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Article Title: Buildings with Photovoltaic Glazing System Using IoT

Buildings with Photovoltaic Glazing System Using IoT

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ABSTRACT

Buildings with photovoltaic glazing systems using IoT (BIPV) is an innovative technology that has the potential to not only generate electricity but also reduce energy consumption. BIPV systems are integrated into the building envelope, which means they serve the dual purpose of generating power and acting as a structural element of the building. This article is explaining the working and IoT-based control mechanism of a prototype model of Buildings with photovoltaic glazing systems, also called BIPV (Building-integrated photovoltaics). BIPV is an innovative technology that can reduce energy consumption apart from electricity production. As the population is increasing there is also an increase in the usage of electricity. To accommodate easy access to electricity, we designed a prototype model of photovoltaic glazing system using IoT. The integration of photovoltaic (PV) systems into buildings has gained significant attention due to the increasing demand for renewable energy sources and the need for sustainable building practices. IoT-enabled PV systems utilize smart sensors, data analytics, and automation to monitor and optimize solar energy's generation, consumption, and storage, resulting in improved energy management and cost savings. The future of PV glazing systems looks promising with potential advancements in efficiency, integration, aesthetics, energy storage, smart connectivity, cost reduction, and sustainable building certifications.

Keywords: Photovoltaic, Building Automation, Energy monitoring, Solar-powered IoT devices, Green Technology.

1 Introduction

BIPV stands for Building-Integrated Photovoltaics, which refers to the integration of solar panels directly into the building envelope or structure, such as roofs, walls, facades, and windows, to generate electricity. Buildings with photovoltaic glazing system is a type of solar energy technology that combines the benefits of traditional building materials with the ability to generate renewable energy, making buildings more sustainable and energy-efficient [1]. Buildings with photovoltaic glazing systems can come in various forms, including solar shingles, tiles, glass windows, and facades. These systems use photovoltaic (PV) cells, which are typically made of silicon or other semiconducting materials, to convert sunlight into

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electricity [2]. The electricity generated by Buildings with photovoltaic glazing systems can be used to power the building's electrical loads, fed back into the grid for credit, or stored in batteries for later use. The integration of PV glazing systems into buildings offers numerous advantages, including increased energy efficiency, reduced reliance on fossil fuels, and lower carbon emissions [3]. Additionally, PV glazing systems can enhance the aesthetics of buildings, providing a sleek and modern appearance that complements the overall design. PV glazing systems can be incorporated into various building types, ranging from commercial and residential buildings to public infrastructure and urban developments. This paper will explore the benefits and features of buildings integrated with PV glazing systems. We will discuss how PV glazing systems work, their advantages, and their potential applications in modern building design.

2 Literature Survey

A Review of Building-Integrated Photovoltaics in Singapore: Status, Barriers, and Prospects by Tianyi Chen[1], ORCID, Yaning An[2],* and Chye Kiang Heng 1[1]
With the help of this study, we can decide if Singapore ought to use this technology. Although the market for BIPV projects, systems, and products has grown, there are still some obstacles to BIPV adoption in Singapore. Future research directions for applications of tropical BIPV are also described. The BIPV system in Singapore serves as a model for a number of other tropical nations dealing with related issues.
Barriers, difficulties, and policy recommendations for solar PV and BIPV systems in India. Author links open a panel overlay Energy Centre, Maulana Azad National Institute of Technology Bhopal, India; Faculty of Mechanical Engineering, University Malaysia Pahang, 26600 Pahang, Malaysia; Akash Kumar Shukla, K. Sudhakar, Prashant Baredar, and Rizalman Mamat, December 23, 2017.
In this article, the status of solar energy and the use of BIPV systems in India are briefly discussed. A review of the region's solar energy potential and installed solar PV/BIPV capacity is also included. The constraints and difficulties India's solar BIPV development is facing are briefly described in this report. Additionally, this study offers policies and suggestions for solar PV and BIPV with reference to the Indian context.
"Advances in Transparent Photovoltaics for Building Integration" by Martínez-Rojas et al. (2021)
It covers different types of transparent photovoltaic materials, their properties, fabrication methods, and integration options into building envelopes.

