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Design and Development of a Maximum Demand Controller for Energy Efficiency in a Smart Home Environment

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KEYWORDS

Smart home
Maximum Demand Controller
Energy Efficiency

ABSTRACT

Nowadays, number of energy efficiency measures are being implemented in the smart home environment to conserve the energy consumption. This research attempts to design and develop a solution for an effective energy consumption in a smart home environment. The microcontroller system monitors the electrical energy consumption in real time and to ensure the power consumption is within the limit or predefined maximum demand value. Once the real time power consumption reaches the pre-set value prior to reaching its maximum demand, there will be an alarm triggered to warn the user that the power consumption is about to reach the predefined value. Once the power consumption exceeds the predefined maximum demand, the connected load will be automatically switched off sequentially one by one based on the pre-planned look up table. Results obtained through simulation and practical are presented in this paper. Recommendations are given for further enhancement of the proposed design for the smart home applications.

1. INTRODUCTION

A smart home is referred to a house in which several interconnected devices and home appliances are performing certain tasks to monitor energy and optimize its usage. It also represents a smart home that satisfies its needs in flexible and intelligent ways. For an effective energy conservation, the consumers should be able to monitor, control and manage the energy consumption in the day-to-day life. The purpose of this research is to design and develop a maximum demand controller for smart home environment and present an effective energy management system that can be used in a smart home.

Smart home is equipped with devices that automate tasks that allows remote access. It can be built into home, controlled by various method such as remotes, switches / including apps. Research into energy saving has been increasing in view of dealing with environmental problems and effectively using energy resources. Therefore, electrical power consumption monitoring on a real-time basis is essential to keep it from exceeding the critical demand level.

2. PROBLEM STATEMENT

The recent development in the smart home appliances attempts to enhance the energy conservation features. However, none of the devices attempts to limit and control the energy consumption to a prefixed value by the consumer. The electrical devices such as air purifier, lights, fans, air-conditioners, and television can be switched off once real time power consumption exceeds the per defined limit based on the sequential switching off plan. Having such a device will not only save the electrical energy and also aids in the reduction of carbon footprint. However, it will be hard to monitor from a device and to set the value if failure occurs due to Wi-Fi or network error.

3. OBJECTIVES

The following are the objectives of the research:

- To design and develop a solution for an effective energy consumption in a smart home environment.
- To monitor the electrical energy consumption in real time.

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- To ensure the power consumption is within the limit or predefined value of maximum demand.

4. LITERATURE REVIEW

4.1 Design and Implementation of smart buildings

The building sector is one of the largest contributors to global energy consumption Greenhouse gas emissions. Advances in building energy technology have played an important role in improving the energy sustainability of the built environment. Extensive research that has mentioned in journal [4] and new technologies have recently emerged for building energy and environmental systems to meet global challenges. This study primarily reviews existing articles in the literature since 2000 to examine technological advances in building energy and environmental systems applicable to smart homes and smart buildings. This overview study focuses on an overview of the design and implementation of energy-related smart building technologies, including energy management systems, renewable energy applications, and today's advanced smart technologies for optimal functionality and energy-efficient performance. In a comprehensive literature search, this study provides detailed solutions or guidelines in various applications to improve the quality of people's daily activities and the sustainability of built environmental systems. It is to identify different techniques for building applications. This paper represents trends in human activity and technological advances in energy management systems and digital solutions by practical design. Understanding the total flow of energy between a building and its environment-connected systems is also important for future building and community levels.

In this review the study focuses on an overview of the design and implementation of energy-related smart building technologies, including energy management systems, renewable energy applications, and current advanced smart technologies for optimal function and energy-efficient performance.

4.2 Design of smart maximum demand controller for peak load management for domestic loads

Energy is the most important and an essential source of life for humans. Among all kinds of resources, electricity is the basis of the development in every society and nation. India's strong and sustained economic growth has created a huge demand for electrical energy. Many power plants have been installed to meet demand, but the supply-demand gap continue to grow wide. One of the ways to overcome this problem in the current scenario is to use existing power sources as optimally as possible and limiting the wastage in the use of electrical energy. This document [3] attempts to propose a methodology to solve this critical problem through peak load management in the case of household loads. This allows us to match supply with demand. In such a way that consumers and suppliers benefit at once. It also describes the application of DSM techniques to household loads that can optimize power consumption during peak hours. Therefore, the reliability of the power supply can be improved. The proposed maximum load limiter is part of the load management. Results are presented to demonstrate the effectiveness of the proposed method for load management.

In this research, the researchers designed the smart maximum demand controller for peak load management for domestic loads by application of DSM Tool. Where the power consumption can be optimized during peak hours, hence the reliability of the power supply can be increased. The solution is to cut the power during the peak hours.

