Peer Reviewed & Refereed Journal
Volume-13, Issue-3 (June 2023)
https://doi.org/10.31033/ijemr.13.3.43

Smart Energy Management: A Futuristic Model For Power Monitoring and Control

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Received: 01-06-2023 Revised: 16-06-2023 Accepted: 30-06-2023

ABSTRACT

Power management in different domains such as residential, educational, and commercial areas is the need of the hour as the demand for energy is rising day by day which is reducing the fossil-fuel storage in the earth's crust as most of the percent of power we are using is made up by burning fossil fuels. Therefore power management is very much important. In this study, an integrated two-stage model is proposed to address the challenges associated with power management, namely (i) power usage monitoring, and (ii) power control for energy conservation. The model is designed such that it will provide a comprehensive solution to optimize power usage. The model is created such that in the first stage the model identifies the time frame during which power consumption is at its peak (up-time) and the time frame when power consumption is minimal (low-time) in laboratories. Further, we have to calculate the approximate percentage of power that we need to allow to the laboratory (characterized as allowed power) during low time as a percentage of total input power. Subsequently, this information serves as input for the second stage of the model, which shuts down the power supply in low time, till the allowed power is reached. It allows the full power supply in uptime.

Keywords— Power Consumption, Power Allocation, Real-Time Clock Functionality, Scheduling System, Controlled Wattage Mechanism

I. INTRODUCTION

In various fields such as industrial, commercial, educational, and residential, power management holds a big part and its importance is growing daily. The electric power saving need arose because global energy demands are increasing daily and fossil fuel resources are available in limited quantities in nature burning of which most of the power is made. Along with that, the concerns for environmental sustainability are increasing day by day. As per the International Energy Agency (IEA), the global electricity demand is projected to grow by 70% over the next two decades [1]. Such positive steep growth puts pressure on existing power generation infrastructure, making it important to implement effective power-saving measures. If we reduce the waste of power then the gap between supply and demand of power can be reduced.

In educational institutions, labs play a major role in students' curriculum. Labs need a lot of power supply to run different machines such as computers. Even when the power is not needed, the power is supplied to the machines, because we sometimes forget to turn off the instruments. This leads to a lot of power wastage. That is the reason we need Smart automation in lab environments which automatically controls the power as per our needs. There are multiple benefits of having a power manager in laboratories such as reduction in operational costs of laboratories, which allows laboratories to allocate their resources more efficiently to fulfill other purposes. Moreover, the greenhouse gas emission will eventually be reduced leading to environmental sustainability.

The aim of this research is to give an optimal comprehensive solution for optimizing power usage in educational as well as in similar sectors which will eventually reduce energy wastage and will enhance environmental sustainability. By fulfilling these objectives, the project strives to contribute to cost savings, reduced environmental impact, and improved laboratory operational efficiency.

II. METHODOLOGY

The model that we have developed works in two stages- (i) power usage monitoring and (ii) power control. In power usage monitoring we first decide in which slot we have to use the maximum power, and in power control, the power gets controlled accordingly.

International Journal of Engineering and Management Research
e-ISSN: 2250-0758 | p-ISSN: 2394-6962
https://ijemr.vandanapublications.com
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https://doi.org/10.31033/ijemr.13.3.43

Working

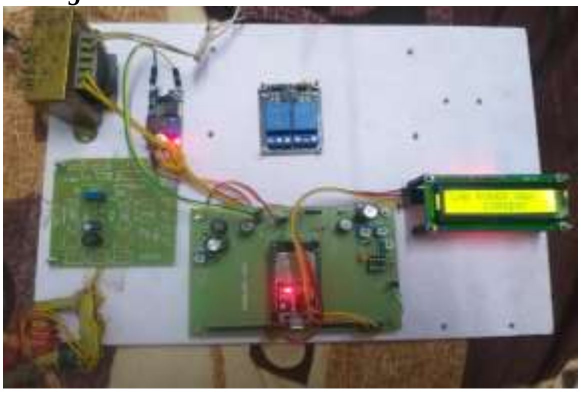

Figure 1: Hardware Image

Figure 2: ESP-32

We used the load panel as the lab's total load. The registry load is used for the experimental setup which is in pure form and indicates ideal load conditions. In this project, we are detecting the load from the current sensor and ADC interface using MCP 3008 which is an external ADC, used for detection of change in current. In this mode, the load is detected which is directly proportional to the change in weightage for the lab load. Here, in this project, the current transformer is connected to four features with a combination of 3 is to 4. In this load, conditions are in the timer and outside the timer. In the outside timer, there is unconditional mode means without reference to the real-time clock. The load is detected. In overload conditions, ESP 32 microcontroller checks the real status of the Load and takes the decision as we have set and controls the relay giving a warning to the user.

