

Smart Single Phase Energy Management System

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ABSTRACT

In modern era, reduction of electrical energy consumption and energy saving are very important and demanding issue in residential and commercial application. The work in this paper proposes the use of specially designed IoT-based smart single phase energy management system using ESP8266, DS3231 real-time clock, and I2C LCD display. This system allows automatically control an electrical load through a relay based on predefined ON and OFF times. Time setting can be adjusted using push buttons or remotely using web interface over firebases platform. The current time, timer status, and relay state are displayed on the LCD, while the ESP8266 enable real-time monitoring and manual relay control from any browser. This system is suitable for home automation, energy management, and scheduled application control.

Keywords: IoT, ESP8266, Digital Timer, Energy Saving System, Real-Time Clock (DS3231), Relay Control, Web Interface, Home Automation

INTRODUCTION

Consumption of electrical energy reduction or energy saving is become one of the main environmental issues due to increasing pollution and global warming that arise use of fossil fuel energy sources. Others, building energy efficiency houses is an alternative solution to reduce greenhouse gas emissions and creating sustainable environment. Others research also focus on energy saving and environmental protection using renewable energy sources (such as solar power) to achieve green power. Energy saving through energy efficiency application or device is an additional solution that can be reduce the greenhouse gas pollution. Energy saving leads to have lower cost of electricity generation and consumption to improve over life.

In recent years, the rapid development of Internet of Things (IoT) technology which allow the monitor and control devices using internet. One of the most common requirements in automation is time-based control of electrical Applications, such as switching light, water heater, industrial equipment's ON and OFF at specific time. Traditional timer switch is often limited facility. Like remote access, and manual control. To overcome these limitations, this project presents the implementation of an IoT-based smart single phase energy management system using ESP8266 microcontroller and DS3231 real-time clock (RTC) model.

In this system uses the ESP8266, which provide Wi-Fi connectivity, allowing the timer to control and monitor using web interface from any device connected to the same network. The DS3231 RTC module highly accurate timekeeping, even power failures, making the system reliable. Users can set ON OFF timing using web browser or physical push buttons. The I2C LCD display is continuously saving the current time, scheduled of ON and OFF timing, and system status, enable easily interaction with the device. the system also supports manual relay control using web interface, which allow Users the scheduled operation whenever necessary. This feature enhance flexibility and ensure that the connected load can be controlled in emergency and special situations. The combination of real-time clock accuracy, wireless connection and Users friendly input methods make this project practical, cost effective, and efficient solution for home automation, energy conservation, and small-scale industrial applications. Overall, this project demonstrates how IoT technology can be effectively used to create smart, reliable, and adaptable timer-based control systems for modern automation needs.

LITERATURE REVIEW

Suggested Energy Savings Solution This suggested energy savings solution is an automated, efficient IoT-based energy savings system which limits excess waste of electric energy via the automation of the operation of electric devices based on scheduling and the ability to remotely modulate the electric device's operation in real-time. The inability of humans to turn lights, fans, motors, or any other device off when no longer needed is one way of creating lots of waste of electrical energy that could otherwise be saved. This increase in electricity usage will cost you more for electricity by increasing both your electrical bill and demand on generating power sources. The proposed solutions will address these issues through creating an automated, user-driven, smart energy management system taking full

advantage of current IoT technology.

At the heart of the system is an ESP8266 microcontroller with reliable processing support, as well as the capability of using Wi-Fi to connect to the Internet. This makes it possible to remotely control everything in the system via a web-based interface from any Wi-Fi-connected smartphone, tablet, or computer on the same network. Additionally, a DS3231 RTC module is included in the system to keep accurate and stable time so that all loads are switched ON and OFF at predetermined times without deviation. The RTC will continue to keep accurate time even after a power outage; allowing for reliability over an extended period of time and while unattended. All loads are controlled via a relay module, which provides electrical isolation between the low voltage control circuitry and the high voltage appliances.

Many control methods enhance usability and flexibility in the system. In terms of local control, users can set on and off times via physical push buttons. Web interface capabilities provide remote scheduling and manual control of devices. The 16x2 I2C LCD display continually displays key system performance-related information such as the current time, scheduled times, and the status of relays. To further help with monitoring system performance, users can use the manual override feature to immediately control any appliance(s) during an emergency; also for coordination reasons when there is a need for schedule-based control to be temporarily suspended.