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3 Proposed Methodology

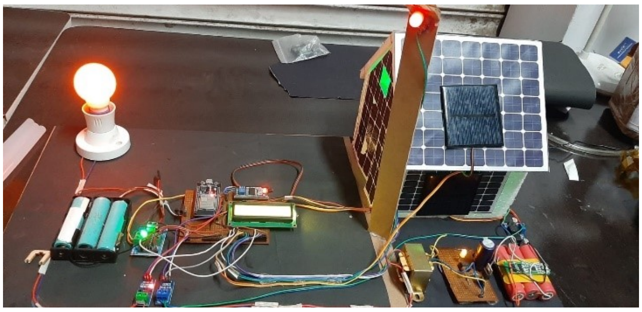

Figure 1: *Prototype model of buildings with photovoltaic glazing system*

As shown in Figure 1 prototype model of buildings with photovoltaic glazing system, when the sunlight falls onto a solar panel, energy from the sunlight is absorbed by the Photovoltaic cells in the panel [4]. This energy produces electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow. The boost converter is added to increase the voltage of solar panels a little bit so that current can flow to the battery of the same voltage as solar panels. Electricity produced by solar panels is stored in the battery installed. BMS is added in this prototype model of buildings with pv glazing system so that it can keep an eye on the charging of the battery. The electricity produced by solar panels is of dc nature, which is not the type of electricity that powers most homes [5]. A dc to ac inverter is added to convert dc current into ac current. The transformer in the inverter increases the voltage level. The transformer is connected to voltage and current sensors which give input to the microcontroller unit. The microcontroller unit traces all the loads connected in the system, it also tracks if the amount of voltage is sufficient enough for the ac loads or not. In this prototype model of buildings with photovoltaic glazing system, we have interfaced the system with the Internet of Things using the open IoT platform Blynk, which helps us to store, collect, and analyze data from Arduino and other supporting hardware.

Basic steps for building a BIPV system physically:

1. Site Assessment: This includes analyzing the location, orientation, shading, and other factors that may affect the performance of this prototype model of buildings with photovoltaic glazing system.
2. Design: This includes selecting the appropriate solar panels, inverters, and other components required for the system.
3. Permits and Approvals: Before the installation process begins, it is important to obtain all necessary permits and approvals from local authorities.
4. Installation: This includes mounting the solar panels on the building, connecting the panels to the inverter, and connecting the inverter to the building's electrical system.

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5. Testing and Commissioning: This includes verifying the electrical connections, checking the system's performance, and ensuring that it meets the required safety standards [6].
6. Maintenance: Finally, it is essential to maintain the BIPV system to ensure optimal performance and longevity.

