International Journal of Innovative Research in Management Studies (IJIRMS)
Volume 8, Issue 5, May 2026. pp.1-8.

SOLAR POWERED SMART GRID WITH IOT BASED MONITORING

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Abstract—*Solar Powered Smart Grid with IoT-Based Monitoring System concentrates mainly on effective energy generation and monitoring. In the proposed system, solar energy will be used for the generation of energy. The energy generated by solar panels will be transferred to the battery after production. Energy stored in the form of electrical energy in the battery will be used for running various electrical appliances like lights, fans, and motors. Microcontroller can be considered as the brain of the system as the decision-making takes place in it. The decision made by the microcontroller depends upon the information received by it. Microcontroller receives information regarding the generation and consumption of electrical power through the sensors for current and voltage. This information is passed on to the users through communication technologies like IoT and GSM technology. Relays are used to control remote operation of electrical appliances. Thus, from the above discussion, it is clear that the proposed system offers many advantages like energy savings and effective utilization of electrical power. Moreover, there will be reduction in reliance on the electricity grid network as well as environmental conservation will become possible. Hence, the proposed system appears to be quite practical and economic.*

Keywords: *Solar Energy, Smart Grid, IoT Monitoring, GSM Communication, Microcontroller, Energy Efficiency, Renewable Power, Smart Control System.*

INTRODUCTION

The high demands for electrical energy, fast pace of industrialization, and environmental consequences caused by existing methods of electricity generation pose a pressing need for sustainable and intelligent energy production. This is why solar powered smart grids systems controlled through the Internet of Things have been developed. In the case of traditional grids, there is a need to generate electricity in large power stations before distributing it. It is also possible that some power loss will occur since distance transmission of electricity may not be efficient enough. Furthermore, the use of fossil fuels has many negative consequences on the environment. This is why the search for alternative sources of energy has become vital. Renewable energy sources have come into play thanks to their eco-friendliness and abundance. In particular, there is solar energy which helps to generate electrical energy using solar panels. Moreover, it can be used both in urban and rural areas. Nevertheless, solar energy generation depends greatly on sunlight availability. Thus, it is necessary to create appropriate management systems. Smart grids help to manage this process efficiently. Apart from the automated system of communication, control units and digital management used by solar power plant, IoT plays an essential role since it enables communication between solar cells, batteries, sensors and other control units in order to achieve optimal efficiency and reliability. This technology continuously analyzes the work of the system in terms of generation, consumption and overall activity of the facility. This power plant provides an opportunity to change energy allocation as required, as well as store some extra electricity to be further used. In addition, the power plant can be controlled remotely, allowing users to monitor their own consumption of energy.

This will help to save some energy and be much more efficient in the process. Finally, due to storage of energy by distributed generation, constant function of the power plant will be ensured. Even though initial costs of construction may be rather high, there will be numerous advantages of cost reduction and improvement in efficiency. Solar powered smart grid with Internet of Things technology will thus provide significant benefits for modern power plants.

EXISTING PROBLEM

Conventional electric power distribution consists of the generation of energy at centralized facilities and direct delivery of produced electricity to consumers through distribution and transmission lines. The main energy sources used by such systems are conventional types of energy generation including coal, diesel, and other types of fossil fuel. Despite the fact that such approach has been practiced for many years, the mentioned conventional systems lack advanced methods of energy monitoring, energy consumption control and management. The first drawback associated with conventional systems of electrical power distribution lies in the inability of the latter to monitor consumers' energy consumption in a timely manner. Consumers receive information regarding energy usage per month only through the billing procedure. It is difficult to monitor the process of energy consumption on a daily basis to find out possible misuse of energy, which leads to energy waste and unnecessary expenses on electricity. Another drawback of conventional systems is the impossibility of remote energy usage control as it requires physical switching off and turning on energy using devices and equipment. This problem may occur in some urgent situations when actions should be taken immediately. Conventional systems of electrical power distribution do not have energy consumption controlling mechanisms. There exists an overwhelming reliance on energy sources that are not renewable. In addition to the costly operations involved, use of non-renewable energy sources like fossil fuel creates a danger to the environment by increasing the level of pollution and global warming. In response to increasing needs for energy, there arises a problem regarding the reliance of energy sources for sustainability. Detection and analysis of faults become extremely difficult. Lack of monitoring causes delays in diagnosis of faults when overloaded circuits, unstable voltage levels, and equipment failures occur. This leads to inefficiency in delivering electricity to users. Furthermore, there exists a problem in the use of data to make decisions. Adequate data is required for effective decision making. Unfortunately, due to lack of proper mechanism for collecting data, it becomes impossible to do so. The aforementioned problems have led to the need of adopting another strategy. An innovative strategy will assist in facilitating remote control, renewable energy usage, and monitoring.

