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Research Article
Voice Controlled Energy Management System

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Abstract

Background: Home automation system has been around for more than a decade. The main concept is to form a network connecting the electrical and electronic appliances in a house. This is an emerging technology, which has changed the way people live. But still none of the companies have been able to establish it as a popular technology as it is difficult to install and use and is not customized for household customers. **Materials and Methods:** This study proposes a Voice Controlled Energy Management System (VEMS) which will allow people to control household devices at home using wireless devices based on user dependent commands for enhanced security. **Results:** This study also monitors the total power consumption and transmits the data to the personal computer and day ahead and yearly forecast is computed using neural network, statistics and regression models. **Conclusion:** The main conclusion of this study is to control all the components through wirelessly and control it as per user demand also power consumption is recorded and calculated the total power consumption in an every year.

Key words: Home automation, wireless devices, voice controlled devices, Xbee, EasyVR, load forecasting, Atmega, Matlab

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Laziness to turn OFF/ON home appliances is a common problem among us. Percentage of wastage of electricity is increasing year by year. Older people are incapable to control home appliances by moving all over their house, especially in a double story house. Definitely they will suffer to control their home appliances if the controls of the appliances are by switches.

Based on the survey conducted during this study, it is found that 62.75% of people occasionally forget to switch off unused appliances while 8.25% of the respondents tend to forget frequently. Besides that, it is also noted that 43.50% people find it troublesome to walk to the switch to switch off an appliance if it is so far. Hence, 31.25% of the above people often leave the appliance switched on.

The importance of switches is inevitable as it enables an appliance to be switched on/off. In comparison to the traditional switches where an appliance can only be switched on/off from the switching socket it is connected to the centralised control system, which enables its user to switch electrical appliance on/off remotely by giving voice commands or even from the remote controller unit hence eliminating the need of walking to the specific appliance to switch the appliance on/off. Therefore, unnecessary time and energy waste is eliminated[1]. In house, multiple sensors are connected to acquire the various signals to control the aplliances[2-4]. All sensors signals are transmitted from various places from home through wirelessly with the help of Bluetooth and Xigbee devices[5-8]. XBee gives better performance than other wireless devices. A distinguishing feature that makes XBee the most suitable wireless device for home automation is its very low power consumption. Apart from that, XBee comes with 128-bit Advance Encryption Standard (AES) which is a powerful security measure in prevention of data intrusion.

Now a day, development in every sector is heading at a very rapid pace and in the same pattern, the demand for power is also growing. While speaking about electrical power, it is important to understand that it has three main sectors i.e., generation, transmission and distribution. Electrical power generated by any source is then transmitted through transmission lines at different voltage level and then distributed to different categories of consumers later on. Effective load forecasts can help to improve and properly plan these three fields of power systems. Accurate models for electric power load forecasting are essential to the operation and planning for a utility company. Load forecasting helps an electric utility to make important decisions, including decisions on purchasing and generating electric power, load switching and infrastructure development[9].

Load forecasting is a difficult task. First, because the load series is complex and exhibits several levels of seasonality: The load at a given hour is dependent not only on the load at the previous hour but also on the load at the same hour on the previous day and on the load at the same hour of the day with the same denomination in the previous week. Also, people are provided with electricity bills after duration of every two months. It is necessary for people to forecast the load consumption for future[10]. Apart from basic turn on/off of devices, this system also monitors the total power consumption and transmits that data to a PC which helps in load forecasting.

MATERIALS AND METHODS

Zigbee over other wireless devices: Table 1 shows the comparison of the different wireless techniques based on its data rate, power consumption, applications and security. Table 1 shows the ZigBee has several advantages than other wireless devices except data transfer rate.