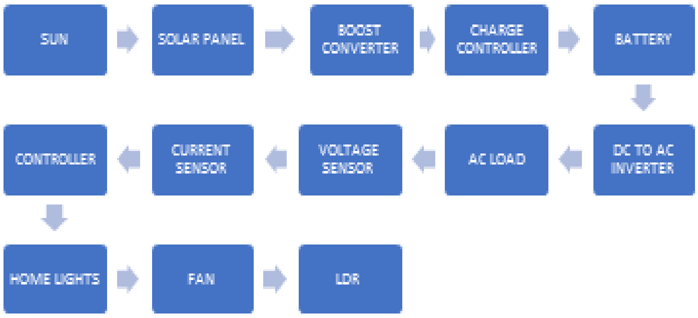

Figure 2: *Flow Chart of BIPV system*

4 System Architecture

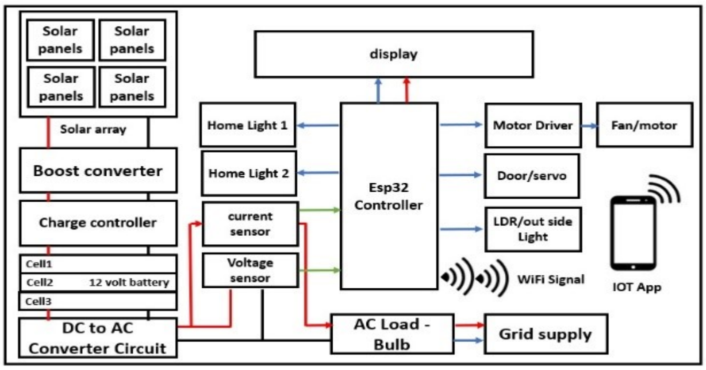

Figure 3: *System architecture of Building with photovoltaic glazing system*

The architecture of a Buildings with photovoltaic glazing system using IoT typically includes the following components:
1. Solar Photovoltaic Panels – These convert solar energy into electrical energy [7].
2. Inverters – These convert dc current into ac current.
3. Batteries – These store the electrical energy produced by solar panels.
4. Monitoring System – This includes sensors, controller, Internet of Things [8]
5. Electrical wiring and cabling – These are used in the connection of the circuit

Other components like structural support, boost converter, electrical meter etc are also included.

5 Components Required

Components and their specifications used in this prototype model of buildings with photovoltaic glazing system using IoT:

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ESP32 Microcontroller: Main processor: Dual-core, Tensilica LX6 microprocessor, clocked at up to 240MHz, Memory: 520KB SRAM, 4MB, Connectivity: Wi-Fi, Bluetooth, Ethernet, CAN bus, and SPI, GPIO pins: 34, Operating voltage: 3.3V, 16x2 I2C LCD, Communication Protocol: I2C, Operating voltage: 5V, Contrast Adjustment: Potentiometer.

Figure 4: *ESP32 Microcontroller unit*

Solar Panel: Power: 100W Operating Voltage: 18V, Open Circuit Voltage: 22V, Short Circuit Current: 5.56A, Efficiency: 19% as shown in Figure 5.

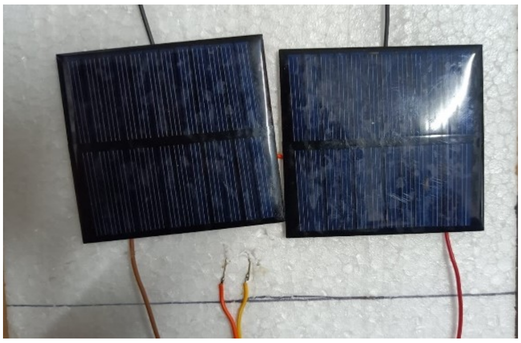

Figure 5: *Solar Panels*

DC to AC Inverter: Input voltage: 12V, Output voltage: 110V/220V, Output power: 1000W, Waveform: Modified Sine Wave as shown in Figure 6.

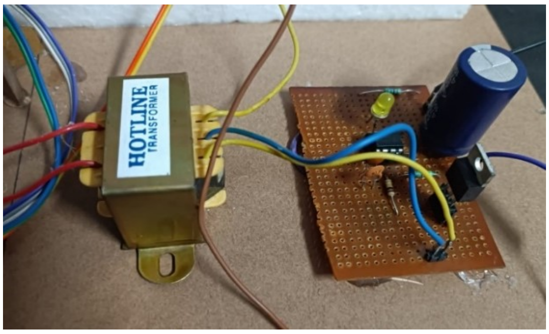

Figure 6: *DC to AC Inverter*

Servo Motor: Operating Voltage: 5V, Torque: 1.6 kg/cm, Rotation angle: 180 degrees, operating speed: 0.12 seconds/60 degrees as shown in Figure7 shows the implementation of servo motor.

