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# Design and Implementation of Smart Energy Management System

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**Abstract:** *It is crucial to create systems that lessen our reliance on non-renewable resources in a world with declining energy reserves and escalating economic crises. Smart Home Energy Management Systems, which employ smart switches to actively monitor energy use by each load, available power, and other parameters to transition between renewable resources and the primary power grid, are becoming more and more popular. The results of several methodologies were combined and analysed after a thorough literature review. The approach described is a synthesis of all the most well-liked approaches. The suggested methodology aims to implement demand response management simultaneously on grid electricity and solar power. The issue was divided into two scheduling scenarios: one assuming only solar power is available, the other assuming just grid power. In order to use the resources available as effectively as possible, the two halves are then combined.*

**Keywords:** Smart Energy

## I. INTRODUCTION

The main goal of the smart grid is to lower energy costs and consumption. In order to reduce peak demand and select lower tariff prices, interruptible loads can be properly scheduled for the residential, commercial, and industrial sectors. Depending on the energy industry, the load is used in different ways. Some loads can be continuously stopped depending on how long they are used, but others might be more user-friendly. It is difficult to schedule appliances efficiently because of the increased load and unpredictable nature of demand. To solve this problem, researchers made the decision to employ optimisation techniques. The literature has documented a wide range of demand-side load scheduling techniques that take into account processing time, complexity, the most precise schedule, and ease of implementation.

The usage of renewable energy sources is of great importance to the contemporary community due to the situation's increased energy consumption and growing worry over the hazards of the environment. In addition, it is quite questionable whether renewable energy sources like solar and wind will be available. Due to the extensive usage of renewable energy sources and smart grid environments, the system is more challenging to manage energy in.

## II. METHODOLOGY

At the moment, conventional energy metres are used in the creation of power monitoring and billing technologies. Individual residences have these metres placed to track their electrical energy usage. One who checks the energy metre in each residence records the energy used and computes the invoices. This procedure takes a long time and is quite ineffective. In addition, manual calculations can be inaccurate, and the process as a whole cannot be scaled due to the sheer volume of labour needed. Consumers' ignorance of their routine behaviour is the main issue. Consumers' monthly feedback is insufficient to accurately gauge how much energy is used by appliances. The majority of the issues with conventional energy metres are resolved by intelligent, network-based smart metres.

