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SMART SOLAR-POWERED CCTV SURVEILLANCE SYSTEM USING IOT AND GSM NETWORK CONNECTIVITY

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ABSTRACT: The increasing demand for reliable and continuous surveillance systems has led to the development of energy-efficient and remotely accessible security solutions. This project presents an IoT-based solar-powered CCTV surveillance system integrated with SIM card communication for real-time monitoring in remote and off-grid locations. The system utilizes a solar panel as the primary power source, ensuring uninterrupted operation even in areas without conventional electricity.An Arduino microcontroller serves as the central processing unit, interfacing with a CCTV camera, GSM module, and IoT communication module. The GSM module, equipped with a SIM card, enables wireless data transmission, allowing users to receive alerts, images, or video feeds via mobile networks. The IoT module facilitates remote access and monitoring through cloud platforms or mobile applications.The system is designed to detect motion or unusual activity and instantly notify users through SMS or internet-based notifications. By combining renewable energy with wireless communication technologies, the proposed solution enhances security while maintaining low operational costs and high reliability.

Keywords: *solar panel, Arduino, CCTV, GSM, IOT module*

I. INTRODUCTION

The rapid growth of security concerns in residential, industrial, and remote areas has significantly increased the demand for intelligent surveillance systems. Traditional CCTV systems depend heavily on continuous electrical power and wired internet connectivity, making them unsuitable for rural, isolated, or disaster-prone regions. To overcome these limitations, an IoT-based solar-powered CCTV surveillance system with SIM card communication is proposed, which ensures uninterrupted monitoring using renewable energy and wireless communication.

Solar-Powered Surveillance Concept

Fig:1 Proposed CCTV

Solar energy serves as the backbone of the proposed system. A solar panel converts sunlight into electrical energy, which is stored in a rechargeable battery to power

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the entire surveillance setup. This approach eliminates dependency on grid electricity and ensures continuous operation even during power outages. Such systems are highly suitable for agricultural lands, highways, border areas, and construction sites where electricity supply is inconsistent.

IoT-Based Remote Monitoring

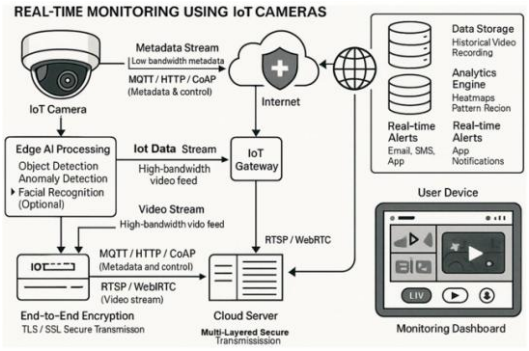

Fig:2 Real time monitoring

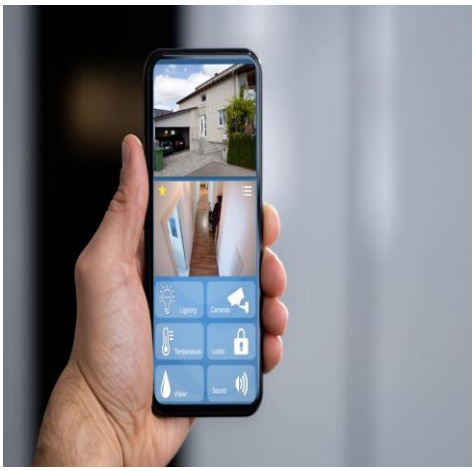

Fig:3 Monitoring through Application

The integration of IoT technology enables real-time monitoring and control of the CCTV system from anywhere in the world. Data captured by the camera is transmitted to cloud platforms or mobile applications, allowing users to view live footage, receive alerts, and manage the system remotely. This enhances situational awareness and provides a smart, connected security solution.

SIM-Based GSM Communication

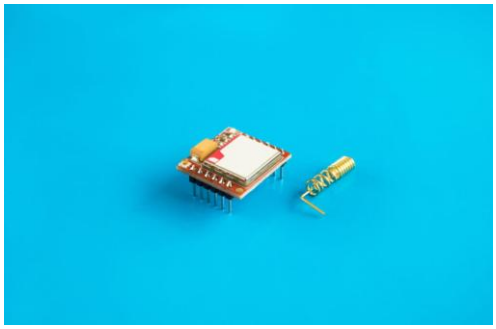

Fig :4 GSM antenna

In locations where Wi-Fi or broadband connectivity is unavailable, GSM modules with SIM card support provide an effective communication alternative. The system uses GSM technology to send SMS alerts or transmit data over mobile networks. This ensures reliable communication in remote areas, making the system independent of local internet infrastructure.

Embedded System Integration (Arduino + Sensors + Camera)

An Arduino microcontroller acts as the central controller, coordinating between different components such as the CCTV camera, motion sensors, GSM module, and IoT module. The system can be programmed to detect motion or abnormal activity and trigger alerts accordingly. This embedded approach ensures low power consumption, cost-effectiveness, and ease of implementation.

