy Generation System (a) Solar (b) Wind (c) Water

Mini water energy system is installed for proposed system as show in Fig. 12 (c). This mini water system used a water tank to store water as rain water, wastage water used in kitchen and washrooms and a water pump, which rotate the shaft by water pressure. Turning shaft will move the copper coil of the mini water system, which induced. This system generate the 1.5 to 7 VAC with peak current 378mA and peak power is 1~2 Watts.

4. Software Design

Software design for this project includes NetBeans IDE 8.0[14], Windows XP operating system. NetBeans IDE is best support for latest Java platform having fast and smart code edit feature, easy and effective project management, and fast user interface development with bug free code.

Software development needs to implement the proposed system a module to module with following methods.

- NetBeans IDE software tool is selected to create a web application, a web application is an application written for the Internet, including those built with Java with JavaServer Pages and servlets. Web Applications consider frameworks such as JavaServer Faces, Spring, Hibernate, and Struts.
- The main objective of this web application is to provide remote control access to the users to minimizing the wastage of electricity.
- To develop a GUI for user interface, need a Java programming is written as in source package. With the help of NetBeans IDE, we create a GUI of home, which includes the appliances on/off push button, security profile using login, logout and resister pages.
Creating a program in NetBeans IDE 8.0, as following steps and run the application.

- Creation of GUI of Home Automation in Java.
- Step 1: Creating a New Project.
- Step 2: Name and Location of the New Project.
- Step 3: Selection of Server and Java Version.
- Step 4: Create Source Packages.
- Step 5: Run the application, right click on the Project and select Run.
- Step 6: Click on the link created, to open the Server.

Fig. 13 shows the control flow chart of the embedded home server. If there is no control messages, the application page display the current status. If the received a message, it will check the command format first. If the message is correct, the home server sends command to microcontroller to turn On/Off and wait for ok message from the microcontroller. Proposed System is designed to support the GUI to let the user easily monitor and control On/Off of each electric home appliances remotely.

GUI to users. Home server receives signal from internet as Wi-Fi/Bluetooth/GPRS and send signal to microcontroller using ZigBee network. Microcontroller controls the appliances as per the user selection. And the user can see their appliances will control on their palm. Fig. 15 (a) and (b) shows the GUI of the user’s home. GUI also includes the authentication of the users by using registration, sign-up and sign-in page as shown in Fig. 15 (a). It is a user-friendly, easy in use and users can access and control the home appliances anywhere and anytime.

5. Implementation Results

Fig. 14 shows the implemented Renewable Energy Management System for Smart Homes. Design of the system for smart homes is installed in practical environment as shown. Smart Home users use the mobile/laptop/tablet to access the home appliances remotely. This is successfully implemented with software and hardware design. Home server has a Web application which programmed in Java Language to provide Home

Fig. 16 illustrates the total electricity generated according to the days.
6. Conclusions

We proposed a Renewable Energy Management System for Smart Homes based ZigBee communication and web server control. This has been successfully completed and tested. The ZigBee Network is setup with home server and microcontroller. It has been developed by integrating feature of hardware and software. In this project, our main focus was the development of an independent energy generation module for smart homes, offices, and industries. Remote access of home appliances provides the energy saving module for the system. Maximum power rating of the experimented solar charge controller is 27W according battery capacities, so the system has been tested by both two 3W DC light and 3W DC fan, which is operated successfully. For charging the battery the instruction of the battery manufacturer has been strictly followed. The upper and lower limits are carefully set so that the battery is not damaged. The project completed successfully with all the features of operations of the solar charge control system as desired. The facilities are affordable and even domestic user can provide themselves a micro generation system in their own homes and accordingly reduce natural gas/oil consumption by renewable energy sources as sort of replacement energy. This project has given an example of energy saving model for urban areas and lightening model for rural areas and expected to reduce home energy uses.

References

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