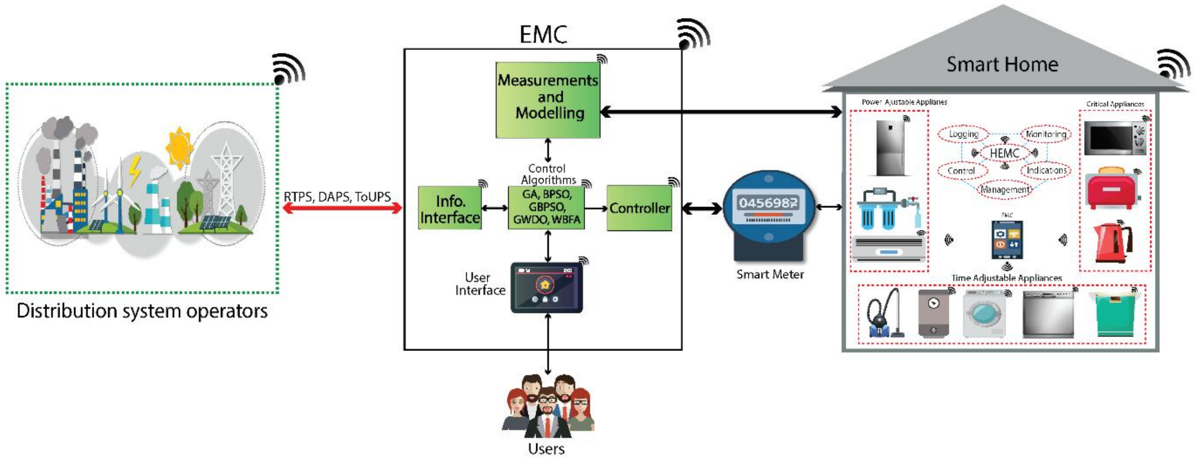


**Figure 1: Overview of SEMS**

Based on regular intervals of electrical energy use, smart metres can offer users usage alerts. Additionally, the regulatory committee receives the information gathered by the smart metre over the network, doing away with the necessity for human computations. This also improves cost estimation and decreases inaccurate quotients in calculations of customs duties. The limits of modern energy metre are minimal. Some of these metres might not have a fully digital structure, which could lead to erroneous measurements, due to their incapacity to accept mechanical components, the effort required to acquire data, and the most recent technological breakthroughs. Implementing a smart grid system is the following stage of the process. Although there are smart meters, smart grid systems are constructed on top of the electrical grid's current infrastructure.

It is difficult to detect variations in the electrical load across appliances due to modern power systems. The load on the electrical grid rises as the population does, necessitating adjustments to the system to make it more scalable Increased grid dependability, effectiveness, and consumption monitoring are the main objectives of smart grids. They also aim to convey consumption by delivering data (in real-time) to consumers and suppliers. Because conventional energy metres use outdated technology, the smart grid replaces them with cutting-edge metres that use computers to instantaneously assess energy consumption and transfer data between homes and regulatory institutions. Additionally, it develops a system that is considerably more effective and scalable.

## III. COMPONENTS REQUIRED

- ARDUINO UNO (ATMEGA 328P)
- XBEE MODULE
- 16*2 LCD MODULE
- DS3231 RTC MODULE
- ETHERNET SHIELD

### 3.1 Arduino Uno (ATMEGA 328P)

Of the many Arduinos, it is the one that is most frequently used. It is newcomers' top preference. It is simple to learn. An ATmega328 regulator powers it. The most significant feature of this type is that the control chip, an ATmega328, is put on the holder of the interwoven circuit's "IC" rather than being fixed to the board. This type contains 14 digital anchorages (I/ O), 6 of which can be utilized as anchorages to control the "PWM labors." As soon as you switch slides, go back, and fix your work on the board. The ATmega328 regulator is similar in design. The ATmega32u4controller, the first-ever model of Arduino motherboard, features a special point that includes an integrated USB connector require the usage of a second processor. The point makes it possible for the panel to instantly look as a keyboard and mouse when it is connected to your device, making it ideal for creating colorful operations that let you operate your PC.

**Figure 1:** Arduino UNO (ATMEGA 328P)

**Pinout diagram**

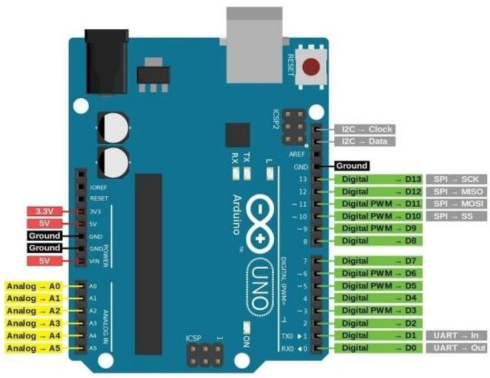


**Figure 2:** Pinout diagram of Arduino UNO (ATMEGA 328P)

- TTL serial data is transmitted and received using serial pins 0 (Rx) and 1 (Tx). The related ATmega328P USB to TTL serial chip is used to connect them.
- External Interrupt Pins 2 and 3 can be set up to initiate an interrupt in response to low values, rising or falling edges, or value changes.
- PWM Pins 3, 5, 6, 9 and 11: Using the analogue- Write () function, these pins produce an 8-bit PWM output.
- SPI Pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK): SPI communication takes place on these pins.
- Built-in LED Pin 13: When this pin is HIGH, the built-in LED is on, and when pin 13 is LOW, the LED is off.

### 3.2 XBEE Module

The Xbee ship is a radio with an embedded system that connects devices wirelessly at the end point. The element that enables communication between the smart plug and the gateway is this ship. The Xbee ship should process all data sent to and received from the device. A variety of wireless communication protocols, including Zigbee, are supported by the Digi International-produced XBee radio series 2. Digi International's terminal programmes XCTU are used to programme the XBee radios. An Xbee Radio Series2 is shown in figure 2.