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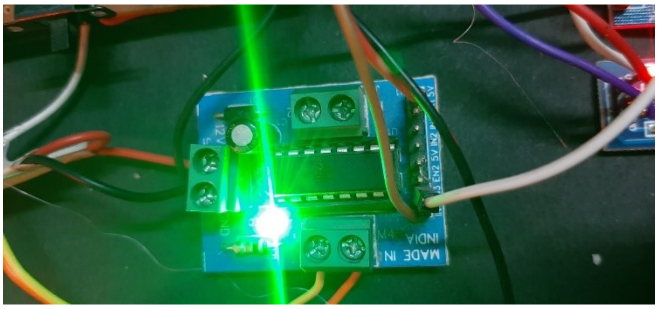

Figure 7: *Implemented servo motor*

LED: Colour: White, Operating voltage: 3V, Forward current: 20mA.
LDR: Resistance in the dark: >1MΩ, Resistance in the light: <10kΩ, Operating voltage: 5V. As shown in Figure 8. LDR changes its amount of light when kept in light.

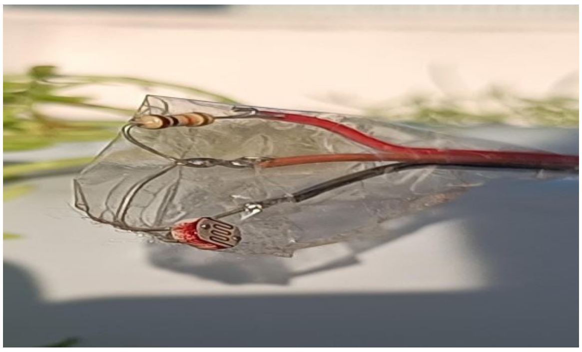

Figure 8: *LDR*

Voltage sensor: Arduino analog input voltages up to 5 v, the voltage detection module input voltage not greater than 5Vx5=25V (if using 3.3V systems, input voltage not greater than 3.3Vx5=16.5V).Arduino AVR chips have 10-bit AD, so this module simulates a resolution of 0.00489V (5V/1023), so the minimum voltage of the input voltage detection module is 0.00489Vx5=0.02445V.
Current sensor: The ACS712 is a fully integrated, Hall effect-based linear current sensor with 2.1kVRMS voltage isolation and an integrated low-resistance current and gives the output signal by measuring the flow of the electrical current (as shown in Figure 8).

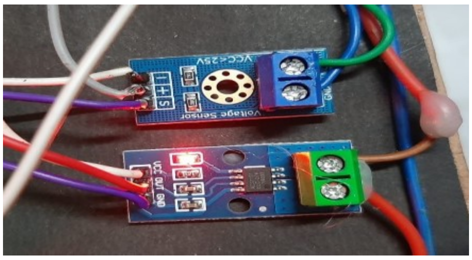

Figure 9: *Voltage and current sensor*

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Other components like batteries, charge controllers, and sensors may be required to complete the BIPV system. To build a BIPV system using ESP32 and Blynk app, we need the following software:

Arduino IDE: This is the Integrated Development Environment (IDE) for programming the ESP32 microcontroller. You can download the latest version of the Arduino IDE from the official Arduino website [9].

ESP32 board package for Arduino IDE: You need to install the ESP32 board package for the Arduino IDE. You can follow the instructions provided in the ESP32 GitHub repository to install the ESP32 board package.

Blynk Library: Blynk is a platform for building IoT applications. You can use the Blynk library to connect your ESP32 to the Blynk You can download the Blynk library from the Arduino Library Manager or from the Blynk GitHub repository [10].

WiFi Library: The ESP32 has built-in WiFi capabilities, and you can use the WiFi library to connect your ESP32 to a WiFi network. You can download the WiFi library from the Arduino Library Manager or from the official Arduino website.