Table 1: Comparison between different wireless devices

Characteristics	WiMax	ZigBee	IrDA Infrared	Bluetooth	Wireless USB	WIFI
Standard/reference	IEEE 802.16a	IEEE 802.15.4	IrDA specifications	IEEE 802.15.1	Certified USB-IF compliance	IEEE 802.11 B -G and others
Distance (max)	50 km	100 m	1 m	100 m	10 m	100 m
Data rate (max)	70 Mbps	250 Kbps	16 Mbps	3 Mbps	480 Mbps	54 Mbps
Connections	Point-hub mesh	Ad-hoc, Peer-Peer	Point-Point	Ad-hoc, 8 devices	127 devices	Point-hub
Line of sight	No	No	Yes	No	No	No
Relative power consumption	High	Very low	Low	Medium	Low	High
Typical application	Wireless metropolitan area network or last mile technology for rural areas	Sensing and controlling application in home automation	Remote controls, mobile phones	Voice and data applications for consumer electronics and personal computing devices	Data applications for consumer electronics and PC peripherals	Data and voice applications, wireless LAN, broadband internet access
Security	Authentication and encryption	Several measures, 128 bit AES encryption	n/a	Authentication and encryption	Authentication and encryption	Authentication and encryption

Table 2: Types of commands in EasyVR commander software

Types of groups	Function
Trigger	The trigger word is used to start the recognition process
Group	A speaker defined group which recognizes users command trained in this group only
Word set	It contains sets of built in speaker independent commands. There are three word sets with 8, 6 and11 commands
Sound table	A special group to play the sound for the system. One built in sound 'beep' is available. User can import any sound in form of wave to use for the system
Password	It can be used up to five words by using speaker verification technology. It is used for security measures

Types of commands in EasyVR shield: Speaker dependent and speaker independent are the two types of voice recognition system. Speaker dependent system is designed for a specific speaker that learns by learning the voice characteristics of that specific person. New users must first train the software by speaking to it, so the computer will analyse how the person talks. This system is useful for security measures. Speaker-independent systems on the other hand, require no training phase with the user and are desirable when many users want to operate the system or when training is difficult. Attached to the EasyVR module is a unidirectional electret condenser microphone which uses 3 V for the operating voltage. The load impedance is 2.2 K and the sensitivity of the microphone is 38 dB[3,6,8]. The EasyVR commander software is used to configure and train the commands into the EasyVR module. Table 2 shows the various types of commands which can be used in the EasyVR commander software. In this study 'Trigger' and 'Group' types of commands are used.

System components: Xbee series 1 is used for wireless data transfer because of increased reliability, no line-of-sight barrier and low power consumption. EasyVR shield 3 is used to record the voice commands because of its easy configuration and use with Arduino. Atmega1284 will be used to control the loads as sufficient number of loads can be connected to it. Power relays with relay driver circuit can also be used for simpler applications.

Process flow: There are two microcontrollers in this study Atmega 328 and Atmega 1284. One Xbee is connected with Atmega 328 working as transmitter to transmit the signals and another Xbee is connected with Atmega 1284 to be the receiver. When people say the voice command, the microphone connected to the EasyVR shield receives it first and then Atmega 1284 receives it. By program controlling, Atmega 328 will send the signals to the transmitter Xbee. When the Xbee is enabled, it will send the corresponding signal to the receiver Xbee by the different voice instructions. When the wireless communication set up successfully, it will send instructions for Atmega 1284 to control the loads. Voice controlled energy management system of this system is shown in Fig. 1.

Two timers, timer 0 and timer 2 are set for four PWM waves to do the function of turn on, turn off and shift the level of lights and fan. Delay function is done by timer 1. In order to tell the user when the light or fan are broken or when the circuit is having fault, the LCD could show the detail to remind user the light or fan broken by open circuit which is the fault detection function.

To forecast the future load, the load at the previous hour, the load at the same hour on the previous day and the load at the same hour on the day with the same denomination in the previous week will be considered and load forecasting is done in MATLAB software.

Interfacing EasyVR shield and Xbee with host microcontroller: The EasyVR 3 module can be used with any host with an UART interface powered at 3.3-5 V, such as PIC and Arduino boards. The initial configuration at power on is 9600 baud, 8 bit data, no parity, 1 bit stop. The baud rate can be changed later to operate in the range 9600-115200 baud.