**Figure 3:** Xbee module

### 3.3 16*2 LCD display

A 16x2 LCD display is a type of liquid crystal display that consists of 16 columns and 2 rows of characters, each of which can display a maximum of 16 characters. These types of displays are commonly used in various applications, such as digital clocks, calculators, and other electronic devices that require a simple user interface. The 16x2 LCD display is typically controlled by a microcontroller, such as an Arduino or a Raspberry Pi. The microcontroller sends data to the display via a parallel or serial interface, and the display then displays the data on the screen.

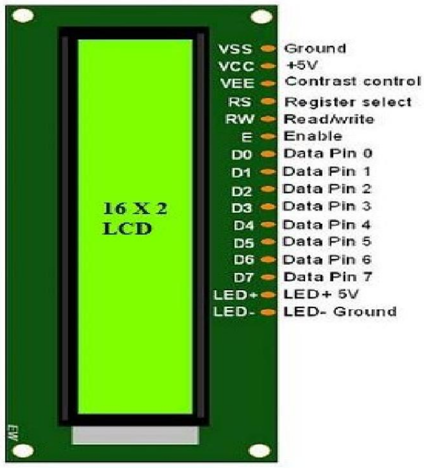


**Figure 4:** 16*2 LCD module

### 3.4 DS3231 RTC Module

A time tracking device that displays the current time and date is the DS3231 RTC module. Real Time Clock is intended by the term RTC. The RTC module uses a DS3231 clock chip. The time and date are typically provided by this module in computers, laptops, mobile devices, embedded system applications devices, etc. I2C is the protocol used by the RTC module. Details like the second, minute, hour, day of the week, day of the month, month, and year—including the leap year correction—are provided by the module. One more intriguing development Either a 12 or a 24-hour configuration can be used to operate it. It can be applied to tasks like data logging, clock construction, time stamping, timers, and alarms.

**Figure 5:** DS3231 RTC module

### 3.5 Ethernet Shield

The Arduino Ethernet Shield is a popular expansion board for Arduino boards that allows them to connect to the internet via Ethernet. It uses the Wiznet W5100 Ethernet chip, which provides a network (IP) stack capable of both TCP and UDP protocols. The Ethernet Shield can be connected to an Arduino board via its SPI bus, and it features an SD card slot that can be used to store web pages, configuration files, and other data. The shield also has a reset button, a micro-SD card slot, and an RJ45 Ethernet connector. The Ethernet Shield can be programmed using the Arduino IDE, and there are several libraries available that make it easy to connect to the internet and send and receive data. It can be used to create a variety of internet-connected projects, such as web servers, email notifiers, and remote-control systems.

**Figure 6:** Ethernet Shield

## VI. BLOCK DIAGRAM

The block diagram for SEMS is shown in figure 7 as follows.