4.3 Smart City and maximum demand controller

In this current era, there are lots of machineries, equipment in every industry. For each machine there is separate operator. There are lot of complications and difficulties for controlling the machine. The emergence to off the supply of the machine which has been difficult due to the time loss to off the supply. In such a case, there is a need of device which will control this machine easily using “ENERGY SAVER” that solve this issue. Battery arrangement is not provided in case of load shading. This project used thermal overload protection; if the temperature of the transformer increase, the limited value then disconnected the system immediately. The circuit works if the transformer observes the temperature. This circuit controls the temperature of the transformer when its temperature reaches to its normal range. In this project, maximum demand control is done manually in various forms, but in this project the purpose is to control the maximum demand that used in human activity using Arduino (controller). [2]

Table 1. Summary of Literature Review

Author	Country	Purpose	Summary points	Year
Dongsu Kim, Yeobeom Yoon, Jongman Lee, Pedro.J.Mago, Heejin Cho	Switzerland	Design and Implementation of smart buildings	Designing and implementation of energy-related smart building technologies, including energy management systems, renewable energy applications and current advanced smart technologies for optimal function and energy-efficient performance.	2022
Dr.P Ravi Babu, P Satya Krishna	Hydrebad	Design of smart maximum demand controller for peak load management for domestic loads	To design a smart maximum demand controller through load management during peak hours, in case of domestic loads. It will help in bringing suuply within the range of demand, such a way that consumer and utility will be benefitted simulatenously.	2018
Priyanka, Minakshi, Satyam, Aatul A.Joshi	Department of Electrical Engineering, Amarutvahini College of Engineering Sangamer, Maharashtra, Indian	Smart City and Maximum Demand controller	Smart city and maximum demand controller project is to introduce to be operated as demand controller by using arduino controller to save energy device to save and consumption of heat and electricity.	2019

In this research smart city and maximum demand controller is introduced and operated as a demand controller by using Arduino controller to save the energy device. This is used to save the heat and electricity. This initive is also helping to reduce excessive amount of device that makes the mechanical for human being use. Moreover, this project help to increase

market value of electrical and mechanical equipment that is working for industrial purpose.

5. METHODOLOGY

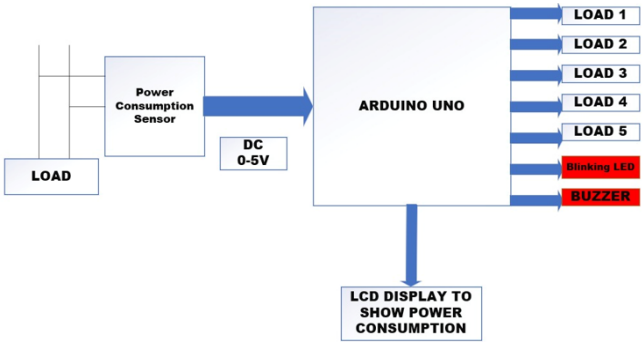

Fig.1. Block Diagram of the proposed model

In the proposed system, Power sensors are used to detect the real time power consumption of the domestic load. Figure 1 shows the block diagram of the proposed model. Power transducers are readily available in the market that can be used for Realtime power consumption. However, due to the technical difficulties, an equivalent variable voltage sensor is employed. *the* Arduino uno is used as a controller of the system that has been programmed with respective sequential control code. The real time power consumption is displayed using the LCD Display. The buzzer and a blinking led acts as the warning to alert the power consumption is a exceeding the predefined value. The load LEDs which are (1-5) will be turned off one by one once the power consumption exceeds the predefined maximum demand value. The flowchart of the proposed model is given in Figure 2. Figure 3 shows the schematic diagram of the proposed model using the Fritzing software.

6. DISCUSSIONS

The proposed model has been tested through hardware implementation and studied. Five different loads were employed to study the effectiveness of the control strategies. The 5 LED,s represents the status of the different types of electrical loads such as refrigerator, water heater, downlights, fan and television. LEDs (RED, BLUE, ORANGE YELLOW and GREEN) are used to notify the status of the load condition. Once the circuit is powered up through laptop to Arduino cable the LED light can be seen light up to resemble the real time load power consumption. In the LCD display the power consumption of each load can be seen along with the total power consumption. The values of the power consumption can be seen has risen after we adjusted the potentiometer, and the value is shown is 27.5 Watt where the warning system can be seen working. The blinking led on the bread board; the buzzer along with the beep sound to alert the user that the power consumption is about to reach the predefined maximum demand value.

