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Smart Control and Monitoring of Rooftop PV Power System

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Abstract
The Internet of Things (IoT) is becoming more and more popular, and both practitioners and scholars are becoming interested in it. In order to offer information and control over the state of the items around us, the major goal of IoT is to bring everything in the world together under a single infrastructure, including things, people, places, and processes. Demand side management is a crucial component of smart grid operations that focuses on improving cost and efficiency through load management and control. In order to regulate all load/energy control units at each client end, this demand side management prototype system employs a Central Energy Management Unit. At each client end, a data-entry circuit is employed for the previous transmission of load scheduling requests.A Global System for Mobile communication is used for wireless data transfer between multiple devices. A few loads, an Arduino Uno, relay modules, current sensors, Proteus software, and Global System for Mobile communication modules make up the lab setup.

Keywords: IoT,PV,Monitoring,smatplug

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I. INTRODUCTION

The Internet of Things (IoT), which is regarded as the basis for the next generation of the Internet, is expected to facilitate improved communications and intelligent operations of gadgets, smart objects, systems, and services. Everything will actually be given a unique identifier as part of a new communication technology revolution so that it may be addressed, connected to other things, and exchange information. Anything from tyres to hairbrushes falls under this category. The definition of the Internet of Things is still not clear or consistent. The Internet of Things (IoT) is a network that links common physical things with recognisable addresses to provide intelligent services. It is based on conventional information carriers like the Internet, telephone networks, and other similar networks.The author suggested that the IoT be defined as "a global network of networked devices uniquely reachable, based on standard communication protocols," since its first expression comprises of the words "Internet" and "Things”. The actual value of IoT, however, comes in its capacity to link a variety of heterogeneous devices, such as smart objects, embedded intelligent sensors, context-aware computations, conventional computer networks, and commonplace things. The designs, systems, protocols, intelligence, applications, suppliers, and sizes of these heterogeneous devices vary[1]. Through applications and management systems that are located in data centres or network clouds, these entities are capable of interacting and integrating with one another in order to gather, create, process, and exchange data.

At the producing, transmission, and distribution ends, several steps must be completed in order to create the smart grid network. utility companies and their consumers working together to enhance efficiency and cost (DSM). Both customers and utilities will gain from load management and control. DSM was viewed as a temporary fix to lower load demand during peak hours until the utility could provide the peak loads. Despite this, there is a growing understanding of the benefits of DSM due to rising demand and advancements in communication technologies. DSM was viewed as a temporary fix to lower load demand during peak hours until the utility could provide the peak loads.Despite this, there is a growing understanding of the benefits of DSM due to rising demand and advancements in communication technologies. By lowering the chance of blackouts and handling system emergencies, DSM increases system reliability. By avoiding the utilities from utilising extra fuel or investing money on new power sources during peak hours, it also helps to lower energy rates. Utility companies benefit from it as well because it saves them money on off-peak storage.

The Internet of Things (IoT) digital security issue is becoming worse as more home and workplace gadgets are connected to the internet. When connected to edge gateways or cloud platforms, IoT will generate more data than any other emerging technology, and it will also generate the quickest data streams through sensors. The Internet of Things, Industrial IoT, and Edge Computing are expanding at an incredibly fast rate and have become a crucial part of our daily lives through applications like intelligent tracking systems in transportation, industrial wireless automation, public safety, personal health monitoring, and health care for the elderly community.The possibilities appear limitless. We are currently residing in what was once believed to be a lifetime away. A developing network of linked gadgets is known as the "Internet of Things" (IoT). The Internet of Things (IoT) network is made up of digital things including machines, tags, and electrical gadgets (UIDs). Among other things, these networked smart devices are utilised for real-time monitoring, data detection, and transfer.

With the advent of IoT, the fourth industrial revolution, often known as Industry 4.0, has reached India. In addition to the recently introduced "Digital India" agenda, IoT is a key component of the developing IoT business and technological landscape. According to a recent report provided by Zinnov in June 2020, IoT investments in India were close to $5 billion in 2019 and are expected to reach $15 billion in 2021.

Exhaustible energy sources like coal are depleting alarmingly quickly, and we are continuing to rely on them excessively. Inexhaustible energy sources like solar and wind energy can be used in this situation[6].An important and limitless source of energy that has recently received attention is solar energy. Investments are being made in the solar industry in the hopes of a future with fewer reliances on fossil fuels. Fuels like coal, oil, and natural gas are scarce and unfriendly to the environment. Therefore, there needs to be a general consensus in favour of renewable energy sources.

Future renewable energy generation will increasingly rely on solar energy. More rooftop solar systems are being connected into networks like grids and industrial areas in order to provide strong grid stability. Consequently, there is a growing requirement to track the energy produced by solar power plants in real-time, identify any issues, and boost the total production of solar systems.Variations in sun irradiation, temperature, and other factors lead to fluctuating power generation from solar panels. Utilizing cutting-edge IOT technology solutions like those depicted in Figure 1, we can autonomously build the machines[8].With the help of these components, we can easily track wireless networks, do away with the drawbacks and risks of existing technical solutions, and create a range of sensors and microcontroller gadgets. The cost functions of the device are as a result far more compact than those of the older control systems.