METHODOLOGY

The proposed energy-saving system's electronic design focuses on time-controlled functions, proper switching of electrical loads, and easy interaction with the system through hardware and wireless interfaces. The system is designed using readily available components that are low-cost and ensure accuracy, stability, and safety. The main electronic components used in this project are the ESP8266 microcontroller, DS3231 Real-Time Clock (RTC) module, relay module, 16x2 I2C LCD display, push buttons, and the regulated power supply. The proposed energy-saving system's electronic design is based on time control, proper switching of electrical loads, and convenient interaction with the system using hardware and wireless interfaces.

The system is developed using components that are readily available and inexpensive while maintaining accuracy, stability, and safety. The main components of the project include the ESP8266 microcontroller, DS3231 Real-Time Clock (RTC) module, relay module, 16x2 I2C LCD display, push buttons, and a regulated power supply. The heart of the electronic design is the ESP8266 microcontroller, which is the central control unit of the system. It receives user inputs, talks to peripheral devices, keeps Wi-Fi connectivity, and controls the relay according to programmed timings. The ESP8266 microcontroller is chosen because of its inbuilt Wi-Fi feature, adequate number of GPIO pins, low power consumption, and compatibility with IoT projects. It has a 3.3V logic level, which allows it to be directly connected to digital components like RTC and LCD using the I2C protocol.

The DS3231 RTC module is employed for time-keeping purposes. It connects to the ESP8266 via the I2C bus using the SDA and SCL pins. The RTC module has a temperature-compensated crystal oscillator, which provides high accuracy and prevents time drift. The RTC module comes with a backup battery that allows the current time to be retained even in the case of a power failure.

A 16x2 I2C LCD module is connected to the ESP8266 to display real-time system data like the current time, ON/OFF timer values, Wi-Fi connection status, and the status of the relay. The use of the I2C interface helps to simplify the wiring process since only two data wires (SDA and SCL) are required. The LCD module helps to improve user interaction with the system since the system status is displayed at all times. The relay module is the output stage of the electronic design and is used for controlling high-voltage AC devices. The relay is actuated by the digital output pin of the ESP8266 microcontroller and ensures electrical isolation between the low-voltage control circuit and the high-voltage load. This ensures the safety of the microcontroller and prevents it from voltage spikes. The relay turns ON/OFF automatically according to the time schedule or manually through the web interface.

For local configuration and control, push buttons are connected to the ESP8266 using internal pull-up resistors. The push buttons enable the user to enter the setting mode, set the ON and OFF times, switch between parameters, and finally save the settings. Software debouncing is used to prevent spurious switching due to noise. The power supply unit delivers a stable DC voltage necessary for the functioning of all the electronic components. The regulated 5V supply is used for the relay and the LCD, while the ESP8266 runs at

3.3V using its internal voltage regulator. The grounding and power isolation are properly maintained to ensure a stable and noise-free operation of the system.