PROPOSED SYSTEM

The system involves the use of a solar-powered smart grid with monitoring capabilities through the internet of things (IoT). This system will manage and control the effective use of energy compared to the traditional ways. Unlike the existing traditional energy system which lacks automation and monitoring capabilities, the newly proposed system will require a combination of renewable energy production, communication ability and automation. Renewable energy that is generated through solar panels as a result of solar radiation is changed to direct current (DC) energy. Such energy is regulated in terms of voltage and controlled in terms of flow by the energy controller. This energy may be directed through invertors to change it to alternate current (AC), while extra energy is stored in batteries in case of lack of sunlight in future. Microcontrollers will be the backbone of this system as a means of communication between the energy produced, consumed, or used as loads by communicating with other sensors such as current sensors and voltage sensors. The information about the process will be displayed on LCD while being transmitted through IoT remotely. Relay modules shall be applied in controlling electrical appliances such as lights, fans, motors, etc. According to the condition or instructions by the user, the system controller turns ON/OFF the load effectively and enables energy saving. In comparison to the current systems, it is advantageous as manual control is applied and energy is wasted inappropriately. Moreover, the system makes smart decisions based on the available data. Any extra energy from the solar panel can be stored in batteries, and during peak times, the excess energy may be used. Furthermore, in case of any faults like overloads and variations in voltages, the affected components can be isolated. As seen, the above system is more efficient, energy saving, remotely accessible, and dependable compared to the existing system. From the explanation, it becomes apparent that incorporating solar energy with IoT technology provides an economical solution to energy management.

COMPONENTS REQUIRMENTS HARDWARE REQUIRMENTS

- MICRO CONTROLLER
- SOLAR
- BATTERY
- CURRENT SENSOR
- GSM
- MAX 232

- LCD
- RELAY
- FAN
- LIGHT
- MOTOR

SOFTEWARE REQURIMENTS

- Embedded C

BLOCK DIAGRAM

The functioning of the Solar Powered Smart Grid with IoT-Based Monitoring entails effective coordination among energy production, monitoring, and control processes. The blocks of the design perform certain functions that contribute to the efficient management of power resources.

1. **Generation of Solar Energy:** Through the use of solar panels, solar energy is converted into electricity in the form of DC electrical energy by means of photovoltaic cells.
2. **Energy Storage System:** It consists of a battery that stores electricity for its subsequent distribution. For protection purposes, one can apply a charge controller for limiting the voltage and preventing overcharging and over-discharge.
3. **Energy Flow Measurement:** To determine the flow of energy within the system, there should be a current sensor. Together with a voltage sensor, it facilitates the monitoring of the consumption and performance of the power resource.