The Internet of Things relies on context-aware computing using network resources and intelligent networking with already-existing networks. There is little question that WiFi and 4G-LTE wireless Internet access will eventually become commonplace information and communication networks. The computing paradigm will need to develop beyond the existing mobile computing scenarios that connect common things and infuse intelligence into our surroundings via smart phones and portable devices if the Internet of Things aim is to become a reality.To make technology invisible to users, the Internet of Things needs three things: (1) a shared understanding of the circumstances surrounding users and their appliances; (2) software architectures and pervasive communication networks; and (3) Internet of Things analytics tools that strive for autonomous and intelligent behaviour. Smart connectivity and context-aware computing are possible with these three underlying presumptions in place.

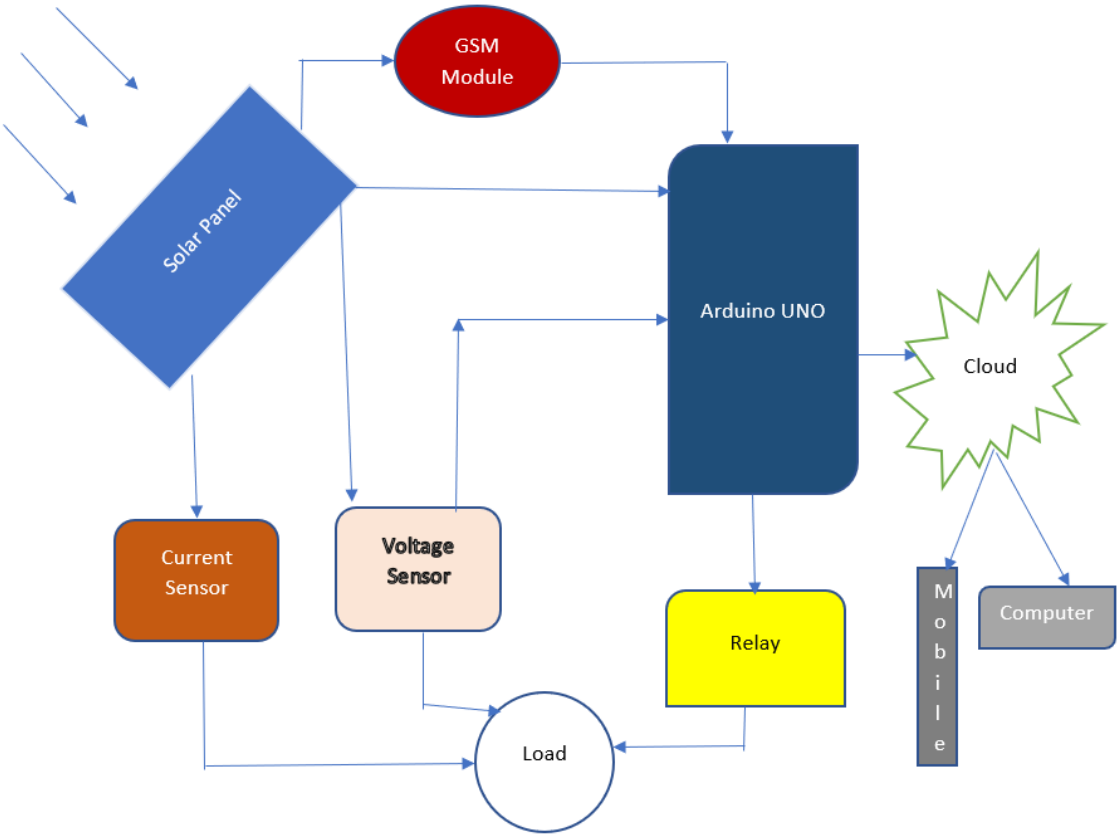

Fig.1 Block Diagram of Solar energy monitoring system

1. Demand side management

The field of demand-side management (DSM) is one that is developing in the energy sector. As part of their efforts to manage costs and lessen the impact of energy shortages on their bottom lines, mileage firms are advocating it less frequently. DSM also effectively manages the unintended consequences of power outages during the busiest hours of the day, as well as in the case of high charges or grid traffic[2]. These characteristics, particularly on weekends and during off-peak hours, might result in increased expenditures and annoyance for drug users. Demand side management helps to address some of the smart grid's challenges (DSM). With this approach, both grid load and electricity costs will decrease.DSM provides customers with resources to help them decide how much and when to use electricity. Load shifting and load reduction are two areas where DSM has an impact. For the DSM algorithm to be implemented, two-way communication between the utility and the end consumer is essential. the end user's willingness to change or lower their energy use[3]. By relocating power demand from peak to off-peak hours, energy generation may be avoided and production costs can be reduced.

Load management programmes and energy reduction programmes are the two major foci of DSM. As part of the energy reduction initiative, loads' performance and energy efficiency are enhanced. Direct load control and indirect load tariff control are two subcategories of load management. Utility suppliers can remotely turn on or off a specific non-critical load thanks to direct load control. The objective is to distribute the loads evenly across the time period in order to discourage utilities from investing in reserve capacity. Direct load control techniques include load shifting, peak clipping, and valley filling. Peak clipping reduces non-critical loads during peak periods, flattening the load curve[4].Peak clipping reduces overall operating costs by saving essential fuel and taking preventative action that would have otherwise led to a major fault scenario. To provide a flat load profile, the loads are increased at off-peak times. In order to heat water or a place, this load management technology turns electrical energy into thermal energy. The load factor is raised and the cost of the energy is decreased since the client is using the energy off-peak. Because of this, utilities and customers both gain when loads are filled outside of peak times. The most well-liked of these methods is the load shifting strategy, which mixes peak clipping and valley filling tactics. Even if the overall load demand is consistent throughout the day, load shifting's goal is to relocate loads from peak to off-peak hours.