6 Results Analysis

As shown in Figure 1 we have successfully implemented prototype model of buildings with photovoltaic glazing system using IoT. In this prototype model we have produced electricity from solar energy with the help of solar panels and then converted dc current into ac by using inverter, as all the domestic load are of ac nature and by interfacing with Internet of Things, we can have home automation. By building this prototype model of buildings with photovoltaic glazing system we have obtained the result that photovoltaic glazing systems can produce electricity from renewable sources while simultaneously acting as a building envelope by incorporating solar cells into building materials. Solar glazing systems use sunlight to generate electricity, which is a renewable source of energy. This means that they do not deplete natural resources and are sustainable in the long run. Solar glazing systems can reduce the reliance on grid electricity, resulting in lower electricity bills for the building owners. With solar glazing systems, the electricity is generated at the point of consumption, thereby reducing transmission losses and improving the efficiency of the electricity grid [10 11]. Solar glazing systems have become more affordable in recent years due to advancements in technology and increased production volumes. Solar glazing systems do not produce any greenhouse gas emissions, making them a clean source of energy that helps in reducing the carbon footprint of buildings [12]. Buildings with photovoltaic glazing systems can benefit from real-time monitoring and control, predictive maintenance, data analytics, smart grid connection, and user interaction through the growing usage of the Internet of Things (IoT) by which we get home automation, we can control the loads of our homes from any mobile location. Buildings with photovoltaic glazing system also promotes distributed generation and low energy consumption.

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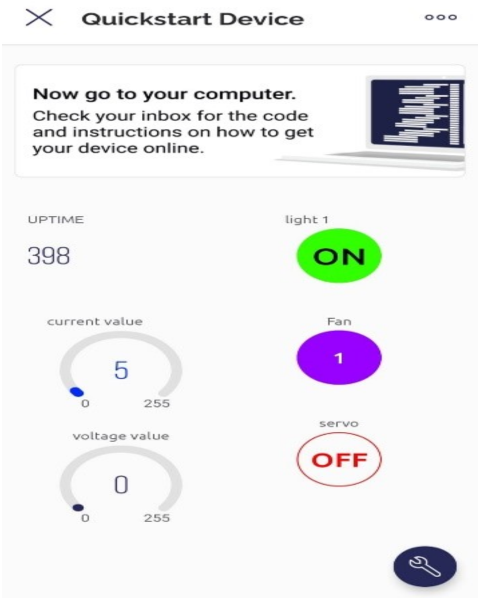

Figure 10: *Blynk app screen window*

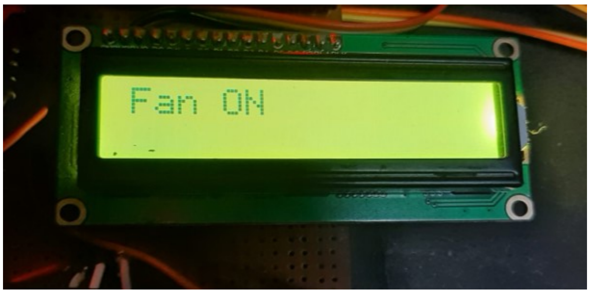

Figure 11: *STD Display for load information*

7 Future Scope

Building-integrated photovoltaic (BIPV) systems are a type of solar energy technology that can be incorporated directly into the design of a building's architecture, allowing the building to generate its own electricity while also serving as a structural element. The future scope of BIPV systems is quite promising, and here are some of the reasons Growing demand for sustainable buildings, Falling costs of solar energy, Advancements in PV glazing technology, and Supportive government policies. BIPV (Building-Integrated Photovoltaic) systems are promising solutions for meeting the energy demands of buildings while reducing their carbon footprint [13]. By integrating solar cells into building materials, BIPV systems can generate electricity from renewable sources while also serving as a building envelope. With the increasing adoption of the Internet of Things (IoT) in various fields, integrating BIPV systems with IoT technologies can offer several advantages, including Real-time monitoring and control, Predictive maintenance, Data Analytics, Smart grid integration, and User interaction

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[14]. In summary, integrating IoT technologies with BIPV systems can offer significant benefits in terms of performance optimization, maintenance, energy efficiency, grid integration, and user interaction. As such, there is a bright future for BIPV systems using IoT, and we can expect to see increased adoption of these technologies in the coming years.

6 Conclusion

The integration of IoT technology in Building Integrated Photovoltaic (BIPV) systems has significant potential for improving energy efficiency and reducing carbon emissions in buildings. By using IoT sensors and devices, BIPV systems can optimize energy generation, storage, and consumption in real-time, and provide valuable data for building managers and occupants. Buildings with photovoltaic glazing systems using IoT technology can also increase the reliability and durability of photovoltaic modules by monitoring their performance and detecting faults or damages [15]. This can help reduce maintenance costs and improve the overall efficiency of the system. Overall, BIPV systems using IoT technology offer numerous benefits, including improved energy efficiency, reduced carbon emissions, increased reliability and durability of photovoltaic modules, and enhanced user experience. As such, this technology is expected to play a critical role in the future of sustainable building design and construction.