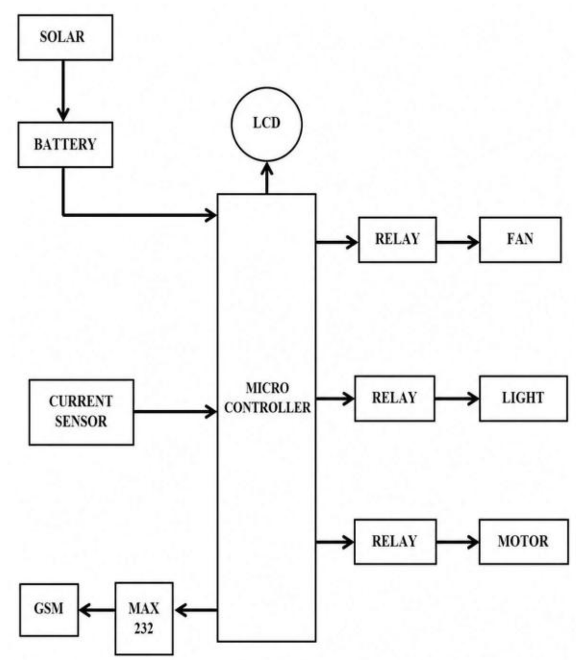

Fig.1.BlockDiagram

4. **Processing and Controlling Processes:** The function of the processing center is performed by a microcontroller that processes input data and initiates control measures according to the set conditions.
5. **Display Unit:** An LCD display serves as the tool that allows monitoring some significant parameters related to voltage and current in the system.
6. **Transmission of System Data:** With the help of GSM or IoT modules, system data is transmitted remotely for further processing.

7. **Switching Circuit for Load Control:** Control units in relay form are employed to control electrical devices like lights, fans, and motors. The switches turn electrical devices ON or OFF depending on the system's operation mode or user instructions.

8. **User Engagement:** The user can engage with the system remotely or manually.

WORKING PRINCIPLE

1. SOLAR PANELS

Photovoltaic Module (Solar Panel): Solar Panel, Photovoltaic Module, or Solar Cell Array refers to the assembly of solar cells that converts the energy of light into electrical energy via the Photovoltaic Effect. Such modules can be used for both domestic and industrial purposes. A solar panel system contains many components such as solar panels, inverters, battery storage, tracker, and cables. Typically, the rated power of solar panels falls within the limits of 100-320 W. Usually, the construction of the solar panels consists of silicon or thin-film solar cells. Solar cells are connected in series to produce greater voltages or in parallel to produce greater current. Solar Panels have waterproof and durable construction, and MC3 and MC4 type connectors must be used to ensure reliability of connections.

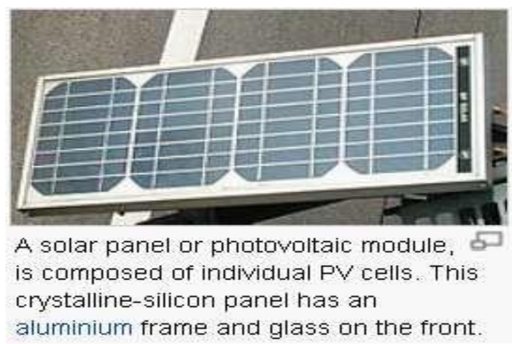

Fig.2.Solar panel

To optimize the functioning of solar panels in the shade, bypass diodes are installed in them. Efficiency decreases in high temperatures, thus ventilation is required for solar panels. The efficiency of the solar panel depends on the technology and materials used for its construction. On average, the efficiency of commercially available solar panels is 17%, although some advanced solar panels increase the efficiency by concentrating light using lenses and mirrors.

2. BATTERY / ENERGY STORAGE

The battery is the energy storage unit where energy produced through photovoltaic effect is stored for future use. We are able to use energy produced during the day time even during night time since the battery stores the energy produced. The need to properly manage battery units is essential to extend its lifetime.

3. MICROCONTROLLER

8051 microcontroller, which was developed by Intel company in 1980, is a low-cost microcontroller that is widely used for automation purposes, electronic devices, robotics, and communication devices. Microcontroller is distinct from microprocessor as it contains CPU, memory, RAM, timer, serial communication port, and input-output ports in one single chip.