2. Proposed Methodology

This system's objectives include developing and implementing a demand side management system with an easy-to-use user interface, managing the functions of load controllers and energy suppliers that collect user-provided data on energy usage, and performing control based on a webserver using energy sensors. Residential customers lack the time necessary to manually handle demand response[7]. An IoT-based system is required for the implementation of autonomous demand response throughout a region. The associated priority is altered in accordance with the priority of the loads that each user is using. Each load is connected to the others using relays. Requests for load reduction will be received via relays, and they will ensure that total power consumption stays below the set demand limit.

As long as the total household power usage is within the set limit, the recommended DSM system enables the home owner to use their loads as needed. The suggested system's Energy sensor, Webserver, and database view will be in charge of monitoring and managing appliances' power use. Here, a time-of-use-based pricing structure is employed to regulate the user's energy use. When compared to peak hours, off-peak electricity consumption is less expensive. Peak hours' power consumption costs per unit are higher than off-peak hours' prices per unit. Each user sends a signal through the communication module requesting power.This communication module is used to gather data on each user's power usage and to give consumers a way to check their power usage and regain access to the status of their appliances[5]. The Webserver has information to track and manage power consumption.

The system's primary goal is to build and create a user-friendly Demand Side Management system that will regulate energy suppliers and controllers. According to each N User's need and peak hour, the Energy organisation will deliver them the appropriate amount of electricity. Each user's power consumption will be measured by an energy sensor for voltage, current, and power. The user interface is used to track and manage the user's status and power usage.

3. Components used in the system

Different components used in the system have been described in this section.

i)Arduino UNO

The Arduino Uno microcontroller board is built around the ATmega328. Indicated in Figure 2 are its six analogue inputs, a 16 MHz crystal oscillator, a power connector, an ICSP header, a USB port, and reset buttons. There are a total of 14 digital input/output pins, 6 of which are PWM outputs. The only thing needed to get started is the insertion of a USB cable, an AC-to-DC converter, or a battery because everything needed to support the microcontroller is already included [10].The ATmega328 microcontroller's recommended input voltage is 5 volts, however the ideal input voltage varies from 7 to 12 volts (limits) Pins for digital I/O: 6-20V, 14 (of which 6 provide PWM output) 6 DC Analog input I/O pins are at pin 50 mA and current 3.3V pins are at pin 40 mA. The bootloader makes advantage of the ATmega328's 32 KB of Flash Memory, 1 KB of EEPROM, 2 KB of SRAM, and 16 MHz of clock speed. Writing and editing programmes is made incredibly simple by the software package, such as the Arduino IDE (integrated development environment). The Arduino UNO board's pins 0 (RX pin) and 1 (TX pin) must be kept vacant when programming commands into them.

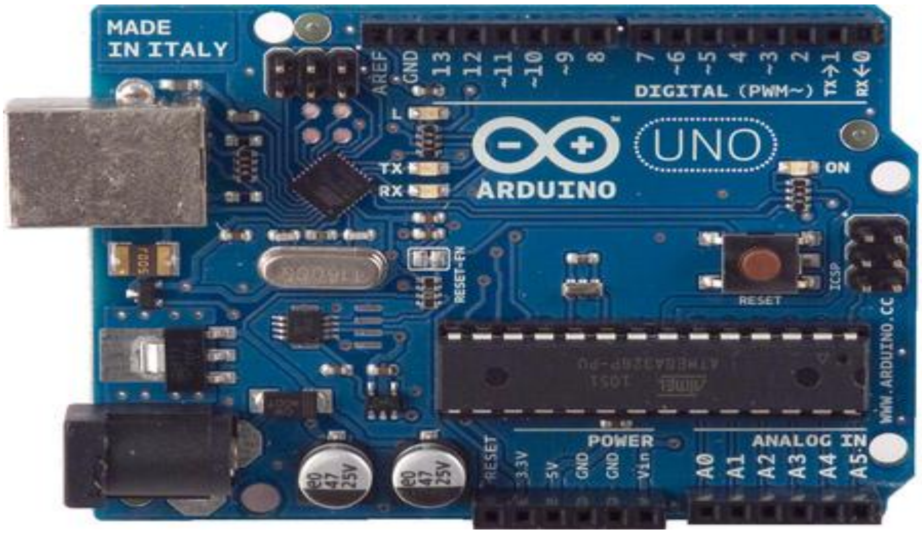

Fig. 2 Arduino UNO

ii) Current Sensor

The linear current sensor ACS712, which is completely integrated and based on the hall effect, has an integrated low-resistance current conductor as well as 2.1kVRMS voltage isolation. It may be summed up as a current sensor that uses its conductor to figure out and measure the amount of applied current, without using any technical jargon. A current sensor that can operate on both AC and DC is the ACS712. At a 5V operating voltage, this sensor outputs an analogue voltage that is inversely proportional to the measured current. Several precisely calibrated Hall sensors are joined by copper wires to form this gadget.

