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Smart IoT Based Solar Monitoring and Tariff Based Billing System

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Abstract: *The rapid integration of renewable energy systems, particularly solar power, into the mainstream grid demands intelligent and real-time monitoring systems. This paper presents an IoT-based Smart Solar Monitoring System integrated with a Tariff-Based Billing Model to efficiently track solar energy generation, calculate consumption, and automate billing processes. The proposed system utilizes Arduino Uno, ESP8266 (ESP-01), ZMPT101B voltage sensor, ACS712 current sensor, and ThingSpeak cloud platform for data visualization. This low-cost, real- time, and scalable system ensures energy transparency, enhances user engagement, and supports energy efficiency goals. Experimental results show the system's ability to provide accurate energy readings and dynamic billing under varying tariff rates.*

Keywords: Internet of Things (IoT), Solar Monitoring, Smart Billing, Arduino, ThingSpeak, Energy Management, Dynamic Tariff

I. INTRODUCTION

With the rising demand for clean and renewable energy, solar power has gained popularity due to its sustainability, affordability, and ease of deployment. In India, solar energy plays a vital role in residential and commercial power generation, supported by government incentives for rooftop systems. However, many users lack access to real-time data on energy generation, usage, and export to the grid, relying instead on basic meters or monthly bills with limited insights.

To solve this problem, the project "Smart IoT-Based Solar Monitoring and Tariff-Based Billing System" proposes an efficient solution that combines real-time monitoring with automated billing. The system measures voltage and current from the solar panel, calculates energy in units (kWh), and applies tariff rates to estimate savings or earnings based on energy usage or export.

Data is displayed on an LCD and simultaneously uploaded to the cloud using Wi-Fi-enabled microcontrollers. By integrating components like Arduino Uno, ESP8266, ZMPT101B, and ACS712 with cloud platforms such as ThingSpeak or Firebase, the system enables remote access to live data and billing insights. This improves transparency and empowers users to track and optimize their solar energy use.

This smart system benefits households, schools, small businesses, and off-grid setups by offering better energy visibility and simplified billing. It represents a significant step toward automated, IoT-enabled solar energy management and supports the broader move to a sustainable energy future.

II. METHODOLOGY

1. Consultation Phase:

We began the project by consulting solar panel users, technicians, and faculty to identify key issues such as lack of real-time monitoring, unclear billing, and the inconvenience of checking physical meters. These insights highlighted the need for a simple, affordable system that could measure solar energy generation and calculate cost savings.

2. Review of Existing Systems:
An analysis of existing IoT-based solar monitoring systems revealed limitations like poor billing integration, reliance on third-party APIs, and lack of offline access. This guided us to design a hybrid system combining local display with cloud monitoring and dynamic billing features.

3. Technical Specifications:
Core components were selected based on reliability and performance: Arduino Uno for processing, ESP32 for Wi-Fi and cloud connectivity, ZMPT101B for voltage sensing, and ACS712 for current measurement. A 16x2 I2C LCD was used for local data display, and sensors were calibrated to ensure accuracy.

4. Prototype Development:
The prototype was built on a breadboard with sensors connected to Arduino. The system calculated voltage, current, power, and applied a billing formula. Data was shown on an LCD and sent to the ThingSpeak cloud via ESP32. The dashboard provided visual insights through graphs.

5. Testing and Validation:
The system was tested under natural and artificial light, comparing readings to multimeter values. Data transmission stability, billing logic accuracy, and LCD visibility were verified. Sensor calibration and code were fine-tuned for better performance.

6. Iterative Improvements:
Multiple testing-feedback cycles led to key upgrades like stable RMS reading, improved LCD formatting, reliable serial communication, and accurate energy-based billing. Future expansion (e.g., mobile alerts, monthly unit tracking) was considered and system design kept modular.

