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IOT - Powered Solar Smart Structures: The Next Phase of Eco-Friendly Living

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ABSTRACT
The world's building industry is a major source of greenhouse gas emissions and overall energy consumption. The built environment's increased energy sustainability has been made possible by significant advancements in building energy technologies. Recent years have seen the emergence of innovative methods and extensive study in energy and environmental systems for buildings in an effort to address global concerns. This study explores technology advancements in building energy and environmental systems that can be used to smart homes and buildings by reviewing published material, primarily from the years 2000 onwards. In order to provide optimal function and energy-efficient performance, this review study focuses on an overview of the design and implementation of energy-related smart building technologies, such as energy management systems, renewable energy applications, and current advanced smart technologies.

KEYWORDS
smart home; smart building; Building management system; building-to-grid integration; renewable system integration; IoT sensors

INTRODUCTION

A significant component in many emerging nations is power generation. The energy consumption peaks as a result of the growth of the commercial and industrial sectors. Therefore, everyone is sensitive to the need for renewable energy sources to generate green energy to meet our energy needs. For the benefit of future generations, this can assist society in reducing greenhouse gas emissions and ozone layer depletion. The solar photovoltaic approach is becoming more and more popular because of its wide availability, low cost, simplicity of installation, and ease of maintenance.

The Internet of Things, or IOT, is a rapidly developing technology that connects objects via a communication protocol and cloud platform to make them smarter and easier to use. A solar panel's efficiency is determined by fundamental factors like temperature, voltage, current, and irradiance. In order to improve PV panel performance and take preventive action by comparing experimental results, a real-time solar monitoring system is therefore crucial. Numerous attempts have been made to conduct solar energy research in the past few years.

Without the use of any contemporary automation technologies, a basic forecasting database is modeled using My SQL to gather raw data, filter out irrelevant values, and provide forecasts.

Furthermore, in order to achieve reliable results, forecasting is done using machine intelligence algorithms. Using LABVIEW, a real-time monitoring and data collection approach for solar PV modules is suggested in order to assess how well various solar PV ratings work.

This is an effective tool for investigating how various PV modules function in relation to real-time data. A microcontroller-based displaying system is suggested to track the many parameters influencing photovoltaic panel performance. The standard operating conditions are used to assess the measured parameters and determine the necessary actions to improve PV performance.

Based on IoT, a low-cost solar panel monitoring system is created for online viewing and performance enhancement. This aids in tracking the location of faults and doing preventive maintenance. A suggested IoT-based cloud monitoring solution for remote photovoltaic plants is created on Raspberry Pi.

In order to investigate the defect diagnostics in PV plants, the fundamental properties of a PV system are examined utilizing the LABVIEW tool for real-time measurement. To maximize efficiency when using sun trackers, a microcontroller and LabVIEW are used to construct a smart monitoring system. It is suggested that a remote solar monitoring and control system be put into place at the plant level. This system encourages decision-making for the central control station, which plays a critical role in processing, storing, warning, and displaying data.[4]

The development of the PV monitoring system relies on both wired and wireless networks to send the data to a remote coordinator that provides a web application for remote access. Using Lab View, a useful graphical user interface for online solar PV monitoring is created. The PV panel's performance is increased by using an Arduino controller to analyze the observed parameters and transmit the data to a server for insightful decision-making.

A low-cost smart design is suggested in order to maximize PV panel efficiency by identifying performance degradation using a continuous monitoring system. A smart controller with a HEM algorithm is used to prioritize sources in order to optimize the utilization of solar power for home power management. Thus, the suggested approach uses an affordable solar PV monitoring system to demonstrate real-time monitoring. Large storage capacity and quick data access are provided via the Smart Controller's communication with the cloud platform.

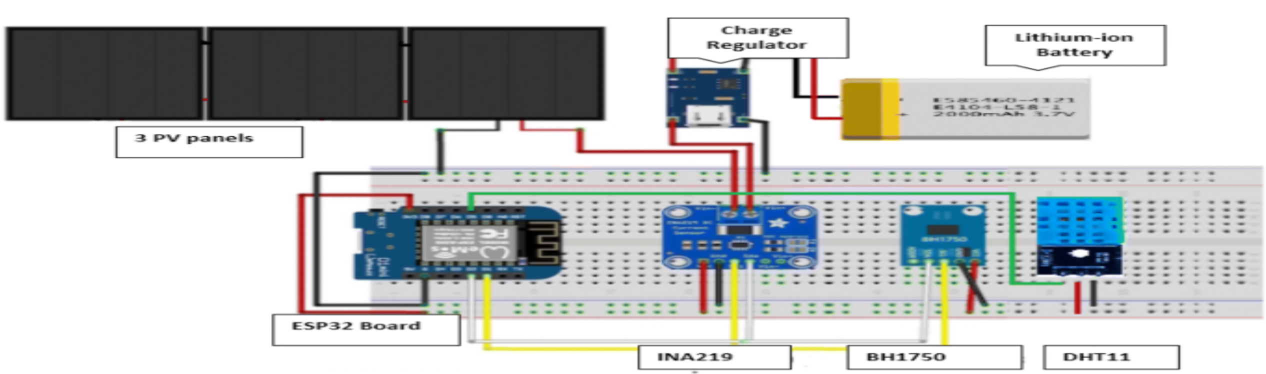

Fig 1: IOT Solar Energy Monitoring

Internet of Things (IoT)-based solar smart buildings are developing as a possible option as the globe struggles with climate change and the pressing need for sustainable living. These structures use solar energy and the Internet of Things (IoT) to create automated, energy-efficient spaces that support convenience and sustainability.