References

1. Qingdong Xuan, Year: 2021, “Daylighting uniformity and utilisation comparison for concentrator-photovoltaic windows in energy-saving applications on buildings Energy”.
2. Ioannidis Zisis, Year: 2020, “Using forced convection and heat recovery to integrate semi-transparent photovoltaics into a double skin façade,” Appl Energy.
3. Martin K. Patel; Elie Azar; Olivia Bouvard; Andreas Schueler; Pierre Hollmuller; Jonathan Chambers, Year: 2019, “Utilising a monte carlo model to assess the electricity-saving potential of electrochromic glazing for lighting and cooling at the scale of the Swiss non-residential national building stock”, Energy, Vol: 185, pp. 136–147.
4. Negin Maftouni; Minoo Askari, Year: 2020, “Solar radiation control employing electrochromic smart windows, a strategy towards building energy optimisation,” Journal of Solar Energy Research, Vol: 5, no: 2, pp. 382- 389.
5. Seppo Sierla; Kari Alanna, Year: 2022, “An overview of smart building applications for machine learning,” Sustainable Cities and Society, Vol: 76, pp. 103445.
6. Annual energy outlook for Year: 2020, Bipartisan Policy Centre. 2020, 12:1672-1679, Energy Information Administration, Washington, DC.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 2(04), April 2023, pp. 1-10

7. Joshua P. Newell; Benjamin Goldstein; Dimitrios Gounaridis, Year: 2020, "The American domestic energy sector's carbon impact," National Academy of Sciences Proceedings, Vol: 117, no: 32, pp. 19122–19130.

8. Jo House; Alaa Al Khourdajie; Alaa Al Khourdajie; William F. Lamb; Thomas Wiedmann; Julia Pongratz; Robbie Andrew; Monica Crippa; Jos GJ Olivier; Dominik Wiedenhofer; Giulio Mattioli; et al., Year: 2021, "An analysis of sector-specific emissions trends and factors from 1990 to 2018," Environmental Research Letters, Vol: 16, no: 7, pp. 073005.

9. Vincent Blouin; Maryam Hamidpour, Year: 2018, "Development of an electrochromic glazing control strategy based on comparison for managing indoor lighting and energy efficiency," Research Gate.

10. M'arta Szab'o; Qudama Al-Yasiri, Year: 2021, "A thorough review of the use of phase change materials in the building envelope for energy efficiency and thermal comfort," Building Engineering Journal, Vol: 36, pp. 102122.

11. Bobby Lynn; Edwin Frazier; Jeff S. Haberl; Minjae Shin; Juan-Carlos Baltazar, Year: 2019, "Analysing the energy efficiency of a net-zero structure in a hot, humid environment," Energy and Buildings, Vol: 204, pp. 109531.

12. Solar Buildings; Neighbourhoods, Year: 2020, "Design Considerations for High Energy Performance by Caroline Hachem-Vermette," Springer Nature.

13. Hongyu Zhou; Som Shrestha; Zhenglai Shen, Year: 2021, "Building envelope and structural co-design using an LCC-based framework that takes energy efficiency and natural hazard performance into account," Vol: 35, pp. 102061.

14. Subhas Chandra Mukhopadhyay; Anurag Verma; Surya Prakash; Vishal Srivastava; Anuj Kumar, Year: 2019, "A review of sensing, control, and iot infrastructure in smart buildings," 2019 IEEE Sensors Journal, Vol: 19, no: 20, pp. 9036–9046.

15. Megha Quamara; Brij B Gupta, Year: 2020, "An introduction to the internet of things (IoT): its architectural features, difficulties, and protocols," Practise and Experience with Concurrency and Computation, Vol.: 32, no: 21, pp. e4946.