JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ADVANCEMENTS IN SOLAR POWERED IOT BASED STREET LIGHT SYSTEM

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Abstract: This paper gives a thorough examination of the most recent advances in solar-powered and Internet of Things (IoT) technologies for street light management and electric vehicle (EV) charging points. The convergence of solar electricity, IoT and smart grid technologies has transformed the street light system to modern smart network. This study focuses on the major characteristics, benefits, problems, and future prospects of this developing technology. Rapid use of non renewable energy resources mainly fossil fuels will make the situation worsen in the near future as these resources are depleting day by day. Thus, now is the need of alternate sustainable energy sources .The Internet of Things is an emerging technology that focuses on connecting things i.e. electronic devices to one another and to humans. The world becomes smarter with the use of this technology; we are building a smart architecture in these operation switches. India is one of the world's largest-growing tech markets and adopting the new field in this technique. The advancement in automation system will support in the resolution of a large range of problems in both the global economy and making the people live smart & comfortable life.

Keyword: **- Solar Energy, Internet of things, Electric Vehicle**

1. INTRODUCTION

Street lighting is a vital part of urban and semi-urban infrastructure. It has a lot of advantages, including enhanced security for drivers and pedestrians. Street lighting now accounts for around 13-14% of the world's yearly power generation [1-4], and the industry is expanding. As a result, tremendous energy is wasted by street lights, making it critical to work on methods to minimise street light consumption.

Several technologies have been used in smart street light systems over the years to improve energy efficiency, reduce costs, and enhance overall functionality. Here are some of the previous technologies used in street light systems and alternate suggested to make them smart.

1. Photocells: They are also known as photoelectric sensors or light sensors and have been widely used in traditional street light systems. These sensors detect ambient light levels and automatically turn the lights on at dusk and off at dim.

2. Timer-based Controls: Timer-based controls were commonly employed in earlier smart street light systems. The lights were programmed to operate on pre-set schedules, regardless of the actual lighting conditions. While simple, this method didn't offer adaptive lighting control based on real-time needs.

3. Motion Sensors: Motion sensors have been utilized to enhance energy efficiency in street lighting systems. These sensors detect movement and trigger the lights to turn on only when activity is detected in the vicinity. This approach helps conserve energy by avoiding unnecessary illumination during periods of low activity.

4. Remote Monitoring and Control Systems: These systems will facilitate the centralized management system for street lights. These systems generally use wired or wireless communication technologies to monitor the status of street lights, detect faults or malfunctions, and remotely control their operation. They provide real-time insights and enable timely maintenance and repair actions.

5. Energy-Efficient Lighting Technologies: in these type of technologies, such as compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs), have been widely adopted in smart street light systems. These technologies offer higher energy efficiency and longer life spans compared to traditional incandescent bulbs, reducing energy consumption and maintenance costs.

6. Dimming and Adaptive Lighting: Dimming capabilities have been integrated into smart street light systems to adjust the brightness levels based on specific requirements. Dimming can be based on preset schedules or controlled in response to real-time conditions, optimizing energy consumption while maintaining adequate illumination. Adaptive lighting systems utilize sensors and data analysis to dynamically adjust brightness levels based on factors like traffic flow or pedestrian activity.

7. Communication and Networking: Communication and networking technologies have been employed to enable connectivity and coordination among street lights. These technologies include wired or wireless networks, such as power-line communication (PLC), Zigbee, Wi-Fi, or cellular networks. They facilitate data exchange, remote control, and real-time monitoring within the street light system.

8. Centralized Management Software: This software provides a platform for monitoring and controlling smart street light systems. It allows operators to view the status of individual lights, adjust settings, generate reports, and analyze data for performance optimization.

9. Renewable Energy Integration: Some smart street light systems have incorporated renewable energy sources like solar, wind, geothermal etc. Solar panels are used to generate electricity, which can be stored in batteries for night time lighting or to supplement grid power during peak demand periods.

2. Related Work

Over the time advancements in technology have led to the integration of these different components and the emergence of more sophisticated and integrated smart street light systems. These systems offer improved energy efficiency, remote management capabilities, adaptive lighting control, and enhanced connectivity, contributing to more sustainable resources .Another area of great interest to many scholars throughout the world is the development of smart street lighting with a control system. The lighting control network is a tremendous improvement to street light systems; deployment of a control system can provide several benefits.

This paper examines current trends in smart street lighting, emphasize on lamp selection and method of controlling light intensity, along with the approach to connecting the sensors together and remotely control the lights, monitor weather conditions and diagnose lamp failure.

The introduction section provides a brief overview of the significance of solar-powered IoT-based street light control and EV charging points. It discusses the need for energy-efficient and sustainable lighting solutions and the increasing demand for EVs, necessitating efficient charging infrastructure.