The XCTU is a software, provided by Digi (the manufacturer of Xbee) is used to configure and manage Xbees and test Xbee networks. The most important configuration settings needed to modify to control the Xbees are CHANNEL, PAN ID, DESTINATION and MY address. For one Xbee to be able to send data to another, it must have the same destination address as the other Xbee's source. To interface Xbee with its host microcontroller, only the Vcc, GND, Din and Dout pins are used and left other pins are left unconnected.

After training and recording with the most recognizable signals, EasyVR. Library is used to get instructions and it will send out the characters in the form of "a", "b", "c" etc. After choosing the baud rate of transmission of 9600, the pair of Xbee could cooperate correctively and efficiently. Figure 2 shows the interfacing diagram of Zigbee with its host microcontroller.

PWM circuits Implementation: Three PWM circuits are used to control the home devices. Figure 3 shows the PWM circuit

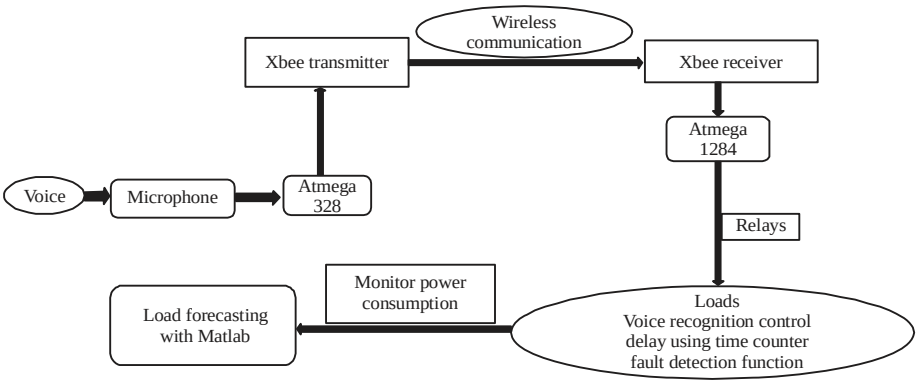

Fig. 1: Block diagram of voice controlled energy management system

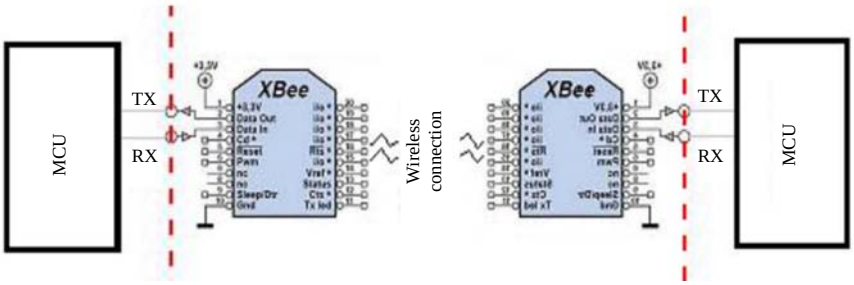

Fig. 2: Interfacing of Xbees with host microcontroller

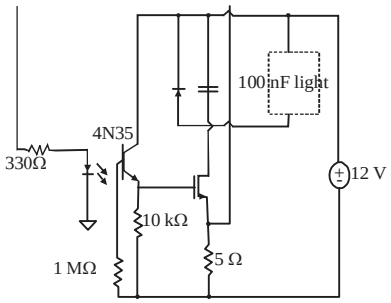

Fig. 3: PWM circuits on the load side

for load. Here 4N35 is used to separate the light with microcontroller because there would be current flow back from motor and will harm the I/O pin of microcontroller. The IRF630 is an N-MOS transistor and works as a switch. When VGS>2 V (which is logic high), DS of the N-MOS link together and work as a shortcut. When VGS<2 V (which is logic low), DS of the N-MOS break and the load will stop working. The diode is used to absorb the energy stored in the load, actually when the motor's supply voltage is suddenly reduced, there will be a risk that the voltage will go back and may harm the microcontroller, so the diode can eliminate the risk.