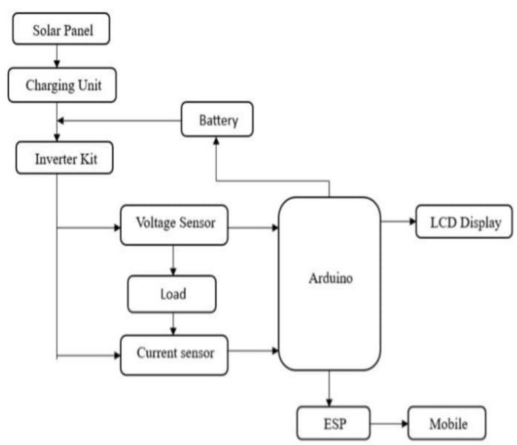

Fig 1. Block Representation

The proposed system is designed to monitor solar energy generation in real time and compute tariff-based billing using sensor data. It consists of a solar panel, inverter, sensors, an Arduino Uno microcontroller, an ESP32 Wi-Fi module, and a cloud platform (ThingSpeak). The main processing is handled by the Arduino, while ESP32 is used as a communication interface for IoT functions.

System Design

The proposed system is designed to monitor solar energy generation, calculate energy consumption and cost, and display the information locally as well as on a cloud platform. It integrates sensing, control, communication, and display subsystems.

1. Power Generation and Conversion

A 12V, 40W solar panel is used to convert solar energy into DC electricity.
This power is stored in a 12V battery.
A compact inverter kit converts the 12V DC into 230V AC, suitable for standard household loads.

2. Sensing Unit

A ZMPT101B voltage sensor is used to measure the AC output voltage.
An ACS712 current sensor (5A) measures the current drawn by the load. Both sensors provide analog output signals, which are fed into the Arduino Uno for processing.

3. Control and Processing Unit

The Arduino Uno acts as the main controller, responsible for:
Reading voltage and current values from sensors. Computing RMS values, power, energy consumed, and estimated cost. Displaying data on an LCD. Transmitting data to the IoT cloud via Wi-Fi.

4. Display Unit

A 16x2 LCD display with an I²C interface is used for real-time local monitoring.
The I²C protocol minimizes wiring complexity, using only SDA (A4) and SCL (A5) lines.

5. IoT Communication Module

An ESP8266 ESP-01 Wi-Fi module is connected to the Arduino using UART (Software Serial).
It handles wireless communication and uploads data to the ThingSpeak IoT platform.

6. Cloud Platform and Visualization

The system uses ThingSpeak, a cloud-based IoT platform, for data logging and graphical visualization. Parameters such as voltage, current, power, and cost are uploaded at regular intervals.
Users can access real-time and historical trends through graphical dashboards.

7. Communication Protocols Protocol Purpose Devices Involved

Protocol	Purpose	Device Involve
I²C	LCD communication	Arduino - LCD
UART	Wi-Fi module interfacing	Arduino – ESP -01
HTTP/TCP/IP	Cloud data transmission	ESP-01 -ThingSpeak server

IMPLEMENTATION

Hardware Setup

The main controller used in this system is the Arduino Uno. A 12V, 40W solar panel is used to generate power, which is then passed through an inverter kit to convert the DC power into 230V AC. A ZMPT101B voltage sensor is used to measure the AC voltage, and an ACS712 current sensor is used to measure the current. These sensors send analog signals to the Arduino. A 16x2 LCD with I²C protocol is used to display voltage, current, power, and estimated billing in real-time. For Wi-Fi communication, an ESP8266 ESP- 01 module is connected to the Arduino using UART communication (Software Serial). This setup helps collect, process, and send data wirelessly to the cloud.

Software Implementation

The software is developed using the Arduino IDE. The Arduino reads data from the sensors, calculates RMS voltage and current, and then finds the power and cost. The values are shown on the LCD for local monitoring. At the same time, the Arduino sends the data to the ThingSpeak cloud platform through the ESP8266 Wi-Fi module. The data is uploaded using standard internet protocols, and the ThingSpeak platform displays graphs of voltage, current, power, and billing. This makes it easy to check the system status from anywhere at any time.