THE CORE COMPONENTS

1. **SOLAR ENERGY SYSTEMS**

At the heart of a solar smart building is its solar energy system. This typically includes:

SOLAR PANELS

Photovoltaic panels installed on rooftops or facades capture sunlight and convert it into electricity. [2]

INVERTERS

Devices that convert the direct current (DC) generated by the solar panels into alternating current (AC) for use in the building.

ENERGY STORAGE SYSTEMS

Batteries that store excess energy produced during sunny periods for use during cloudy days or at night.

SMART GRID INTEGRATION

Systems that allow the building to sell excess electricity back to the grid or draw from it when needed.

2. IOT SENSORS AND DEVICES

IoT technology brings intelligence and automation to solar smart buildings through a network of interconnected sensors and devices:

ENERGY MONITORING SENSORS

Track real-time energy production and consumption.

ENVIRONMENTAL SENSORS

Monitor temperature, humidity, and light levels to optimize indoor climate.

OCCUPANCY SENSORS

Detect presence in rooms to control lighting, HVAC, and other systems.

SMART METERS

Provide detailed information on energy usage, helping to identify patterns and inefficiencies.[6]

3. AUTOMATION AND CONTROL SYSTEMS

These systems use data from IoT sensors to automate building operations, enhancing energy efficiency and occupant comfort:

SMART THERMOSTATS

Automatically adjust heating and cooling based on occupancy and weather conditions.

AUTOMATED LIGHTING

Control lighting intensity and duration based on natural light availability and room usage.

APPLIANCE CONTROL

Manage the operation of appliances to reduce energy consumption during peak hours.

REMOTE ACCESS

Allow occupants and managers to control and monitor systems via smartphones or computers.

THE ROLE OF DATA ANALYTICS AND AI

Data collected from IoT sensors is analyzed to optimize building performance. Machine learning algorithms can identify trends and predict future energy needs, enabling:

ENERGY USAGE ANALYTICS

Detailed insights into consumption patterns to enhance efficiency.

PREDICTIVE MAINTENANCE

Anticipate maintenance needs for solar panels and other systems to prevent breakdowns.

MACHINE LEARNING

Continuously improve system performance by learning from historical data.

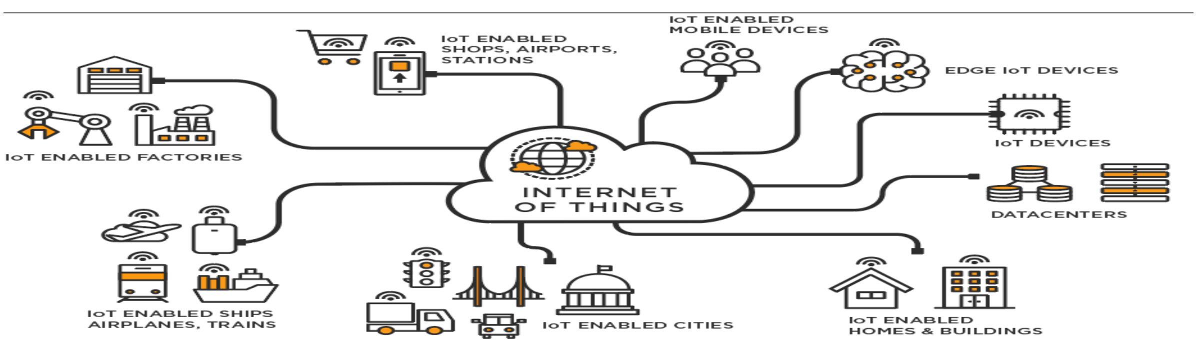

Fig 2: IOT Solar Energy Management

INTEGRATION WITH BUILDING MANAGEMENT SYSTEMS (BMS)

A centralized Building Management System (BMS) integrates all components, ensuring seamless operation:

CENTRALIZED CONTROL

A single interface to manage all building systems, from energy to security.[5]

INTEROPERABILITY

Ensure compatibility and communication between different devices and systems.[1]

BENEFITS OF IOT-BASED SOLAR SMART BUILDINGS

ENERGY EFFICIENCY

Optimize energy use to reduce waste and lower utility bills.

SUSTAINABILITY

Decrease carbon footprint through renewable energy generation and efficient resource management.

ENHANCED COMFORT

Create a comfortable living or working environment with automated climate control and lighting.

COST SAVINGS

Significant savings on energy costs and potential income from selling excess power to the grid.[3]

ENERGY RESILIENCE

Increased independence and reliability with on-site energy production and storage.

CHALLENGES AND CONSIDERATIONS

Despite their numerous benefits, IoT-based solar smart buildings face several challenges:

HIGH INITIAL COSTS

Significant upfront investment required for installation of solar panels and IoT infrastructure.

DATA PRIVACY AND SECURITY

Safeguarding sensitive data from cyber threats.

SYSTEM INTEGRATION

Ensuring compatibility and smooth integration of diverse systems and devices.

MAINTENANCE

Regular upkeep of solar panels and IoT devices to maintain optimal performance.

CONCLUSION

IoT-based solar smart buildings represent the future of sustainable architecture. By combining solar energy with IoT technology, these buildings offer a powerful solution to the challenges of energy efficiency, sustainability, and occupant comfort. As technology advances and costs decrease, we can expect to see more of these innovative structures transforming our cities and our way of living.

This paper highlights the potential and practicality of integrating solar energy and IoT technology to create smarter, more sustainable buildings. The convergence of these technologies offers a promising pathway to address environmental challenges while enhancing the quality of life for occupants.

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