At the low voltage of the PWM cycle, load is turned on and the diode is reverse biased. The inductive current flow is downward when PWM is changing from high level to low level and the inductive current flow is upward when PWM is from low level to high level. The capacitor is used to remove the high frequency. At the source of IRF630, a resistor is added to do the function of fault detection. Atmega 1284 is used to test the voltage between source and ground to check if the device works in a right way. If not, the LCD will show the device is at fault.

Load forecasting using MATLAB

Algorithm:

Step 1: Initialize the input data

Import the load data from excel file to MATLAB worksheet

Step 2: Initialize the network model

Step 3: One year load data is provided as an input to network

Step 4: Train the neural network to predict the particular hour load demand as an output

Step 5: Evaluation of the predicted load

Predicted load output can be analyzed by using the Mean Absolute Percentage Error (MAPE) that can be defined as:

$$MAPE = \frac{1}{M} \times \sum_{i=1}^{m} \frac{L_{actual} - L_{predicted}}{L_{actual}} \quad (1)$$

where, L_{actual} and $L_{predicted}$ are the actual load and predictive load respectively and M is the number of data points.

Step 6: Plot the graph between actual and forecasted load to visualize the predictive accuracy

RESULTS AND DISCUSSION

In this module, predefined comments are fed to the system. The proposed system is speaker independent module also it responds to any user. Once voice of "Bedroom on" is recognized by the voice recognition chip, the command will send out a character of "a" through the Xbee from the Atmega 328 and received by Atmega 1284. Once the interrupt service routine is on, the character will be stored in the UDR. Atmega 1284 will address what the command is and operate the corresponding device. Table 3 shows the list of voice commends and their corresponding functions. Similarly the other letters will be sent according to the commands given.

User can modify the letters as per their requirements. Similarly the user can add or delete the commands. If user say DELETE, all predefined program will be deleted and user can feed new data into the microcontroller. We have demonstrated nine different commands to control the diffferent electrical appliances. Table 4 shows the comparision of proposed system over other systems.

In Lim and Yeap[1] control of appliances have been done with the help of voice. Voice has been converted into character and information has been sent. But only two devices are controlled and device is not universal. In Hasan *et al.*[2], Thakur and Sharma[3] and Lian *et al.*[4], they have used voice based device control and they controlled only few number of appliances. None of the systems predict the load which is presented here. The proposed design has unique advantages than other proposed system. This system is universal and it controlles more devices than other system. Moreover, load forecast is added in this work which is not available in the axisting system.

The load curves are plotted showing actual and forecasted loads and MAPE (Mean Absolute Percent Error) is calculated for all load forecasting techniques.

Figure 4 and 5 show the result of different load forecasting techniques. Neural network model and curve fitting model produces the better result than regression and multiple regression models.

Different forecasting models have been used to demonstrate the Mean Error Absolute Error (MAPE) for loads and day ahead loads. Neural network model gives the least value 3.820%. Table 5 provide different load forecasting techniques for the day.

Table 3: Commands stored in EasyVR commander software

Command	Function
G1_BEDROOM_ON	Turn on bedroom------'a'
BEDROOM_OFF	Light off----------'b'
BEDROOM_DIMMER	Bedroom dimmer------'c'
FAN_ON	Turn on fan----------'d'
FAN_OFF	Shut fan----------'e'
FAN_LOWER	Fan lower----------'f'
LOUNGE_ON	Lounge on----------'g'
LOUNGE_OFF	Turn off lounge--------'h'
30SEC	Bedroom on for 30 sec---'i'
DELETE	Erase all-'z'