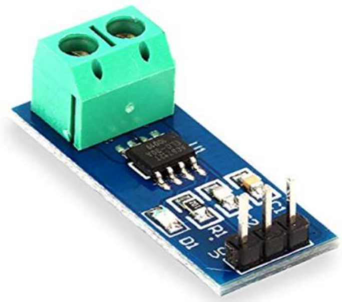

Fig. 3 Current Sensor

The output of the instrument slopes upward as the primary copper conduction current increases (from pins 1 and 2 to pins 3 and 4). There is 1.2 m of internal resistance in the conduction route.

iii) GSM Module

Figure 4 displays It uses a GSM modem with a SIM900A chip. At 900 MHz and 1800 MHz, the SimCom SIM900A dual-band GSM engine operates. Transmissions through SMS, voice, and data are all compatible. It needs a 12 V, 2 A external working voltage. On the device are three status LEDs with the labels PWR (power), SIG (signal), and RING [11]. When the modem is functioning properly, the SIG LED blinks, but the PWR LED is always lighted as long as power is present. In the event that a message or call is received, the RING LED will begin to flicker.At the base, there is a SIM card slot. Data communication with an Arduino is accomplished using the TXD, RXD, and GND pins [15].

Fig. 4 GSM Module

iv) LCD Display

LCDs must inform the user of the data packets being transmitted to the CEMU end at the customer end data input circuits. Here, the Hitachi HD44780 driver is being utilised with a 16x2 parallel interface LCD. Basic LCD functionality is already provided by this Arduino library in the Arduino IDE (as an example).As a result, it is easier to connect LCD to Arduino and scripts may be created to suit a variety of needs. A 10kX external potentiometer (POT) is connected to the LCD's Pin 3 for contrast control. 8-bit data interfaces for reading and writing to registers are present on pins 7 through 14. The anode and cathode pins that power the LED backlight are 15 and 16, respectively.

Fig. 4 LCD Display

v) USB Host Shield

The data entry circuit at each client end requires USB ports, as seen in Figure 5, but the Arduino UNO does not have any. As a result, in order to connect an external USB device to Arduino (such as a keyboard), a USB host shield is required. The MAX3421E USB peripheral/host controller, on which it is based, provides the analogue and digital circuitry necessary for the microcontroller to accept data from USB peripherals[19]. It uses the power pins, ICSP connections, and digital I/O pins 8 through 10 and attaches directly onto the Arduino board. The power pins are used to supply power, while the ICSP connections are used to send or receive data utilising serial peripheral interface (SPI) protocols.Using the Interrupt (INT) and Slave Select (SS) interfaces on the Arduino when transmitting data to a peripheral device, timing issues in a microcontroller are fixed. The programme is reset by pressing the RESET button on the USB shield, which is also a feature.

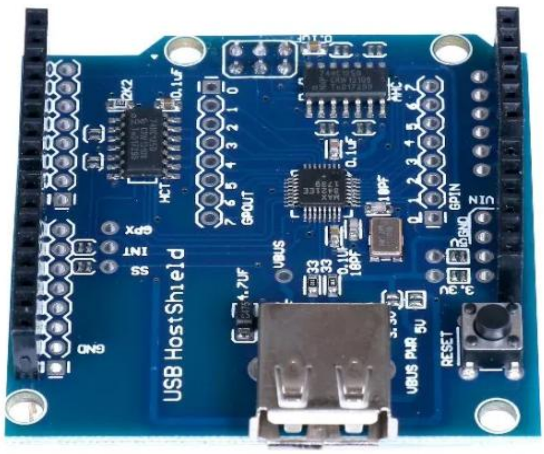

Fig. 5 USB Host Shield

vi) Potentiometer

A three-terminal resistor with a sliding or rotating contact that modifies the voltage divider is referred to as a potentiometer. When only the wiper and one terminal are used, Figure 6 shows how it functions as a variable resistor or rheostat.

Fig. 6 Potentiometer

vii) Relay Module

It is a single-channel, 12 V, sealed, optically isolated, small relay module. As shown in Figure 7, the input pin is used and connected directly to the Arduino's digital pins. Switches marked COM and NO/NC are used to connect the appliances.

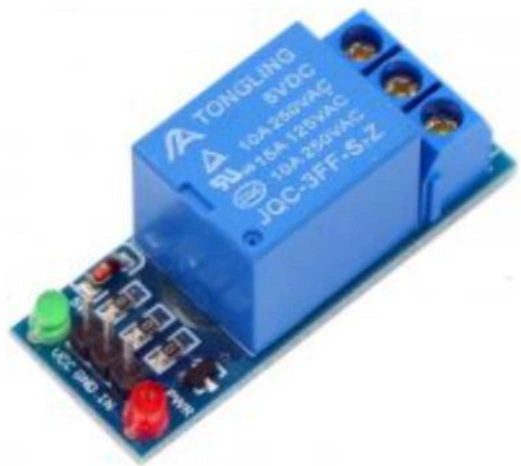

Fig. 7 Relay Module

viii) LED

LEDs are a specific kind of diode that use electricity to create light. Light Emitting Diode is what LED actually stands for. And the analogy between the diode and LED illustrates this.

4. Implementation

There are essentially three separate subsystem types in this DSM prototype design, two of which are placed at the load end for each customer and one of which is placed in the middle at the CEMU end. The various parts of the DSM system are as follows:

i. Circuit for management of load ends
ii. Circuit for inputting loadend data
iii. End control circuit for CEMU

i) Circuit for management of load ends

In accordance with the command signals that the CEMU transmits via the GSM module, this control circuit regulates the on and off timings of the loads. Figure 8 illustrates a control circuit design for a single load. Solar energy has enabled the two modules to have an external 12 V DC supply (Arduino UNO and GSM). The TXD and RXD pins of the GSM are linked to the Arduino's digital pins 7 and 8, respectively, for serial data exchange. The Arduino's digital pins 7 and 8 may be altered to act as RX and TX pins, respectively, by writing code to the pins using the Arduino IDE.The solar-powered 12 V DC supply is linked to the relay module.