Table 1: - A Comparative analysis of different IoT technology

Paper Reference	Technology	Sensor type	Failure detection	Speed	Efficiency	Maintenance cost	Demerits
[5]	GSM	PIR	YES	SLOW	High	Low	High initial cost & depend on climatic conditions
[6]	IOT	IR	NO	FAST	Low	Low	Time Consuming
[7,8]	GPS/GPRS	PIR	NO	SLOW	Low	Low	More power consumption & don't penetrate solid walls.
[9]	WSN	PIR	NO	SLOW	Low	Low	Security Concern & limited coverage area
[9]	Zigbee	PIR	NO	SLOW	High	High	Low data rate and limited use of the star topology.

[10]	LoRa	N/A	YES	Low	High	Low	Need a new network & small payload.
[11]	NBIoT	RF Motion & Speed sensors	YES	High	High	Low	Expensive.

3. Existing Systems

The existing technologies focus on solar power generation technologies, including photovoltaic cells, solar panels, and solar tracking systems. It explores their efficiency, scalability, and integration possibilities with IoT platforms for real-time monitoring and optimization. Solar power generation for smart street lights is an excellent way to provide sustainable and efficient lighting for urban areas. Here's a general overview of how it works:

1. Solar Panels: They are also known as photovoltaic (PV) panels, which are installed on top of the street light poles or nearby area. These panels received sunlight and convert it into direct current (DC).

2. Charge Controller: The DC current produced by the solar panels is fed into a charge controller, which regulates the flow of electricity and prevents overcharging of the battery.

3. Battery Storage: The charge controller is connected to a battery, typically a deep-cycle battery, which stores the excess electricity generated during the day. The battery allows for continuous power supply during night time or cloudy days when solar energy is not available.

4. LED Lights: Smart street lights are equipped with energy-efficient LED lights, which consume less electricity compared to traditional street lights. The LED lights provide bright and focused illumination while minimizing power consumption.

5. Light Sensor and Controller: Smart street lights often incorporate light sensors to detect ambient light levels. When the sensor detects the low light conditions during dusk or night time, it triggers the LED lights to turn on automatically. This feature ensures that the street lights operate only when needed, further optimizing energy usage.

6. Control System: A control system or central management software can be implemented to monitor and control the smart street lights. It allows for remote monitoring, adjustment of brightness levels, and even automated fault detection and reporting.

7. Grid Connectivity: As an alternative source of electricity smart street lights with solar power generation can be connected to the main power grid. This allows excess electricity generated during the day to be fed back into the grid, and in return if needed the lights can draw power from the grid.

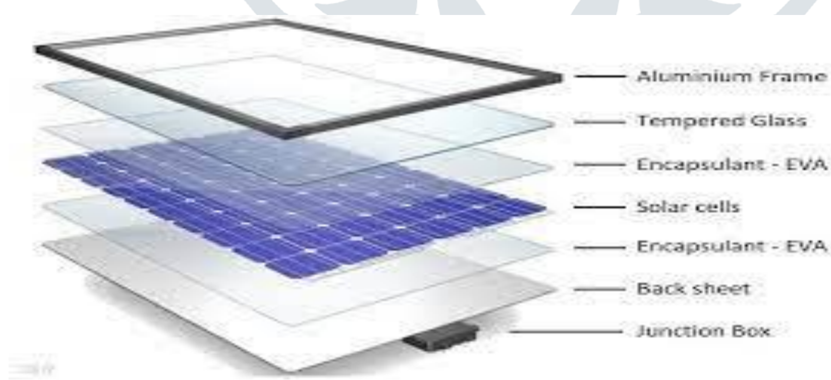

Figure 1 :- Layers of Solar panel

The benefits of solar-powered smart street lights include reduced energy consumption, lower operational costs, reduced carbon footprint, and increased reliability. Additionally, these systems can be integrated with smart city infrastructure, enabling advanced features like real-time monitoring, adaptive lighting, and data collection for analytics and optimization. It's important to note that specific implementations and configurations of solar-powered smart street lights may vary depending on factors such as geographical location, lighting requirements, and budget considerations.

4. **IoT-Based Street Light Control**

It discusses the use of sensors, actuators, and wireless communication protocols for intelligent and adaptive lighting solutions. The section also covers the benefits such as energy savings, reduced maintenance costs, and enhanced safety. An IoT (Internet of Things) based light control mechanism allows for remote monitoring and control of lights using internet connectivity. Here's a general overview of how it works:

1. Smart Lights: The system uses smart lights equipped with IoT capabilities. These lights are typically LED lights that can be controlled remotely.