It is a Harvard architecture-based microcontroller where program memory and data memory are placed separately in order to increase the speed of the processing. The central processing unit of the microcontroller consists of Arithmetic Logic Unit. Registers in the microcontroller include accumulator, B register, program counter, stack pointer, data pointer, and program status word.128 bytes internal RAM with register bank, bit-addressable, and general-purpose RAM sections are included in this microcontroller. Up to 64 KB of the external memory can be added to access the data and programs. 32 I/O pins are provided by the microcontroller arranged in 4 ports (Port 0 to Port 3), using which, external devices such as sensors, switches, LEDs, motors, and display panels can be interfaced. Along with these ports, there are two 16-bit timer/counter circuitries that are useful for generating delays and pulse counting.

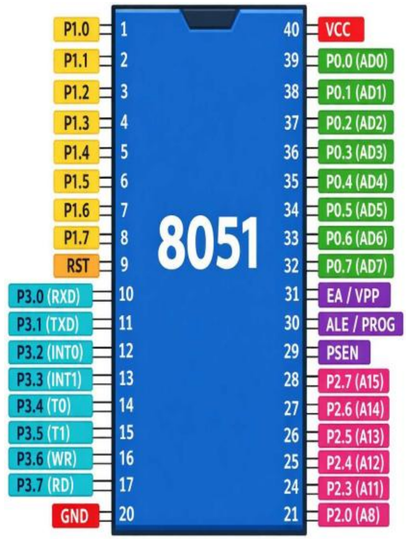

Fig.3.8051 Microcontroller

Solar panels act as the main energy generation component in the entire process. Energy obtained from solar panels is derived from the phenomenon of solar radiation. Photovoltaic effect plays an integral role in generating the above energy. Energy generation process depends on factors such as solar radiation, panel efficiency, and the environment among others. In this case, we generate environment-friendly energy since solar panels are used.

4. CURRENT SENSOR:

The sensors are constantly monitoring the values of electrical parameters like current and voltage in the system. This data is then transmitted to the microcontroller for analysis.

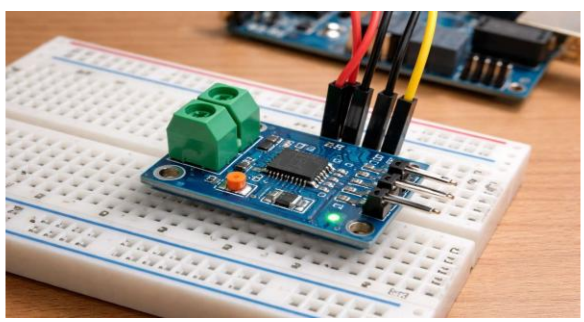

Fig.4.Current sensor

Thus, the sensors are important to identify the power usage and also check if there is any abnormality in the system for its efficient operation.

5. RELAY MODULE (4-CHANNELS):

A relay module is used to switch on/off loads according to certain conditions. They allow the microcontroller to control various loads such as lights, fans, electric motors, etc. This ensures that there is an effective energy saving mechanism in the system.

6. GSM/IOT MODULES:

The GSM (Global System for Mobile Communications) device refers to cellular mobile communication devices that facilitate the transfer of information via voice calls, text messaging, and internet connection through GPRS due to its incorporation of SIM (Subscriber Identification Module) card. GSM modules offer the capacity of working in various frequencies, including 900MHz, 1800MHz, 850MHz, and 1900MHz.