To provide a common reference and prevent ground loop issues, the GND or negative pin of the 12 V supply from solar power is always linked to the GND pin of the Arduino (circulating current may flow if both the grounds are not at the same potential). An alternate approach is to combine all 12 V DC power sources into a single unit with the necessary/appropriate current ratings. However, while choosing this configuration with independent sources, the ratings of the power supplies that are available in the lab are rapidly taken into account.The message (command signal) supplied via CEMU is used by the Arduino to control the relay module. For instance, the Arduino will send HIGH to the relay's "input pin" in order to allow the relay switches to make contact with the load #1's NO and NC ports if the command signal is "ona" (for customer #1, load #1). The relay switches establish contact from NC to NO ports, turning OFF the load #1, and the Arduino broadcasts LOW to the input pin of the relay if the command signal is "offa" (for customer #1, load #1).

The rectangular piece coloured red stands in for the GSM module, while the rectangle piece coloured black stands in for the Arduino UNO board.Two relays and two current sensors are present for each load. The instantaneous current is converted by the current sensor into an equivalent analogue voltage based on its sensitivity. The analogue voltage value is converted to digital counts after that. The present sensor code takes all of these factors into consideration before raising the digital count by the appropriate number. It is the responsibility of the current sensor to ascertain if the consumer truly consumes the desired load.

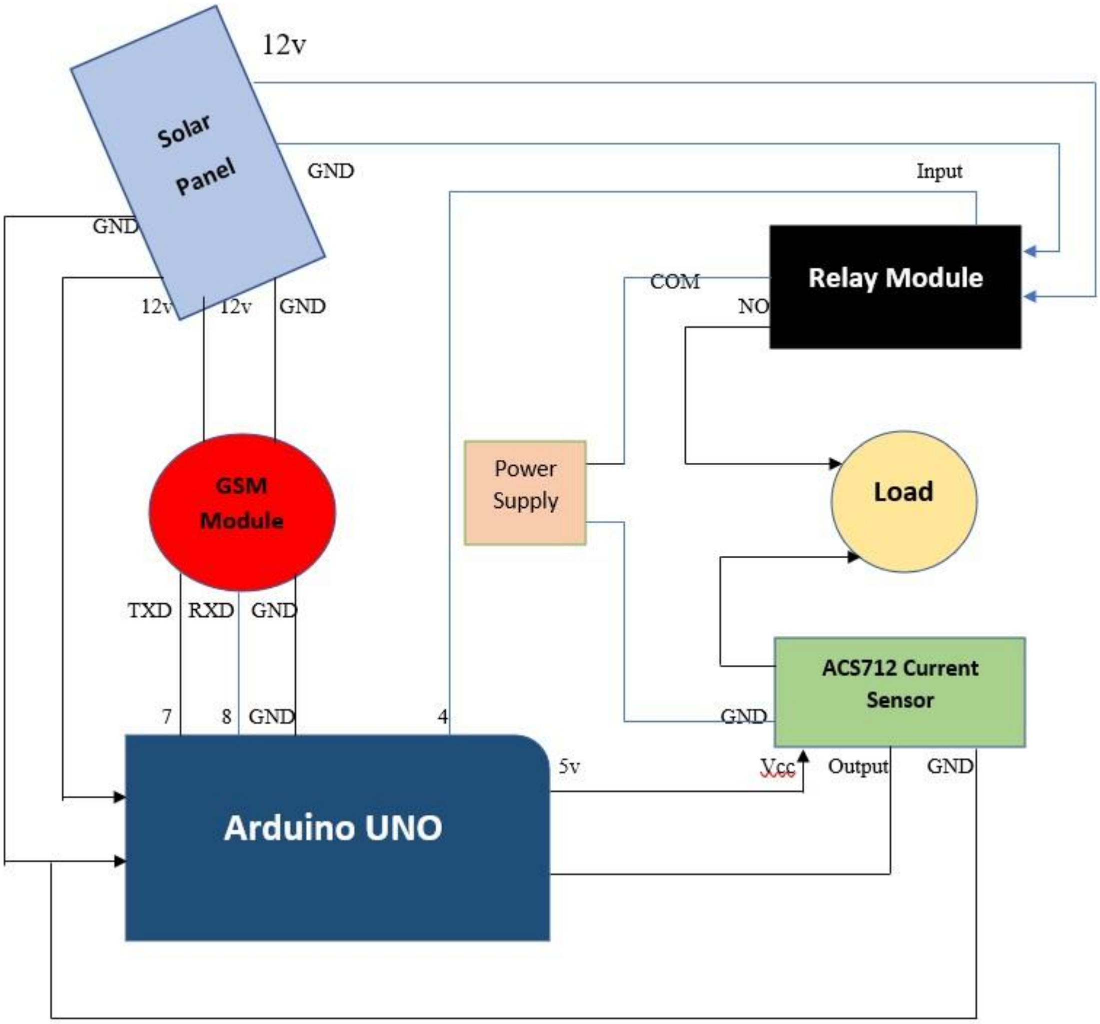

Fig. 8 Circuit for management of load ends

ii) Circuit for inputting loadend data

The CEMU receives the data packets (client requests) through the data input. The CEMU constructs the load scheduling pattern after receiving these data packets. Figure 9 depicts the circuit diagram for the data entry circuit. For serial data interchange between Arduino and GSM, the TX pin and RX pin of the GSM are connected to digital pins 0 (RXD pin of Arduino) and 1, respectively.