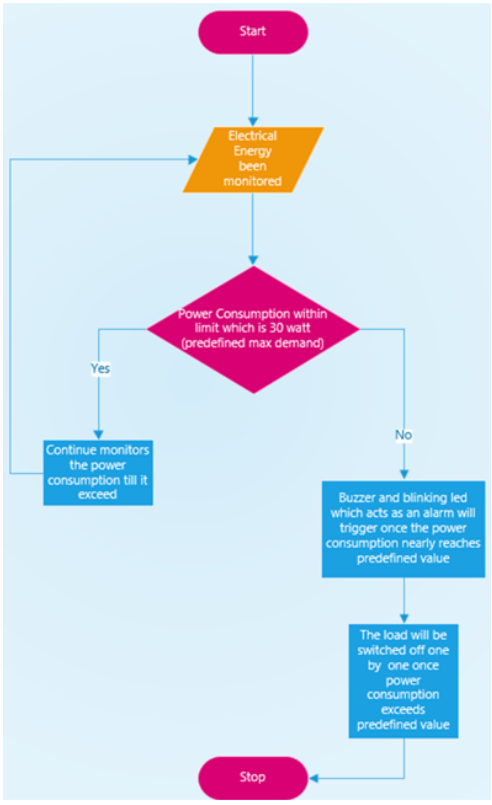

Fig. 2. Flowchart

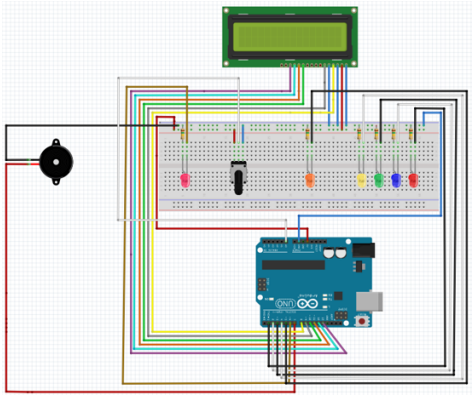

Fig. 3. Schematic Diagram

It is observed that when the load consumption rises and nears to the predefined value, a warning sign and alarm are observed. When the power consumption increases beyond the maximum demand value, the load are automatically gets disconnected sequentially as per the order programmed.

7. RESULTS

All the components have been fixed on the breadboard and all the connection is made for the hardware implementation. The proposed model works well as per the planned strategies with the early warning prior to reaching the predefined maximum demand.

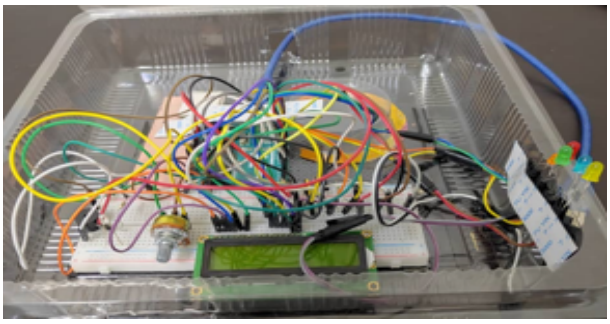

Fig. 4. Hardware implementation

Figure 4 shows the hardware implementation of the proposed model. Once the circuit is powered up through laptop to Arduino cable the load led lights were seen lighting up. In the LCD display the power consumption of each load was displayed along with the total power consumption.

Fig. 5. Load Power Consumption

Figure 5 shows the power consumption of various loads. The values of the power consumption can be seen has risen after we adjusted the power sensor equivalent potentiometer, and the value observed is 27.5 Watt at which, the warning system can be seen working. The blinking led on the bread board as a warning sign and the buzzer alarm were initialized to alert the user that the power consumption is about to reach the predefined maximum demand value.

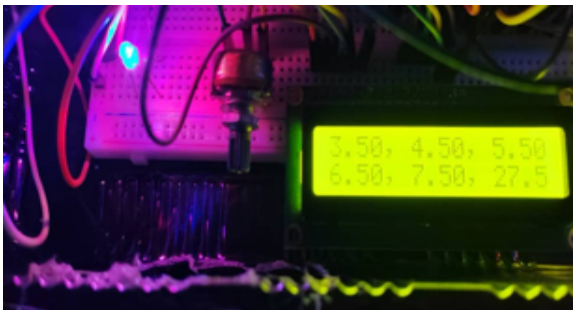

Fig. 6. Warning System

Figure 6 shows the warning system of the hardware implementation. When the load power consumption reaches the predefined maximum demand limit, the loads were switched off automatically as the sequential order programmes. Unwanted or unimportant loads were removed at initial stage until the real-time power consumption drops back below the predefined maximum demand limit.

Figure 7 shows the predefined maximum demand value being displayed in the LCD display. The system won't allow the load power consumption to exceed the maximum demand value set. Thus, the energy consumption is closely monitored, regulated and controlled for effective energy efficiency.