Need and Significance of the System

With increasing security threats and the limitations of traditional surveillance systems, there is a strong need for autonomous and energy-efficient monitoring solutions. The proposed system addresses key challenges such as power dependency, lack of connectivity, and limited accessibility. By combining solar energy, IoT, and GSM communication, the system provides a self-sustaining, reliable, and scalable surveillance solution.

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This technology plays a crucial role in smart cities, rural development, military applications, and disaster management, where continuous monitoring is essential. The system not only improves safety but also reduces operational costs and supports eco-friendly practices through the use of renewable energy.

II. LITERATURE SURVEY

The development of an IoT-based solar-powered CCTV surveillance system with SIM communication is supported by extensive research in three major domains: IoT surveillance systems, solar energy monitoring, and GSM-based communication systems. The following review summarizes key contributions from existing studies.

1. IoT-Based Surveillance Systems

Recent studies highlight the effectiveness of IoT in enabling real-time monitoring and intelligent surveillance. Researchers have demonstrated that IoT-based systems integrate sensors, cameras, and cloud platforms to provide continuous monitoring and remote access. These systems allow users to receive alerts and access live video streams through mobile devices.

A study on smart surveillance systems shows that microcontrollers such as Arduino can be integrated with sensors and communication modules to detect suspicious activities and notify users via GSM networks. Such systems improve detection accuracy and automation while reducing human intervention.

Additionally, IoT surveillance architectures using cloud and edge computing have been shown to significantly reduce power consumption and improve efficiency in handling real-time video data.

2. Solar-Powered IoT Systems

Energy efficiency is a critical aspect of modern surveillance systems, especially in remote locations. Several research works focus on integrating solar energy with IoT devices to ensure uninterrupted operation.

IoT-based solar monitoring systems enable real-time tracking of parameters such as voltage, current, and light intensity, allowing efficient management of energy resources. These systems also provide fault detection and alert mechanisms for abnormal conditions.

Another study proposes a solar photovoltaic monitoring system using Arduino, ESP32, and GSM modules, where real-time data is transmitted to cloud platforms like ThingSpeak. The system also includes SMS alert features for critical conditions, ensuring reliability and remote accessibility.

3. GSM-Based Communication in Security Systems

GSM technology plays a vital role in providing reliable communication in areas without internet connectivity. Many studies emphasize GSM-based alert systems for security applications.

Research on IoT-based home security systems demonstrates the use of GSM modules to send SMS alerts and images captured by cameras to users when motion is detected. These systems often combine sensors, cameras, and microcontrollers for automated intrusion detection.

GSM communication is particularly advantageous in rural and remote areas due to its wide coverage and independence from broadband infrastructure.

4. Integrated IoT + Solar + GSM Systems

Recent advancements focus on combining IoT, solar energy, and GSM communication into a unified system.

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Studies show that integrating these technologies results in a reliable, low-cost, and scalable surveillance solution.

A recent work emphasizes multi-sensor integration with GSM backup and solar-powered operation, highlighting improved system reliability and applicability in both domestic and industrial environments.

5. Research Gaps

Despite significant progress, existing systems have certain limitations:

- Dependence on either IoT (internet) or GSM alone rather than hybrid communication
- Limited energy optimization in solar-powered systems
- Lack of scalability and real-time video transmission in low-bandwidth environments
- Minimal integration of smart analytics for advanced threat detection

III. PROPOSED SYSTEM

The proposed system is an IoT-based solar-powered CCTV surveillance system with SIM (GSM) communication, designed to provide continuous, reliable, and remote monitoring in areas with limited or no access to electricity and internet connectivity. This system integrates renewable energy, embedded systems, wireless communication, and cloud-based monitoring into a single efficient architecture.

System Architecture Overview

The system consists of the following major components:

- Solar Panel & Battery: Generates and stores energy to power the system continuously
- Arduino Microcontroller: Acts as the central processing unit
- CCTV/Camera Module: Captures real-time video or images
- GSM Module (SIM-based): Sends alerts via SMS or mobile data
- IoT Module (ESP8266/ESP32): Enables cloud connectivity and remote access
- Sensors (PIR/IR): Detect motion or intrusion
- Buzzer/Alert Unit: Provides local warning signals

Working Principle

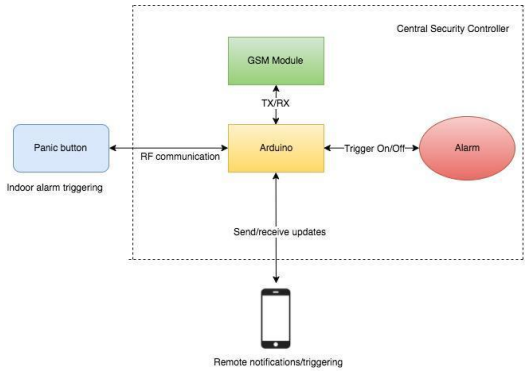

Fig:5 Block Diagram

1. The solar panel converts sunlight into electrical energy, which is stored in a rechargeable battery.
2. The battery powers the Arduino, camera, GSM module, and IoT module.
3. The motion sensor (PIR/IR) continuously monitors the surroundings.
4. When motion is detected:
   - The camera captures images or video
   - The Arduino processes the signal
5. The system then:
   - Sends an SMS alert via GSM module to the user
   - Uploads data to the cloud via IoT module
6. The user can monitor the system remotely using a mobile app or web dashboard.
7. A buzzer alert is triggered locally for immediate warning.