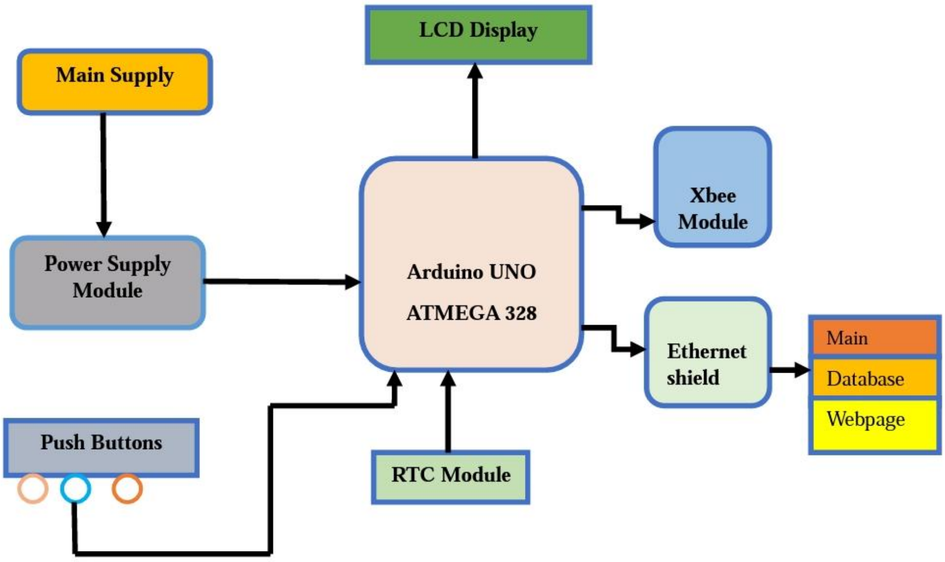


**Figure 7:** Functional Block Diagram of SEMS

## V. FLOW CHART

A smart home energy management system (EMS) is a technological solution that enables homeowners to monitor and control their home's energy usage. One important feature of a smart home EMS is the ability to schedule loads according to priority levels. The scheduling of loads in a smart home EMS involves assigning priority levels to different devices and appliances in the home based on their importance and the homeowner's preferences. For example, a refrigerator and lighting may have a higher priority level than a washing machine or a TV.

The EMS can then use this information to automatically adjust the usage of each device based on the priority level. For instance, if the demand for electricity is high, the EMS can reduce the power consumption of lower priority devices or delay their operation until a later time. To achieve this, a smart home EMS typically uses various sensors and algorithms to monitor energy consumption in real-time and forecast future usage patterns. This information is then used to make decisions on load scheduling and energy management.

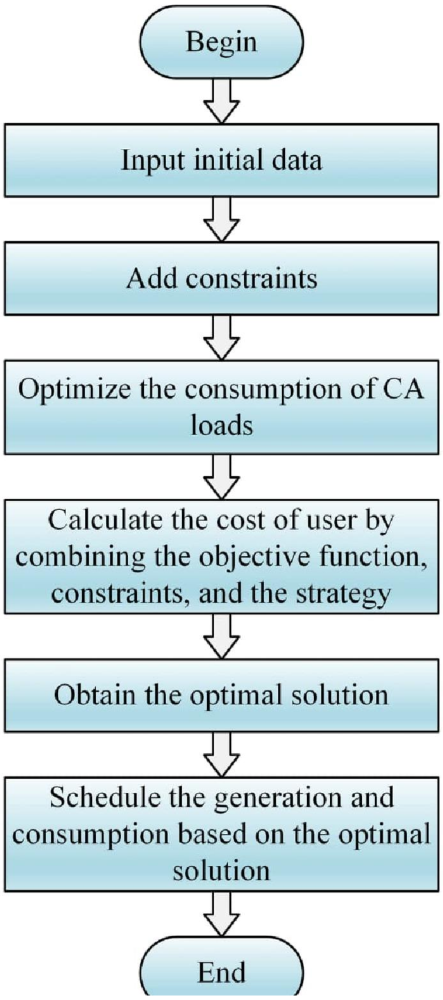


**Figure 7:** Flow Chart of Smart Energy Management System

## VI. ALGORITHM

As part of the intended SEMS control technology, smart socket units linked to certain appliances employ the XBee module in AT communication mode to communicate with the SEM unit gateway (central controller). Energy consumption data from each installed smart socket as well as the maximum demand limit data provided by utilities are delivered to the SEM unit of the suggested technique. Additionally, SEM optimizes the scheduling of each appliance using a reliable power negotiation mechanism. The proposed SEMS integrates the following algorithms into the SEM unit gateway and Smart Socket Module (SSM) in order to handle demand side energy management for the best use of energy.

Before being processed by the microcontroller unit, the real voltage and current signals undergo signal conditioning. The circuit's analogue values, which are sampled using a built-in 10-bit ADC, are read using an ATMEGA328 Arduino Uno microcontroller kit. Each sampled signal provides the instantaneous voltage and current data, and the maximum sampling rate is dependent on the ADC's precision.