Fig 7. Predefined Value Reached

Table 2. Load consumption pattern

Variable	Load 1	Load 2	Load 3	Load 4	Load 5	Power
1	1	2	3	4	5	15
2	1.5	2.5	3.5	4.5	5.5	17.5
3	2	3	4	5	6	20.0
4	2.5	3.5	4.5	5.5	6.5	22.5
5	3	4	5	6	7	25.0
6	3.5	4.5	5.5	6.5	7.5	27.5
7	4	5	6	7	8	30.0
8	4.5	5.5	6.5	7.5	8.5	32.5

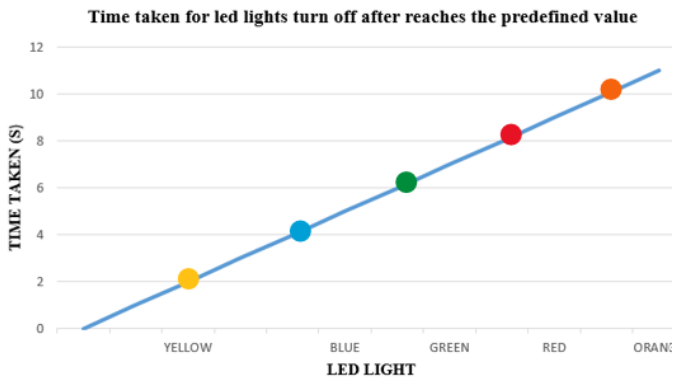

Fig. 8. Line Graph

Table 2 shows the real time load consumption pattern of the domestic load. Figure 8 shows the characteristics of load removal with respect to the time after the attainment of predefined maximum demand limit. The following method is adopted for the estimation of electrical energy consumption. Electricity consumption cost per household according to TNB depends on living habits, number, family size and age of electrical appliances and hours of usage. The customers can

calculate estimated of electricity cost for different appliances as stated below:

- Number of hours electrical / electronic appliances used
- Power rating of electrical / electronic appliances and its efficiency
- Domestic tariff rate per kilowatt – hour (kWh)

Electricity Consumption (kWh) = Total Power Consumed (watts) × Hours of operation × n days ÷ 1000.

Electricity bills are calculated based on the current domestic tariff rate.

- Under full load $P = X\ kW$

Real-time Energy Consumption (kWh) can be estimated as follows:

$$E_{rt} = \frac{Xhn}{1000}$$

- Under maximum demand Power consumption = MD kWh

Electricity Consumption (kWh) under maximum demand can be estimated as follows:

$$E_{md} = \frac{MD.hn}{1000}\ kWh$$

Percentage Energy Saving Achieved can be calculated as

$$Percentage\ Energy\ Saving = [\frac{E_{rt} - E_{md}}{E_{rt}}]\ x\ 100$$

Based on the study, the energy saving of 6.25% were achieved based on the tested load consumption. It is observed that the achievement of energy saving is directly proportional the load amount. If the load is high, then higher energy savings can be achieved. Colour coding were used to differentiate the various domestic loads as shown in Table 3.

Table 3. Load and Item Table

LOAD	ITEM
LOAD 1 (LED 1)	YELLOW
LOAD 2 (LED 2)	BLUE
LOAD 3 (LED 3)	GREEN
LOAD 4 (LED 4)	RED
LOAD 5 (LED 5)	ORANGE

The load power is adjusted using the potentiometer output voltages as an input to microcontrollers. A look up table as shown in Table 4 is used estimate the equivalent power consumption. The hardware implementation of the proposed model yield a significant saving as expected.

Table 4. Power and Voltage Table

POWER(W)	VOLTAGE (V)
15.0	1.5
17.5	2
20.0	2.5
22.5	3
25.0	3.5
27.5	4
30.0	4.5
32.5	5

8. CONCLUSION

In summary, this proposed model can monitor and calculate the total power consumption in real-time. This research is also to able keep the power consumption within the predefined limit by switching off the electrical and electronic appliances once it exceeds the predefined maximum demand value. Having such smart maximum demand controller, the consumer has the control over the electrical energy consumption and obviously reduce the electrical bill charges. The proposed model not only reduces the monthly bill but also conserve the electrical energy consumption and helps in reducing the carbon footprint.

9. RECOMMENDATIONS

For the further enhancement of the proposed model, we recommend that the power consumption can be monitored through IoT via the smart phones. We also recommend that we can choose which electrical and electronic devices to switch off before it reaches the power consumption limit since in this research all the electrical and electronic devices are switched on and off together, even though it switches off one by one when exceed the 30-watt power limit.

This research can be improved by having an IoT in which user can monitor the power consumption using their smart phones whenever they wanted to and can set the predefined value in their smartphones too. Another recommendation in this research is the user have options to decide which electrical and electronical devices can be kept on and off rather than having all the electronical devices turned off once it reached the predefined value. To make this research more valuable it can be improved by having let the user know how much they must pay for the power consumption that is been used so far rather than waiting for the TNB bill.

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