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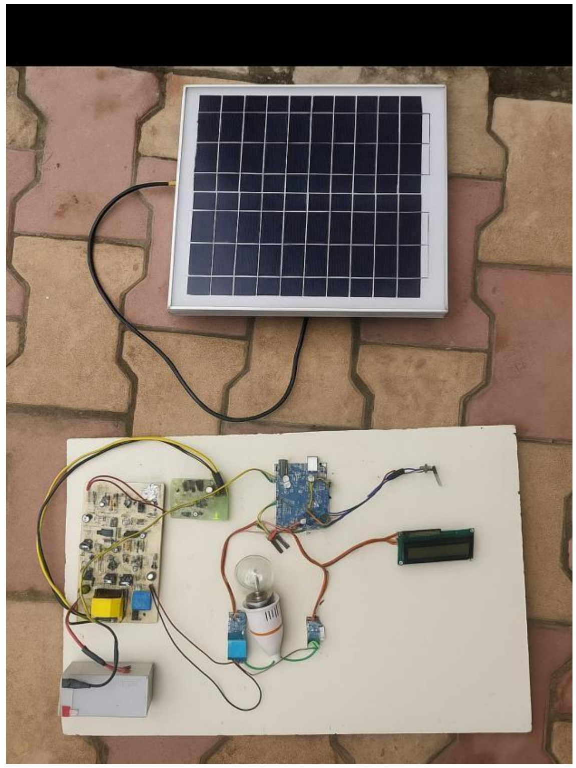

IV. CONCLUSION AND FUTURE SCOPE

The proposed system successfully demonstrates a smart and cost-effective solution for real-time monitoring of solar energy generation and tariff-based billing. Using the Arduino Uno as the main controller, along with voltage and current sensors, the system accurately calculates power consumption and estimates billing. The integration of an ESP8266 Wi-Fi module enables data transmission to the ThingSpeak cloud platform, where users can view live graphs of voltage, current, and power. The use of an LCD with I²C interface allows local display of real-time values. This system is easy to implement, low-cost, and highly suitable for homes, small offices, or academic institutions using solar energy.

In the future, the system can be enhanced in several ways. Features such as mobile app notifications, energy saving alerts, and automatic fault detection can be added. The system can also be expanded to monitor multiple solar panels or grid-connected hybrid systems. Integration with IoT-based home automation or smart meters could make it more advanced. Machine learning algorithms can be applied to predict solar generation and optimize energy usage based on weather and load patterns.

V. LIST OF ABBREVIATIONS

1. IOT Internet of Things
2. LCD Liquid Crystal Display
3. AC Alternating Current
4. DC Direct Current
5. RMS Root Means Value
6. ZMPT101B Voltage Sensor Module
7. ACS712 Current Sensor Module
8. ESP Espressif Systems Platform

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REFERENCES

[1] Adhya, S., Saha, D., Das, A., Jana, J., & Saha, H. (2016, January). An IoT based smart solar photovoltaic remote monitoring and control unit. In 2016 2nd international conference on control, instrumentation, energy & communication (CIEC) (pp. 432-436).

[2] Katyarmal, M., Walkunde, S., Sakhare, A., & Rawandale, U. S. (2018). Solar power monitoring system using IoT. Int Res J Eng Technol (IRJET), 5(3), 2395-0056.

[3] Patil, S., Vijayalakshmi, M., & Tapaskar, R. (2017). Solar energy monitoring system using IOT.Indian Journal of Scientific Research, 149156

[4] Phung, M. D., De La Villefromoy, M., & Ha, Q. (2017, August). Management of solar energy in microgrids using IoT-based dependable control. In 2017 20th international conference on electrical machines and systems (ICEMS) (pp. 1-6). IEEE.

[5] Embedded Systems: Architecture, Programming and Design by Raj Kamal –McGraw Hill Education, 3rd Edition, 2018

[6] Solar Photovoltaics: Fundamentals, Technologies and Applications by Chetan Singh Solanki – PHI Learning Pvt. Ltd., 3rd Edition, 2015

[7] Shrihariprasath, B., & Rathinasabapathy, V. (2016, March). A smart IoT system for monitoring solar PV power conditioning unit. In 2016 World Conference on Futuristic Trends in Research and Innovation for Social Welfare (Startup Conclave) (pp. 1-5). IEEE.

[8] Department Of International Electronics and Electrical Engineering (Ieee) 2017 Proposed Paper Smart Meter Using Iot by Bibek Kanti Barman, Et Al.

[9] IoT Based Smart Energy Metering System for Electricity Users, Md. Mohitul Haque, Zakir Hasan Choudhury, and Fakir Mashuque Alamgir, International Conference on Innovation in Engineering and Technology (ICIET), 23–24 December 2019.

[10] Durgadevi S, Tirupur Sundari K, Komathi C Smart energy metering for cost and power savings in home-use applications IEEE's 7th International Conference on Electrical Energy Systems (ICEES) in 2021 | 978-1-7281-7612-3/20/$31.00.