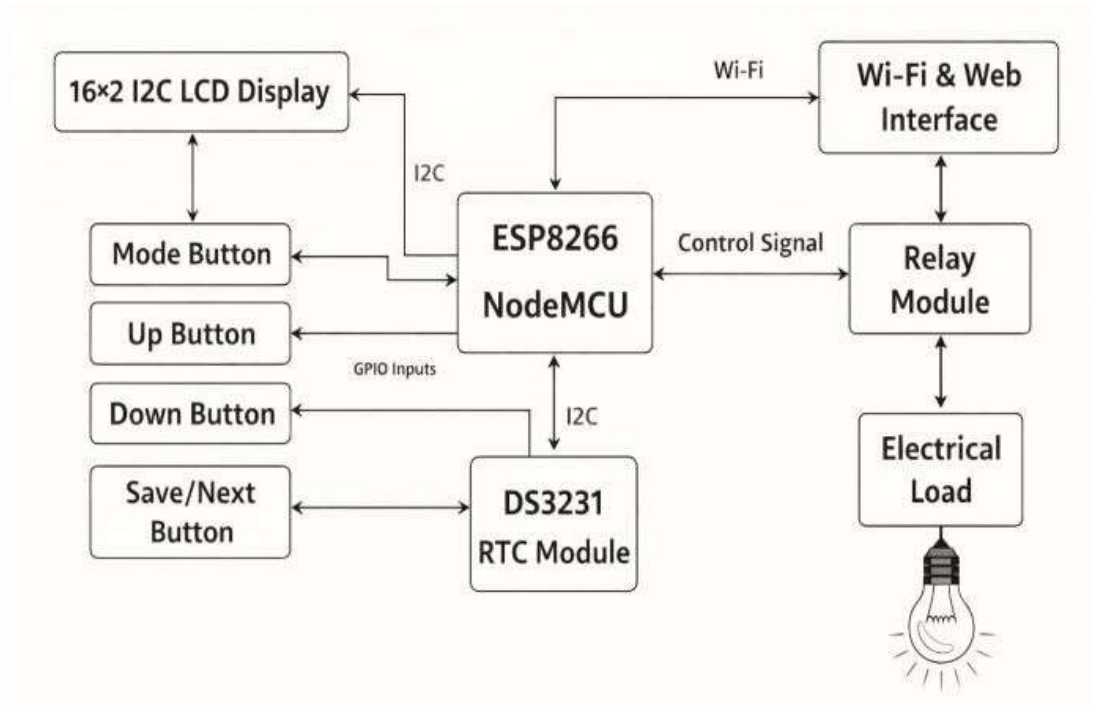


Figure 1: Main block diagram of the proposed energy saver

In general, the electronic design of the proposed system is quite simple, efficient, and scalable. The design ensures accurate time-control, safe appliance switching, and flexible user interaction through both hardware buttons and wireless communication. This efficient electronic design makes the proposed system suitable for real-world energy-saving applications in homes, offices, and small industries.