2. Communication Network: The smart lights are connected to a communication network, usually via wireless technologies such as Wi-Fi, Bluetooth, or cellular networks. This connectivity enables them to communicate with a central control system or directly with a user's device.

3. Central Control System: A central control system, often hosted on the cloud, manages and coordinates the smart lights. It acts as a bridge between the lights and the user, facilitating communication and control.

4. User Interface: Users can access the control system through various interfaces, such as mobile apps, web portals, or voice assistants. These interfaces allow users to interact with and control the lights remotely.

5. Sensor Integration: An IoT based light control systems can embed sensors together and provide automation. These light sensors can detect nearby light levels and adjust the brightness of the lights accordingly. Motion sensors can trigger lights to turn on or off when movement is detected.

6. Automation and Scheduling: Users can set up automation rules and schedules to control the lights automatically. For instance, lights can be programmed to turn on at sunset and turn off at sunrise. Users can also create custom schedules or automate lights based on specific events or conditions.

7. Energy Monitoring and Optimization: The system can monitor energy consumption of the lights and provide insights for optimization. It can track usage patterns, identify energy-intensive areas, and suggest energy-saving measures.

8. Integration with Other Systems: IoT-based light control mechanisms can integrate with other smart systems or devices. For example, lights can be synchronized with security systems to enhance safety, or integrated with smart home platforms for seamless control and coordination.

9. Data Analytics: The system can collect and analyze data from the lights, sensors, and user interactions. This data can be used to generate insights, identify trends, and optimize lighting operations and energy efficiency.

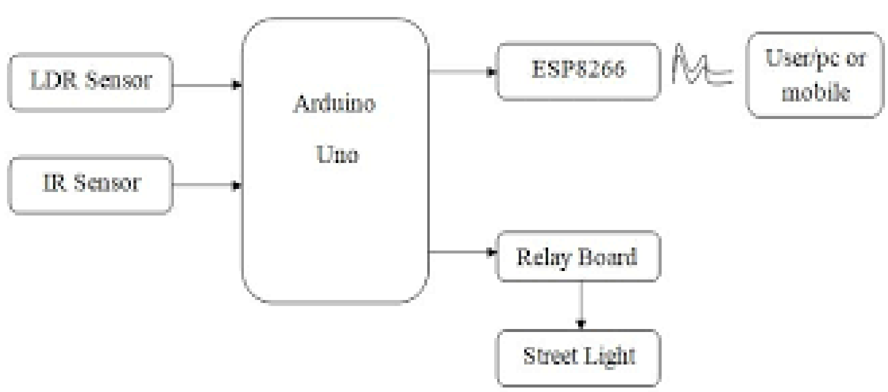

Figure 2:- Block Diagram of Proposed system

Overall, an IoT-based light control mechanism offers convenience, flexibility, and energy efficiency by allowing users to remotely control and automate their lighting systems while enabling data-driven insights and optimizations.

5. Proposed System

Integration of Solar Powered and IoT based system with EV charging Point. This section highlights the synergies between solar power, IoT, and smart grid technologies. It explores the potential for grid integration, load balancing, and energy management through advanced analytics and machine learning algorithms. The integration of solar power, IoT (Internet of Things), and smart grid technologies offers numerous benefits for renewable energy generation, energy management, and grid optimization. Here's an overview of how these technologies can be integrated:

1. **Solar Power Generation**: Solar power systems such as solar panels or solar farms generate electricity from sunlight. These systems convert solar energy into usable electricity through photovoltaic (PV) technology. Solar power is a clean, cheap and renewable energy source that can be used for various applications.

2. **IoT Connectivity**: IoT enables the connection and communication between devices and systems over the internet. In the context of solar power, IoT can be used to monitor and control solar installations, optimize energy production, and enable remote management.

a) Monitoring: IoT sensors can be installed in solar panels and other components to collect data on energy production, temperature, performance, and overall system health. This data is transmitted to a central control system for analysis and monitoring.

b) Control and Optimization: IoT connectivity allows for remote control and optimization of solar power systems. It enables operators to adjust parameters, optimize energy production, and detect and respond to issues in real-time, improving overall system performance and efficiency.

3. **Smart Grid Integration**: The smart grid refers to an intelligent electricity distribution system that incorporates advanced communication, control, and monitoring capabilities. Integrating solar power and IoT into the smart grid infrastructure can bring several advantages:

a) Grid Stability and Resilience: Solar power integration can help balance the grid by providing clean and distributed energy generation. IoT sensors can monitor grid conditions and adjust solar generation in response to demand, ensuring grid stability.

b) Energy Management and Demand Response: IoT connectivity allows for real-time energy monitoring and demand response capabilities. Solar power generation data can be analyzed to optimize energy dispatch and consumption, reducing peak demand and enhancing grid management.

c) Grid Integration and Flexibility: IoT-enabled smart grid infrastructure can seamlessly integrate solar power systems into the overall grid operations. It facilitates bidirectional power flow, enabling excess solar energy to be fed back into the grid, reducing strain on centralized power generation, and supporting grid flexibility.

d) Grid Optimization and Fault Detection: IoT sensors and data analytics can assist in identifying grid faults, power outages, and issues in real-time. This information enables faster fault detection and restoration, enhancing the reliability and resilience of the grid.

e) Billing and Metering: IoT connectivity allows for accurate metering, billing, and energy tracking. It enables real-time monitoring of energy generation and consumption from solar systems, facilitating fair and transparent billing practices.