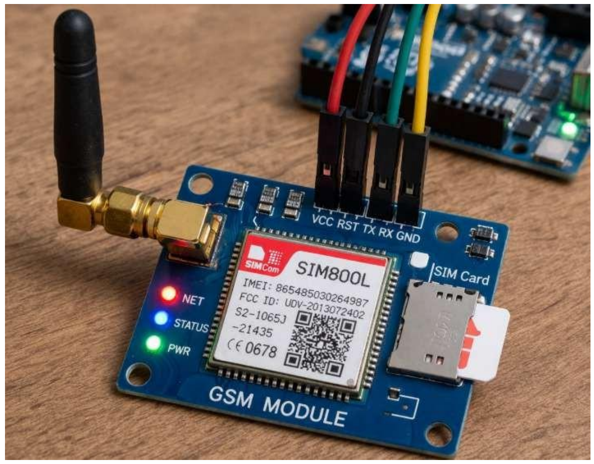

Fig.5.GSM Module

The major components of the GSM module include modem, SIM card holder, antenna, power source, and UART communication interfaces. This module supports integration with the controller units like Arduino, Raspberry Pi, and PIC. It involves the use of AT commands that work on determining whether there is any network present and send SMS. The popular GSM modules comprise SIM800, SIM900, and SIM808, whereby the latter contains GPS technology.Some of the significant applications of GSM modules include smart homes, alarm systems, electricity meters, vehicle tracking devices, medical devices, and automation gadgets. The notable features of GSM modules involve broad network coverage, low cost, and easy installation. Nevertheless, these modules require network signals, high power consumption, and are slower than the 4G and 5G modules.

7. 16×2 LCD DISPLAY:

The LCD display is responsible for performing local monitoring through displaying the real time voltage and current values. It makes it easier for users to monitor the system without the use of any other equipment. LCD is a passive display technology that uses embedded systems to display texts, figures, or numerals.

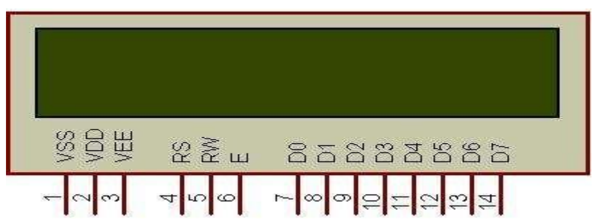

Fig.6.Liquid Crystal Display

Unlike LEDs, LCD does not generate its own light but manipulates light depending on electrical signals sent to it. For these reasons, LCD needs an additional light source like natural light or artificial light from a backlight system for it to be visible. The nature of the LCD allows it to have low energy consumption and high contrast, thus making it ideal for devices that use batteries. LCD works both reflectively and transmissivity. LCD could also be designed to work either light scattering or absorbing light. Character LCD is typically implemented using Hitachi HD44780 chip or compatible chips. Character LCD comes in many forms such as 16×2, 20×4, among others. A typical 16×2 character LCD displays 16 characters in two lines.

NO.	Symbol	Function
1	VSS	0V Power Supply (GND Level)
2	VCC	Power supply for Logic circuit
3	V0	Power Supply for Driving the LCD
4	RS	Data / Instruction select
5	R/W	Read / Write select
6	E	Enable signal
7-14	DB0-DB7	Data Bus line
15	LED A	Power supply for LED
16	LED K	Power supply for LED

Most LCD displays are made up of 14 pins, but there are also those that have 16 pins for backlighting purposes. Some of the most important pins are RS (Register Select), R/W (Read/Write), Enable, and data pins DB0 to DB7. Data transfer can be done via 8-bit or 4-bit modes.In order to write characters, letters, and numbers, ASCII codes are passed via the data pins where RS = 1.

However, when giving commands like clearing the display or shifting the cursor, RS = 0 is employed. The busy flag (DB7) signals the readiness of the LCD to accept new information.