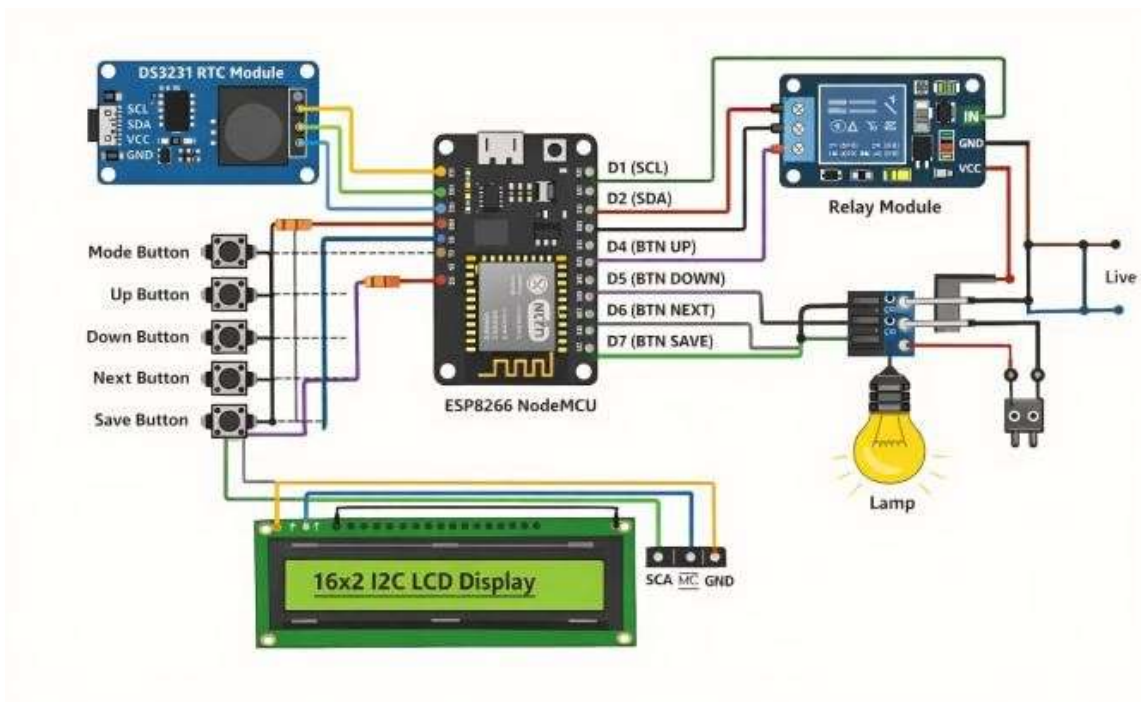


Figure 2: Main circuit diagram

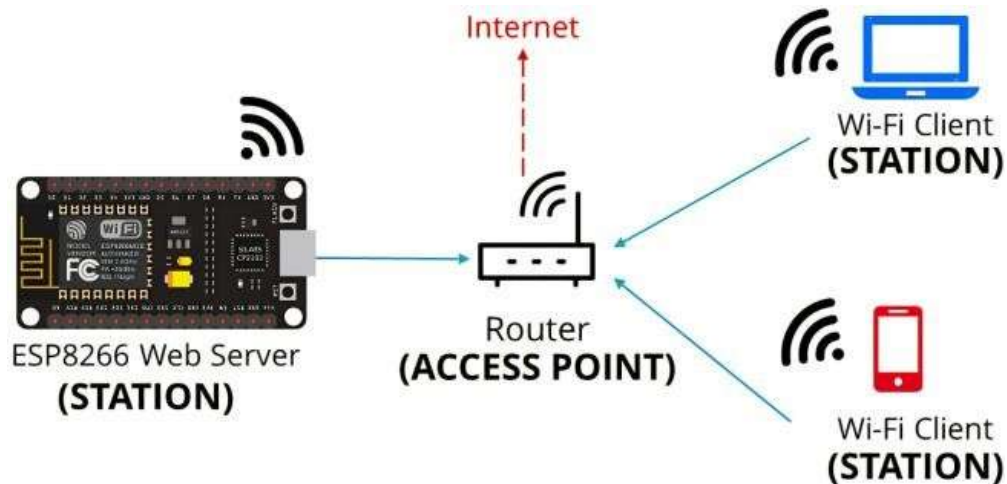


Figure 3: Communication diagram with ESP8266 using Wi- Fi

The block diagram of the proposed IoT-based digital timer and energy-saving system explains the interaction of different hardware and software components used to implement the automated and efficient control of electrical appliances. Every block in the block diagram has a different function, which together makes a complete energy management system.

ESP8266 NodeMCU (Main Controller)

The ESP8266 NodeMCU is the main controller of the system. It reads the input signals from the push buttons and the real-time clock module, processes the timing information, and then controls the relay based on the information. It also manages the Wi-Fi connection and provides a web server that enables the user to control the system from a distance. The decision-making process, including the comparison of the current time with the ON and OFF times, is done by the ESP8266.

DS3231 RTC Module

The DS3231 Real-Time Clock module is used to provide accurate time information to the ESP8266 using the I2C communication protocol. The DS3231 RTC module is able to keep the correct time even during power failures, thanks to the backup battery. The ESP8266 module is continuously reading the current time from the RTC module to turn the relay ON/OFF according to the programmed schedule.

16×2 I2C LCD Display

The 16×2 I2C LCD display is employed to display real-time information of the system to the user. The display shows the current time, ON and OFF timings, Wi-Fi connection, and the status of the relay. The LCD module is connected to the ESP8266 using the I2C bus.

Push Buttons (User Input Unit)

The push buttons act as the local user input unit. Buttons like Mode, Up, Down, and Save/Next enable the user to enter the timer setting mode, change the ON and OFF times, switch between parameters, and finally save the entered parameters. The push buttons are linked to the GPIO pins of the ESP8266 and make use of the internal pull-up resistors.

Wi-Fi and Web Interface

The Wi-Fi module is a representation of the wireless communication feature of the ESP8266. Using this module, users are able to access a web page hosted by the ESP8266 for the purpose of setting timer values, viewing the status of the system, and controlling the relay manually.

Relay Module

The relay module is an electrical switching component that is used to control high-voltage AC devices. The relay module receives commands from the ESP8266 and provides a safe interface to switch the high-voltage load ON/OFF based on the timer schedule or manual override command.

Electrical Load

The electrical load is any appliance like a lamp, fan, pump, or any other electrical device that is connected to the relay. The functioning of the load relies solely on the state of the relay, which is controlled by the ESP8266 based on the programmed timings or commands.



Figure 4: Mobile Web Interface

The web interface is a significant component of the proposed IoT-based digital timer system because it allows the remote monitoring and control of electrical appliances using a standard web browser. The web interface is run on the ESP8266 microcontroller itself using its Wi-Fi capability and web server, and users can access the system by typing the IP address of the device in a mobile or computer browser. After the ESP8266 is connected to the Wi-Fi network, it creates a local IP address that serves as a gateway to the control panel. When the user types in the IP address in a browser, a simple and user-friendly web page is opened. The web page displays the status of the relay (ON or OFF), providing real-time feedback on the appliance that is connected to the relay. The web page also contains input fields that enable the user to input the ON time and OFF time of the relay in hours and minutes, respectively. The input values are transmitted to the ESP8266 when the user clicks on the save button.