Pins 2, 3, and 4 of the Arduino are linked, accordingly, to the LCD's D7, D6, D5, and D4 in order to transmit data. Pins A (anode) and K (cathode), which are linked to the Arduino's 5 V and GND pins, respectively, provide power for the illuminated display.It should be noted that while receiving a 12 V DC supply from solar power, the Arduino board generates a 5V DC supply at the corresponding pin. As a result, the Arduino board generates a 5V DC output, which is utilised to power the LCD backlight through the GND pins. Use pin R/W to change the operation modes between read and write. Since Pin R/W is connected to GND and the LCD is being used as a display device in this application, the LCD is permanently placed in write mode.

There is a list of potential messages that might appear on the LCD in the Appendix. To allow the user to change the contrast, Pin V0 is linked with a 10k potentiometer. Instead of using the USB connector present on the Arduino UNO, the USB keyboard is linked to Arduino using a USB host shield. The Arduino board and USB host shield are directly connected. The Arduino uses its serial peripheral interface (SPI) for communication. The Arduino's power pins are also used by the USB host shield to run it. The hardware setup for the data entry circuit is shown in Figure. You can enter on a keyboard and look at the LCD to verify that the relevant data packets have been sent to the

CEMU. This is made feasible by firmware that is part of the Arduino UNO, which is also in charge of using the GSM module to deliver the data packets. The consumer sends data packets to the CEMU for each load. The data packets are divided into the following four sections:

- Customer information
- load information
- load wattage or power
- load ON interval.

A typical message may be "1 2 0200 3zy," for instance. Here, the first number (1) designates the client's identification, while the second number (2) designates client 1's second load.

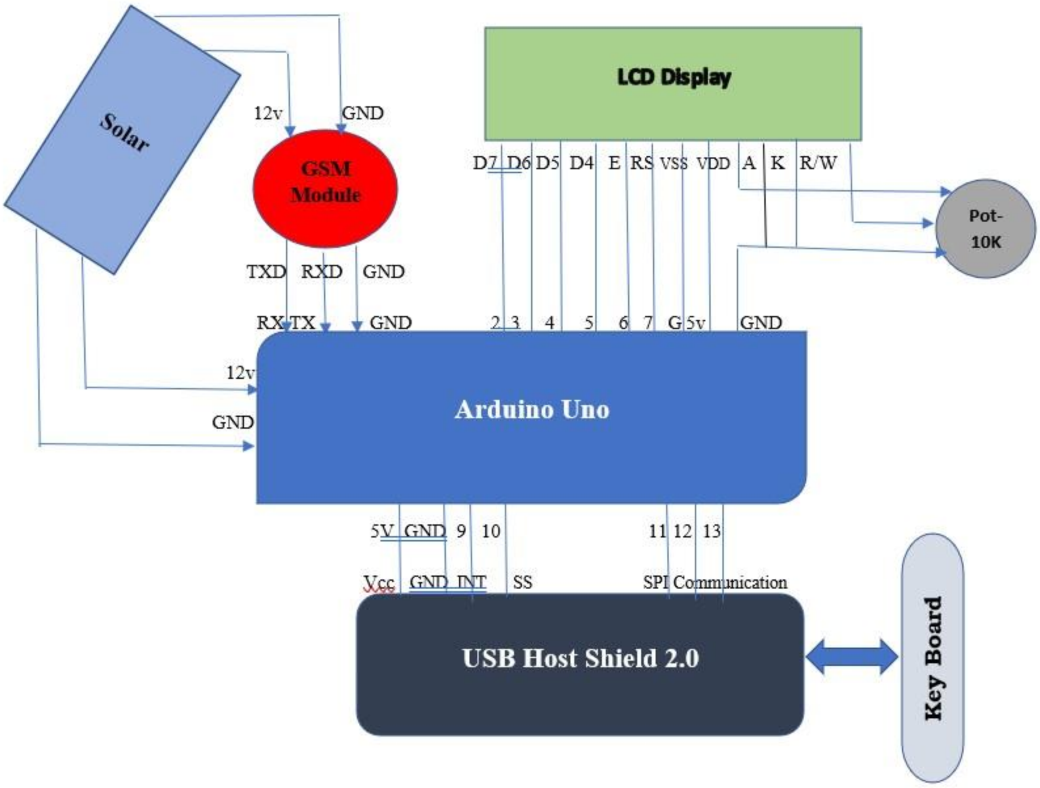

Fig. 9 Circuit for inputting loadend data

The fourth number (3), which is the last number, denotes the interval at which the load wants to turn on. The power rating is shown by the third number (0200). The letters "z" and "y" are only used as markers and are put after the full description of the load. The microcontroller can utilise these to gauge when the message has been sent. When a "y" is input at the load end data entry circuit, the microcontroller sends the message "1 2 0200 3z" to the CEMU via a GSM modem. As a consequence, the submit button is represented by the letter "y".Similar to this, when it receives data from the CEMU end, the Arduino recognises that the contents before the letter "z" are the actual data packets and only keeps those.

iii) End control circuit for CEMU

The data input circuit depicted in Figure 9 is used by the data input circuits at the load end to feed data packets to the CEMU. The processed data are sent into the DSM algorithm once the data have been processed. The result of the DSM algorithm provides a load scheduling plan for each load. The command signal is then sent by the CEMU in the prescribed pattern to each load. It is important to keep in mind that the CEMU has two separate processors and two distinct programming languages. The first is the Arduino microcontroller, which uses embedded technology to produce a pre-written software that is designed to "receive data packets and deliver command."The system computer analyses the data and sends it to the DSM software in MATLAB to find the best scheduling pattern after receiving the data packets from Arduino through the USB connection link. As a result, communication between MATLAB and Arduino is necessary. To do this, built-in library files are available in the most recent version of MATLAB. a USB cable (type-A to type-B) The type-A end of the cable is attached to a system port on one end, while the type-B end is connected to Arduino on the other.