The other mode is the conditional mode. In this mode, the keypad is used for entering time. We can decide to start and end time conditions which are nothing but practical timings pre-decided by the department. If the timer condition is set for 20 minutes, the power is allowed to all the loads. But, before and after that particular start and end time, the load is in reduced mode (that is the power allowed to only 30% of the loads)

Components

ESP32: It is the heart of the lab power manager system. With its dual-core Xtensa LX6 processor [6] and integrated Wi-Fi and Bluetooth capabilities, it offers the necessary processing power and connectivity for real-time power monitoring, control, and optimization. The ESP32 [3] features digital, analog, and PWM pins for versatile connectivity with sensors and peripheral devices. It supports Wi-Fi 802.11 b/g/n and Bluetooth, enabling wireless communication with other devices and networks. It is facilitated by the Arduino IDE or the ESP-IDF, providing an intuitive interface and comprehensive development tools for customization and control [4][5].

Relay: The JQC 3F (T73) relay is a very important component of the lab power manager model. It allows the switching operation to the model. It is how the model can achieve the controlling operation. It usually operates with a current of 5 Amperes and a DC voltage of 25 V [2]. Also for the circuits which are AC, it operates with a current of 7 Amperes and 120V DC voltage. The main work of the relay is to work as a switch. It gives a lot of flexibility in power-managing situations. It is an electromechanical switch. It regulates the power supply to the model. It allows control over electrical circuits. The relay is basically controlled by the ESP32 microcontroller. This is why relay is used in this model. It plays a role of a switch in short in this lab power manager project.

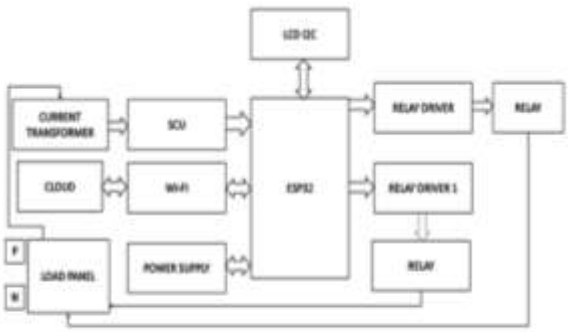

Figure 3: Block diagram of power manager

Current transformer: A very important component in the lab power manager model is the current transformer. It provides a correct measurement of electrical current. It gives the proportional signal in output which represents the current that is flowing through our circuit. It allows the ESP32 microcontroller to capture the real-time data of current. Using this data, ESP32 decides the further action to be taken (which is set by us). It works within a very specific rating of voltage, that's why it is compatible with the lab power manager model. This is how power monitoring and power control are achieved. We have used a step-down current transformer.

III. RESULT AND DISCUSSION

The model that we have developed works in two stages- (i) power usage monitoring; (ii) power control. In power usage monitoring we first decide in which slot we have to use the maximum power, and in power control, the power gets controlled accordingly.

Table 1: Observation Table

Day No.	Timing of experiment	up-time duration	Power Consumption	
			Without Power Manager	With Power Manager
1	Morning	3 hours	8 kWh	5 kWh
1	Afternoon	3 hours	5 kWh	3 kWh
2	Morning	3 hours	6 kWh	3 kWh
2	Afternoon	3 hours	3 kWh	2 kWh

In the time frame in which maximum power is allowed, this model doesn't play any role. At other times the allowed power percentage is reduced to the lowest possible power which we have already set on the system using the keypad. We have got following observations

Thus power wastage is reduced and power saving is achieved.

IV. CONCLUSION AND FUTUERE SCOPE

Using this model the wastage of power is significantly reduced and power saving is achieved which ultimately leads to the saving of fossil fuels (in case we are using the power generated by non-renewable resources of energy.)A further modification is possible, such as integrating Artificial Intelligence so that AI can detect which load (device) should be allowed to use after the specific time frame by analyzing our devise-usage data. This model can be used in all industries, and, if used globally, power saving can be achieved on a large scale.

The future scope covers lot of aspects. More features can be added in this project for example enhancement in algorithms of processor, which will in turn give better more flexible automation and control. One algorithm can be integrated to save the energy by analyzing the power usage pattern. Data analytics techniques can be used to analyze those patterns. Remote monitoring can be done using improved hardware capabilities. Smart grid technologies can also be applied. This project can be designed in a way so that it would serve large area.

AUTHOR CONTRIBUTION

Dr. N. B. Sambre: Conceptualization of the Lab Power Manager project, design of the experimental setup, and supervision of the overall research. Conducted experiments using the Lab Power Manager, collected and analyzed data, and performed statistical analysis.

Ankita Bagul: Development of the software architecture for the Lab Power Manager, including power management algorithms and control logic. Implementation of the Lab Power Manager hardware, including circuit design, component selection, and PCB layout.

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