Apart from the automatic control of the timer, the web interface also allows manual override. Through the use of specific buttons or links on the webpage, the user can immediately switch the relay to the ON or OFF position irrespective of the set timing. This is particularly helpful in cases where an emergency arises or in situations where temporary manual control is necessary. The web interface is mobile-friendly and runs smoothly on smartphones, even those with low capabilities. The fact that there is no need to use any external cloud server or mobile app means that the system runs entirely within the local network, which enhances reliability, security, and speed. In general, the web interface increases the flexibility of the system, convenience, and is vital in ensuring efficient energy management through remote control and monitoring.

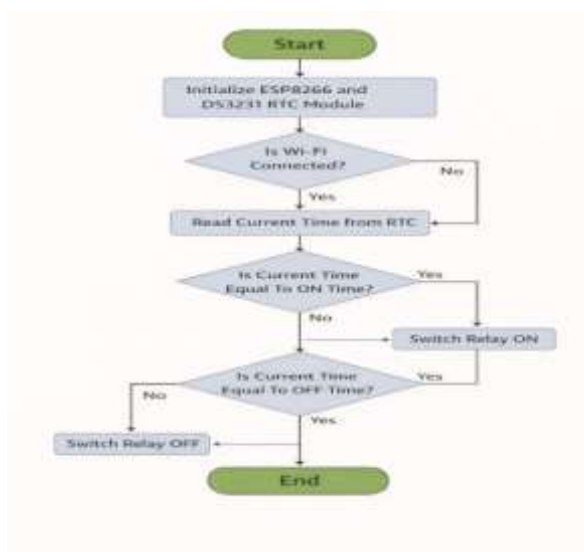


Figure 5: Flow chart of program

The flow chart illustrates the complete functioning of the IoT-based digital timer and energy-saving system from the time the power is turned ON. When the power is turned ON, the ESP8266 module initializes all the hardware modules like the RTC module, LCD display, relay, Wi-Fi, and web server. After successful initialization, the system enters the main loop.

In the main loop, the ESP8266 is continuously checking for user inputs from push buttons and web interface requests. If the setting mode is enabled, the system will allow the user to modify the ON and OFF timing values using the buttons, and the values will be stored. If the system is in normal mode, the current time will be retrieved from the RTC module and displayed on the LCD along with the timings.

Then, the controller compares the current time with the set ON and OFF times. If the current time satisfies the ON condition, the relay is turned ON, and the electrical load is switched ON. If the OFF condition is satisfied, the relay is turned OFF, and the electrical load is switched OFF. If manual control is chosen using the web interface, the relay will act according to the user's command, ignoring the automatic timer. This process continues in a loop, ensuring continuous monitoring, accurate time-based control, and efficient energy utilization without human intervention.

CONCLUSION

The digital timer and energy-saving system using the IoT-based platform successfully verifies the efficiency of the system in preventing wastage of power consumption by automatically and intelligently controlling electrical appliances. The system uses the ESP8266 microcontroller and a high-accuracy DS3231 real-time clock to provide precise time functions. The addition of a relay module in the system enables the user to switch off high-voltage appliances safely, and the 16x2 I2C LCD displays real-time system status.

The system provides both automatic and manual control through a web interface. This provides the user with flexibility and convenience. Local control using push buttons is also provided, which is an added advantage when internet access is limited. The fact that the system can be accessed and controlled through a browser using an IP address makes the project simple, cost-effective, and feasible.

In general, the proposed system is effective in reducing energy wastage, lowering electricity bills, and ensuring smart energy management. The system is also cost-effective, scalable, and can be applied in various settings such as homes, offices, industries, and agricultural systems. This project work emphasizes the potential of automation through IoT in ensuring energy efficiency and sustainable energy use in modern electrical systems.

FUTURE SCOPE

The project can be upgraded by incorporating cloud connectivity for remote control from anywhere, mobile apps for easy management, and the ability to handle multiple appliances. Energy consumption sensors can monitor real-time consumption, and connectivity with voice assistants and automation sensors (motion, light, temperature) can make the project smarter. All these upgrades will help in developing a complete smart energy management system for homes, offices, and industries.

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