The USB cable regulates power supply and data transmission for Arduino. The CPU sends commands to the Arduino when the DSM algorithm has finished running.The Arduino sends signals to the load end control circuit, which then uses the GSM network to relay those signals. The LEDs show which loads need to be switched ON at specific intervals based on the final load scheduling pattern.

Here, it is assumed that the laptop serves as the computational heart of the DSM algorithm. The GSM module on the Arduino makes it easier to send and receive data packets. Two control loops—the speedier MATLAB control loop and the slower Arduino control loop—are present as a result of the presence of two CPUs (since GSM module takes some time to send SMS). For dependable and efficient handshaking between the two CPUs, a suitable delay must be introduced to the faster loop. After selecting the load schedule, the CEMU notifies the consumers of each load's control signals. Only the ON/OFF command and the load identification are present in the control signal. For instance, if the GSM module of customer #1 receives the control signal "ona," the load #1 is turned ON; likewise, if the GSM module of customer #3 receives the control signal "offe," the load #5 is turned off.

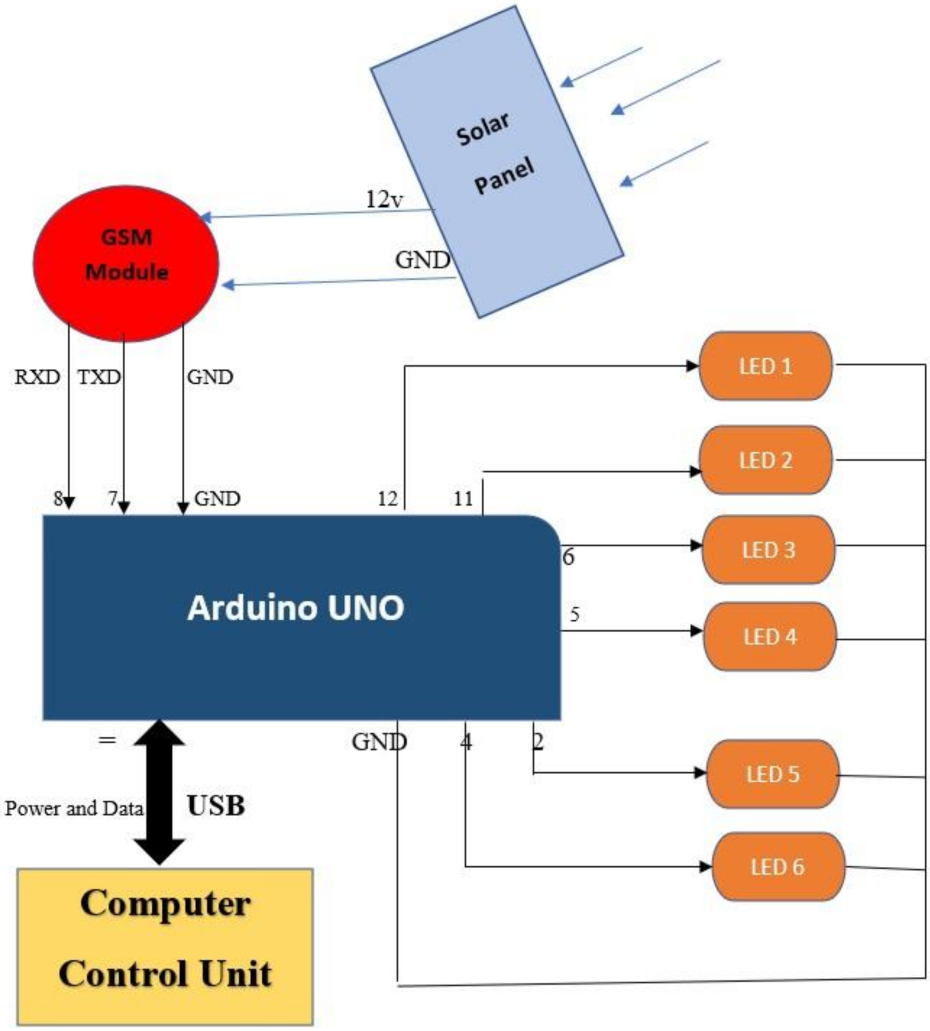

Fig. 10 End control circuit for CEMU

5. Result analysis

In this project the circuit designed by using Proteus Software. A software tool set called Proteus Design Suite (created by Labcenter Electronics Ltd.) is primarily used for drawing PCB Layouts, simulating Electronics & Embedded Circuits, and making schematics. Its benefits include automated PCB layout and wiring, hybrid circuit simulation, peripheral circuit co-simulation, and intelligent main layout.Before Hardware implementation the circuit designed and run in this Software because in Hardware directlyimplemented errors are maybe occurs.