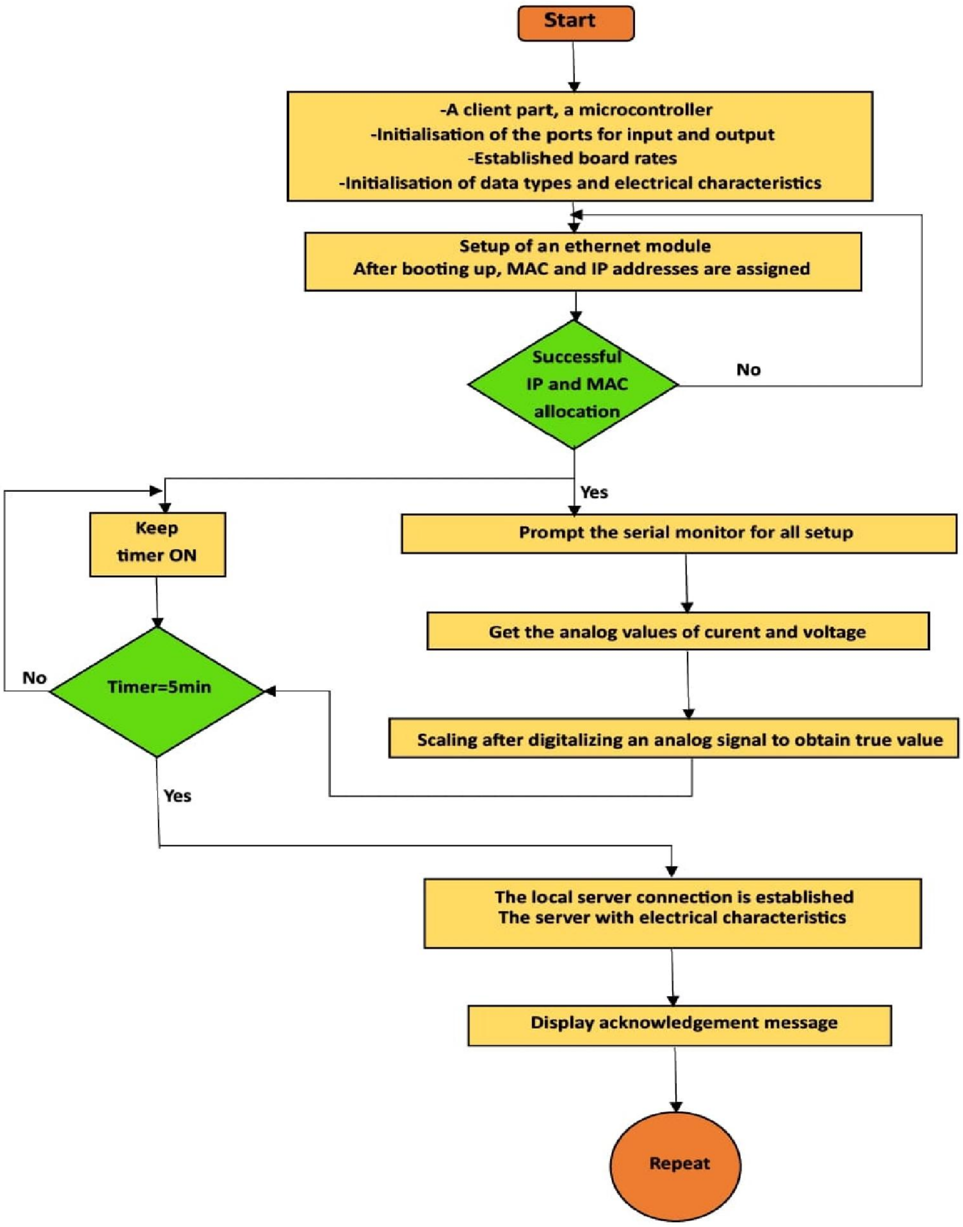


**Figure 8:** Flowchart of algorithm for SEMS

## VII. RESULT ANALYSIS

Two identical XBee modules are used in SEM systems to connect over ZigBee. both an XBee module with a smart socket configured as a router and an XBee module with a SEM unit configured as a coordinator. ZigBee connectivity is employed in the application transparent (AT) mode in the experimental setup. In order to gather all the data on power consumption from the loads connected to the smart sockets, the coordinator in the SEM unit broadcasts a data request message to the routers installed in the smart sockets in the pre-set order. The coordinator of the SEM unit then transmits the control signal to the router. String-formatted data is collected from the router.