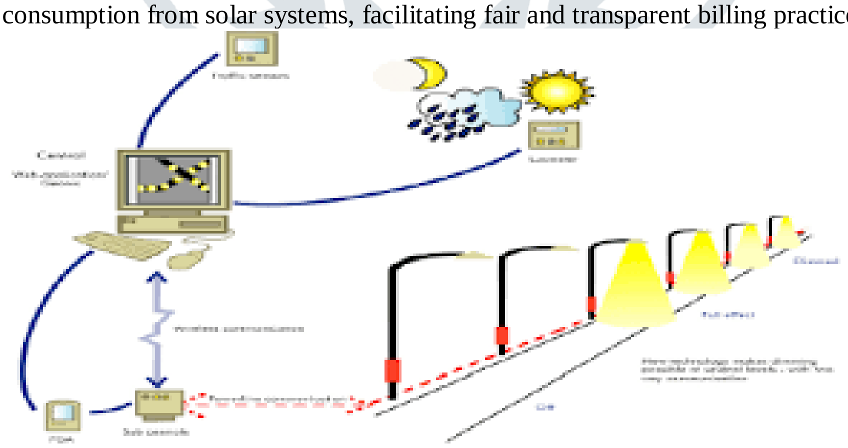

Figure 3: Integrated System with IoT

The integration of solar power, IoT, and smart grid technologies brings a holistic approach to renewable energy generation, energy management, and grid efficiency. It supports sustainable and efficient energy systems, improves grid stability, and enhances the overall reliability and resilience of the electrical infrastructure.

6. Challenges and Future Perspectives

This section identifies the challenges and limitations of solar-powered IoT-based street light control and EV charging points, such as initial costs, scalability, interoperability, and cyber security. It concludes by discussing the future prospects of the technology and potential research directions. The integration of solar power, IoT (Internet of Things), and smart grid technologies offers numerous benefits for renewable energy generation, energy management, and grid optimization. Here's an overview of how these technologies can be integrated:

1. Solar Power Generation: Solar power systems, such as solar panels or solar farms, generate electricity from sunlight. These systems convert solar energy into usable electricity through photovoltaic (PV) technology. Solar power is a clean and renewable energy source that can be harnessed for various applications.

2. IoT Connectivity: IoT enables the connection and communication between devices and systems over the internet. In the context of solar power, IoT can be used to monitor and control solar installations, optimize energy production, and enable remote management. IoT sensors can be installed in solar panels and other components to collect data on energy production, temperature, performance, and overall system health.

This data is transmitted to a central control system for analysis and monitoring. While challenges such as interoperability, data security, and scalability need to be addressed, future perspectives bring exciting opportunities. Advanced energy management algorithms, peer-to-peer energy trading, vehicle-to-grid integration and integration with other renewable energy sources are among the prospects that can further enhance the integration of solar power, IoT, and smart grid systems. IoT connectivity allows for remote control optimization of solar power systems. It enables operators to adjust parameters, optimize energy production, and detect and respond to issues in real-time, improving overall system performance and efficiency.

7. Conclusion

The integration of solar power, IoT, and smart grid technologies holds great promise for revolutionizing the energy landscape. By combining the clean energy generation of solar power with the connectivity and intelligence of IoT and smart grid systems, we can built a more efficient, sustainable and reliable energy system. Solar power provides a renewable and environmentally friendly energy source, reducing reliance on fossil fuels and mitigating climate change. IoT enables the monitoring, control, and optimization of solar power systems, allowing for real-time data analysis, remote management, and energy efficiency improvements. Smart grids enhance grid stability, enable bidirectional power flow, and optimize energy management, ensuring reliable and efficient distribution of electricity.

The proposed system can contribute to reducing carbon emissions, enhancing grid stability, empowering energy consumers, and driving the transition towards a cleaner and more connected future. By providing a comprehensive analysis of solar-powered IoT-based street light control and EV charging points, this research paper aims to contribute to the growing body of knowledge in this field. It serves as a valuable resource for researchers and policymakers interested in understanding and implementing these technologies for a greener and smarter future.

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