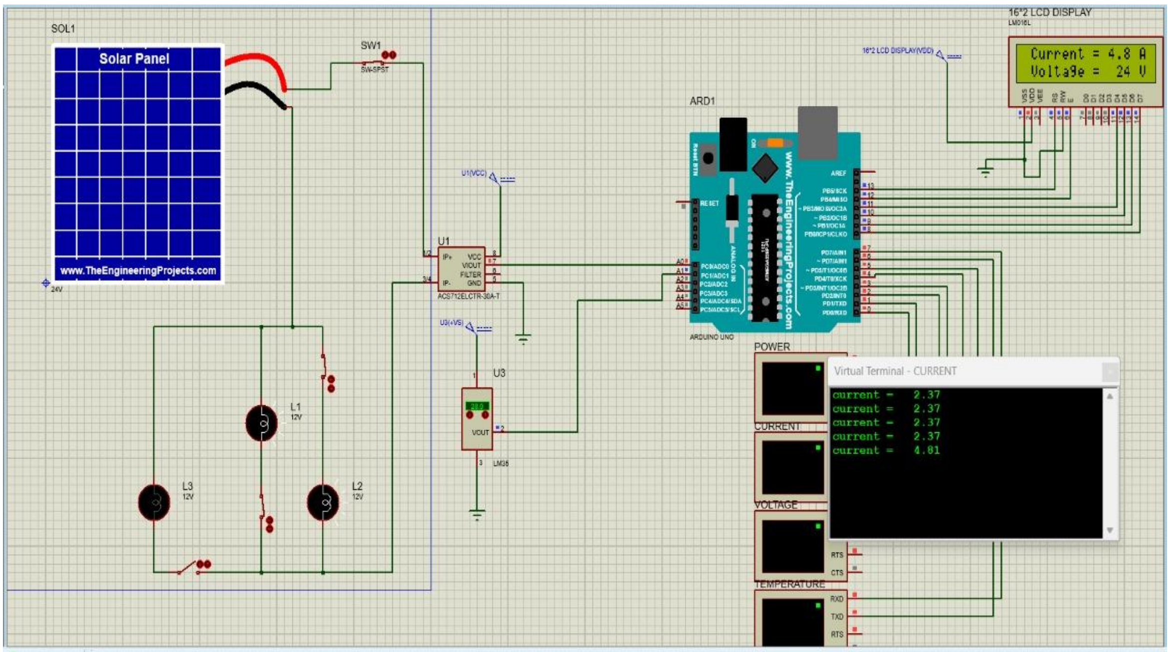

Fig. 11 Solar PV Power Monitoring System

In Above figure 11 shows the Design of solar power monitoring system in Proteus Software. After given the valve to circuit and run We can observe the current readings. Then implemented the code in Arduino UNO and connection are made by the circuit diagram shown in Figure 12. The hardware results are same as the circuit results in proteus Software.

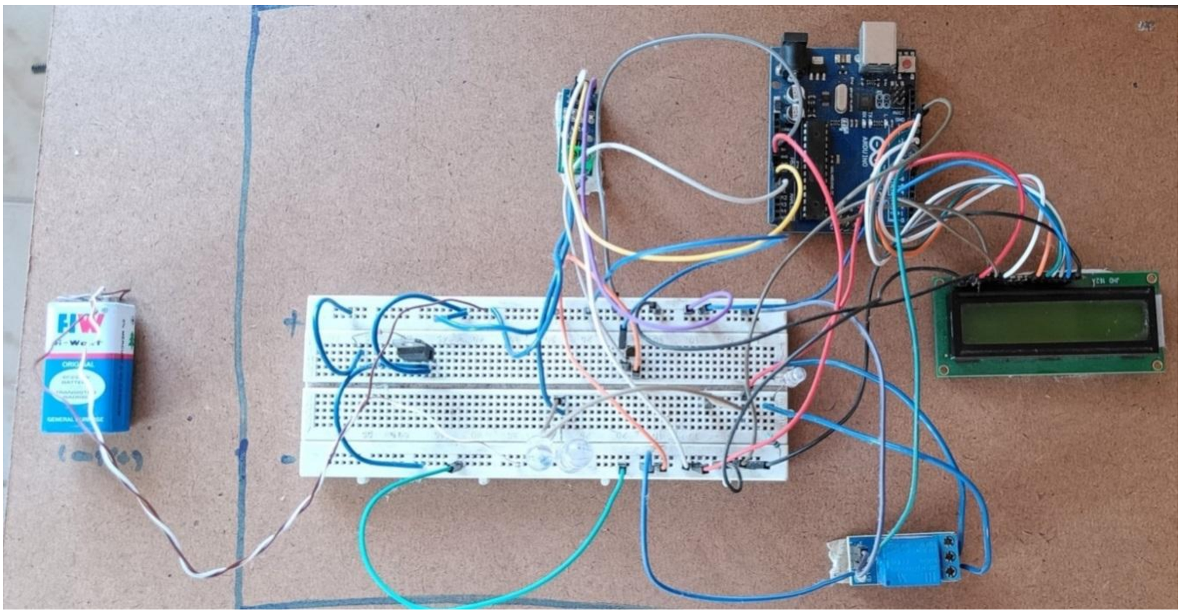

Fig. 12 Hardware implementation of Solar PV Power Monitoring System

II. CONCLUSION

Both utilities and customers profit from the DSM and dynamic pricing system. The DSM, in the eyes of the utility, not only lessens the burden of peak-hour power demand but also spares them from having to store energy. Energy storage has significant up-front and recurring costs, which could lead to losses. If the load can be distributed fairly, two-way communication between utilities and customers can eliminate the need for bulk power storage.

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