Both an XBee module with a smart socket configured as a router and an XBee module with a SEM unit configured as a coordinator. ZigBee connectivity is employed in the application transparent (AT) mode in the experimental setup. In order to gather all the data on power consumption from the loads connected to the smart sockets, the coordinator in the SEM unit broadcasts a data request message to the routers installed in the smart sockets in the pre-set order. The coordinator of the SEM unit then transmits the control signal to the router. String-formatted data is collected from the router. In order to determine the true values of the electrical parameters, they are subsequently translated to their equivalent decimal representation.

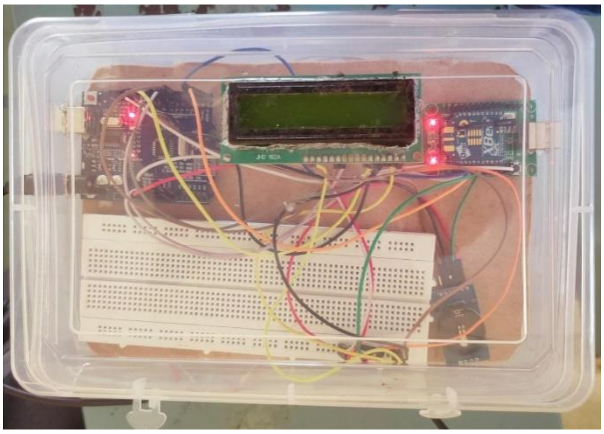

**Figure 9:** Experimental setup of Smart Energy Management System

### 7.1 Advantages

Load scheduling algorithms are designed to optimize the use of energy resources in a smart energy management system. The use of a smart socket module in such a system can offer several advantages, including:

- **Energy efficiency**: By maximising the utilisation of energy resources, load scheduling algorithms can aid in lowering energy usage. Individual appliances' power usage can be regulated using smart socket modules, ensuring that they only use energy when it is required.
- **Cost savings:** By reducing energy consumption, load scheduling algorithms can also help to reduce energy bills. Smart socket modules can be used to monitor and control energy usage, allowing homeowners to identify and reduce energy waste.
- **Increased comfort and convenience:** Load scheduling algorithms can be designed to ensure that appliances are only used when needed, reducing the risk of overloading circuits and improving overall safety. Smart socket modules can also be used to automate the use of appliances, making it easier for homeowners to manage their energy usage.
- **Reduced environmental impact:** By optimizing energy usage, load scheduling algorithms can help to reduce the environmental impact of energy production. This can be particularly important in areas where energy production is heavily reliant on fossil fuels.
- **Flexibility:** Load scheduling algorithms can be designed to be flexible, allowing homeowners to adjust their energy usage based on their specific needs. Smart socket modules can also be used to remotely monitor and control energy usage, providing greater flexibility and convenience.

Overall, the combination of load scheduling algorithms and smart socket modules can offer a range of benefits for smart energy management systems, including increased energy efficiency, cost savings, improved comfort and convenience, reduced environmental impact, and greater flexibility.

## VIII. CONCLUSION

Tests are performed to demonstrate how effectively the power optimisation algorithm incorporated within the controller performs on the hardware setup for the SEMS prototype. XBee series-2 modules are used to build the wireless ZigBee connectivity between the smart socket device and the SEM controller. In the initial test, the three different loads taken into consideration by the new changeable priority functionality is shown. Additionally, it is possible to adjust a product's priority ranking in response to consumer demand. Additionally, cost optimisation techniques are used by the SEM controller, which plans the operation of a SEM. The SEM controller also plans the use of a certain appliance during off-peak hours by using cost optimisation algorithms.It employs the lower slab rate and considers the ToU tariff in order to lower the cost of electricity. The consumer is informed of the increased electricity use that takes place during peak hours through buzzers and LED indicators. Last but not least, information on individual load power utilisation is accessible through a safe internet gateway connected to an IoT environment.

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