Table 4: Comparision of proposed system over other system

Reference study No.	Control	Data transfer	Load forecast	No. of appliances controlled	Universal
1	Voice	Character	No	2	No
2	Voice	Character	No	2	No
3	Voice	Character	No	2	No
4	Voice	Character	No	1	No
Proposed	Voice	Character	Yes	4	Yes

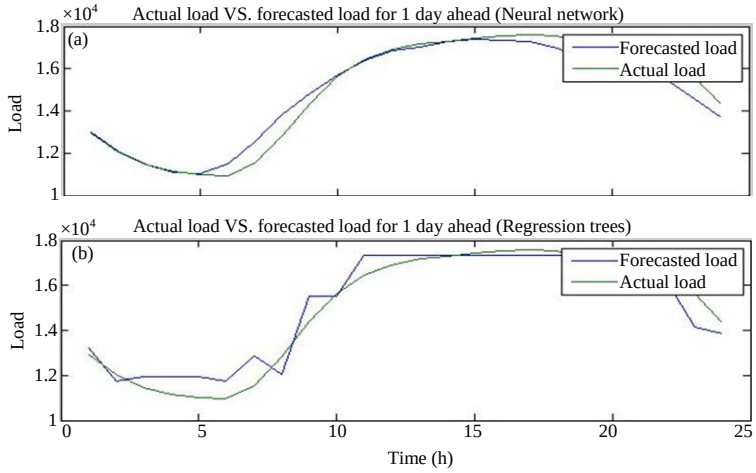

Fig. 4(a-b): Load curve and MAPE using (a) Neural network model and (b) Regression trees model

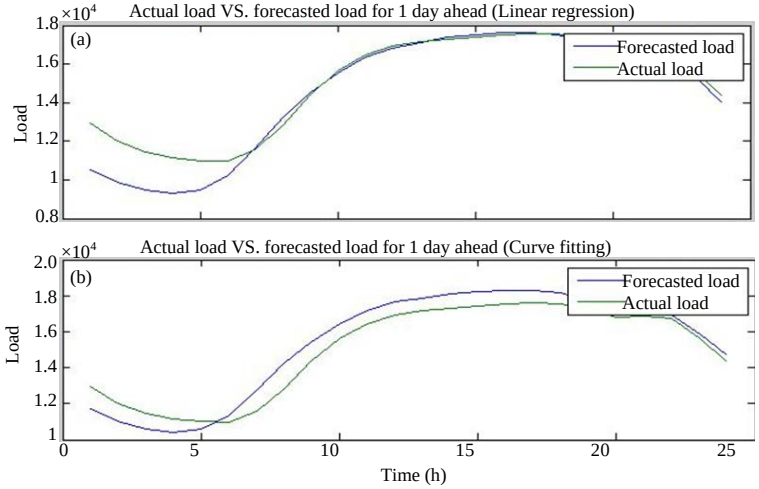

Fig. 5(a-b): Load curve and MAPE using multiple (a) Linear regression models and (b) Curve fitting model

Table 5: Comparison of different load forecasting techniques

Method	MAPE for historical loads (%)	MAPE for day ahead loads (%)
Neural networks	2.948	3.820
Regression trees	1.716	3.995
Multiple linear regression	5.810	4.665
Curve fitting model	5.619	4.931

CONCLUSION

This study concentrates the voice based controlling the home electrical appliances. This technique will be useful for following peoples:

- Person with disabilities
- Aged
- Person who fail to remember

It developed the portable device for controlling the appliances. The main advantage of this device is universal. User can add or delete the number of appliances by modifying the code of the processor. Another significant improvement of this study is user can predict the tariff of energy consumption. This study can be extended to make a self learning voice recognition system where there may be no need to make changes in the main program.

SIGNIFICANT STATEMENT

This study concentrates the controlling of various home appliances through voice. This is portable and universal device. User can change the number of appliances also they can change the existing comments. This device is mainly targeted for aged and disability peoples.

Also, this device has facility to monitor and predict the energy consumption. This device will alert the user when energy consumption goes beyond the threshold.

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