Instruction	Instruction Code										Description	Execution time (fosc= 270 kHz)
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Clear Display	0	0	0	0	0	0	0	0	0	1	Write “20H” to DDRAM and set DDRAM address to “00H” from AC	1.53 ms
Return Home	0	0	0	0	0	0	0	0	1	-	Set DDRAM address to “00H” from AC and return cursor to its original position if shifted. The contents of DDRAM are not changed.	1.53 ms
Entry Mode Set	0	0	0	0	0	0	0	1	I/D	SH	Assign cursor moving direction and enable the shift of entire display.	39 μs
Display ON/ OFF Control	0	0	0	0	0	0	1	D	C	B	Set display(D), cursor(C), and blinking of cursor(B) on/off control bit.	39 μs
Cursor or Display Shift	0	0	0	0	0	1	S/C	R/L	-	-	Set cursor moving and display shift control bit, and the direction, without changing of DDRAM data.	39 μs
Function Set	0	0	0	0	1	DL	N	F	-	-	Set interface data length (DL: 8-bit/4-bit), numbers of display line (N: 2-line/1-line) and, display font type (F:5×11dots/5×8 dots)	39 μs
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address counter.	39 μs
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address counter.	39 μs
Read Busy Flag and Address	0	1	BF	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Whether during internal operation or not can be known by reading BF. The contents of address counter can also be read.	0 μs
Write Data to RAM	1	0	D7	D6	D5	D4	D3	D2	D1	D0	Write data into internal RAM (DDRAM/CGRAM).	43 μs
Read Data from RAM	1	1	D7	D6	D5	D4	D3	D2	D1	D0	Read data from internal RAM (DDRAM/CGRAM).	43 μs

* “-“: don’t care

8. Power Management Circuit:

This component is responsible for providing stable power to all other components in the form of a stable voltage level. This helps to avoid any risk of voltage fluctuations.

9. Connecting Wires and Breadboard:

These are the components which make the electrical connection between all modules.

CONCLUSION

To conclude, Solar Powered Smart Grid with IoT-based Monitoring is an advanced and efficient energy management technique in our time. Through the incorporation of solar energy and IoT, the method ensures a more effective generation, monitoring, and control of electrical energy. The solar panels capture the energy in light and use it to generate electrical energy. The generated energy is stored in batteries before it is transferred to the load equipment which includes lightening, fans, and electric motors. By introducing sensors and microcontrollers in the method, it becomes easier to monitor vital elements of electrical energy including the voltage and current. Communication tools provided by IoT simplify the

Process of remote monitoring and regulation of activities in the system. It is also easier to remotely control electrical equipment in the grid using relay equipment. Solar grid with IoT Monitoring serves a significant purpose in minimizing energy wastages while embracing efficiency and energy sources. Solar Powered Smart Grid with IoT-based Monitoring is environmentally friendly and cost-effective at the same time. Solar Powered Smart Grid with IoT-based Monitoring can be applied in residential estates, industrial establishments, smart city infrastructure, and rural settings, among others.

REFERENCE

[1] S. Kirmani, A. Mazid, I. A. Khan and M. Abid, "A Survey on IoT-Enabled Smart Grids: Technologies, Architectures, Applications, and Challenges," Sustainability, 2023. https://www.mdpi.com/2071-1050/15/1/717

[2] Marulasiddappa H., Divyashree O., Jhansi T. Reddy and Radha S., "IoT-Based Solar Power Monitoring," International Journal of Engineering Research & Technology, 2023.https://www.ijert.org/iot-based-solar-power-monitoring

[3] A. S. Sonawane and A. V. Naik, "IoT Based Smart Grid to Remotely Monitor and Control Renewable Energy Sources," IJRASET Journal, 2024. https://www.ijraset.com/research-paper/iot-based-smart-grid-to-remotely-monitor-and-control-renewable-energy-sources

[4] S. Sen, R. Gadipuuri and M. Mulpuri, "IoT-Integrated Framework for Real-Time Monitoring and Control of Renewable Energy in Smart Grids," International Journal of Intelligent Systems and Applications in Engineering.https://ijisae.org/index.php/IJISAE/article/ view/7070

[5] V. Hardas, S. Ingole, S. Sheikh and S. Kale, "Solar Panel Monitoring System Using IoT," IJRASET Journal. https://www.ijraset.com/research-paper/solar-panel-monitoring-system-using-iot

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