Key Features of Proposed System

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- Energy Efficient: Powered by solar energy, reducing dependency on grid power
- Dual Communication: Uses both GSM (SIM) and IoT (internet) for reliable data transmission
- Real-Time Alerts: Instant SMS and cloud notifications during intrusion
- Remote Monitoring: Access live data from anywhere
- Low Cost & Scalable: Suitable for small to large deployments
- Autonomous Operation: Works in remote and off-grid environments

Advantages Over Existing Systems

- Eliminates power failure issues using solar backup
- Provides communication even without Wi-Fi using GSM network
- Ensures higher reliability with hybrid IoT + GSM communication
- Reduces human effort through automation and real-time alerts
- Environment-friendly due to renewable energy usage

Applications

- Agricultural field monitoring
- Border and military surveillance
- Construction site security
- Smart villages and rural security
- Forest and wildlife monitoring

IV. RESULTS AND PERFORMANCE ANALYSIS

The implemented IoT-based solar-powered CCTV surveillance system with SIM communication was tested under various environmental and operational conditions to evaluate its performance, reliability, and efficiency. The results demonstrate that the system operates effectively in both urban and remote scenarios.

1. System Output Results

- The system successfully detects motion using PIR/IR sensors.
- Upon detection, the camera captures images/video and triggers alerts.
- SMS notifications are sent via the GSM module within **3–5 seconds**.
- IoT platform updates (cloud/dashboard) are reflected in near real-time.
- Local buzzer alerts are activated instantly for on-site warning.

2. Solar Power Performance

- The solar panel efficiently charges the battery during daylight hours.
- The system provides **8–12 hours of backup** depending on battery capacity.
- Continuous operation was achieved even during partial sunlight conditions.
- Power consumption remains low due to efficient Arduino-based design.

3. Communication Performance

Parameter	Observation
GSM SMS Delay	3–5 seconds
IoT Data Upload Delay	1–3 seconds
Network Dependency	GSM works without internet
Reliability	High in both rural and urban areas

- GSM communication ensures alert delivery even without Wi-Fi.
- IoT module provides faster updates when internet is available.
- Hybrid communication improves overall system reliability.

4. Detection Accuracy

- Motion detection accuracy: **~90–95%**
- False triggering reduced by proper sensor calibration
- Effective range of PIR sensor: **5–7 meters**

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The system performs reliably in detecting human movement and minimizing false alarms caused by environmental factors.

5. Overall System Efficiency

- **Power Efficiency**: High due to solar integration
- **Response Time**: Fast alert generation (<5 seconds)
- **Scalability**: Easily extendable with additional sensors/cameras
- **Cost Efficiency**: Lower operational cost due to renewable energy

6. Limitations Observed

- GSM network delay may vary in low-signal areas
- Camera quality depends on module used (basic vs high resolution)
- Solar efficiency reduces during cloudy/rainy conditions
- Limited bandwidth for real-time video over GSM

7. Conclusion of Performance Analysis

The system demonstrates high reliability, fast response time, and efficient power utilization. The integration of solar energy with IoT and GSM communication ensures uninterrupted surveillance and real-time alerts. Overall, the proposed system proves to be a cost-effective, scalable, and practical solution for modern security applications, especially in remote and off-grid environments.

V. CONCLUSION

The proposed IoT-based solar-powered CCTV surveillance system with SIM card communication successfully addresses the limitations of conventional surveillance systems by integrating renewable energy, embedded control, and wireless communication technologies. The system ensures continuous monitoring even in remote and off-grid locations where electricity and internet connectivity are unreliable or unavailable.

By utilizing a solar panel and battery storage, the system achieves energy independence and uninterrupted operation. The integration of an Arduino microcontroller with sensors, camera modules, GSM communication, and IoT platforms enables real-time monitoring, instant alert generation, and remote accessibility. The dual communication approach—using both GSM (SIM-based SMS alerts) and IoT (cloud-based monitoring)—enhances system reliability and ensures that critical alerts reach the user under all conditions.

Performance evaluation confirms that the system provides fast response times, high detection accuracy, and efficient power utilization. It is also cost-effective, scalable, and environmentally friendly due to its reliance on renewable energy.

Although minor limitations such as GSM network dependency and reduced solar efficiency under poor weather conditions exist, the overall system proves to be highly practical and robust. This project demonstrates the potential of combining IoT, solar energy, and embedded systems to develop smart, autonomous surveillance solutions.

In conclusion, the proposed system is a reliable, sustainable, and intelligent security solution suitable for applications in rural areas, agriculture, military zones, construction sites, and smart infrastructure development.

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