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INTELLIGENT MONITORING AND SELF-MAINTENANCE SYSTEM FOR SOLAR PV SYSTEMS: DESIGN, DEVELOPMENT, AND SURVEY BASED ANALYSIS

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Abstract: However, conventional PV monitoring and maintenance methods rely heavily on manual inspection, leading to inefficiencies, delayed fault detection, and reduced system performance. To address these challenges, this study presents an intelligent monitoring and self-maintenance system designed to enhance the performance and reliability of solar PV installations. The proposed approach is based on sensor-driven data acquisition, where multiple sensors, including a Light-Dependent Resistor (LDR), temperature sensor, light intensity sensor, rain sensor, and DHT11 humidity sensor, are integrated to continuously collect environmental and operational data such as panel temperature, ambient temperature, humidity, light intensity, rainfall duration, and dust accumulation. Data communication and control are achieved using the SIM800L GSM module and ESP32 Wi-Fi microcontroller, enabling real-time monitoring, automated alerts, and IoT-based management through Firebase, Google Sheets, and a custom Flutter mobile application. The 20x4 LCD display and ESP32 web server provide a user-friendly local interface, while the Flutter app offers remote access to data visualization and control. The system incorporates automatic cooling and cleaning mechanisms that activate based on sensor readings, reducing manual intervention and ensuring optimal power generation efficiency. Field testing conducted on fifteen solar PV systems across Sri Lanka demonstrated measurable improvements in energy output and a significant reduction in manual maintenance requirements. Furthermore, an AI-based analytical framework was introduced to evaluate performance trends and generate predictive maintenance recommendations using data from cloud storage platforms, supporting proactive maintenance decisions. This intelligent and cost-effective self-maintenance system minimizes human involvement, lowers operational costs, and enhances the lifespan and efficiency of solar panels, thereby improving the overall sustainability of solar PV systems. The proposed approach provides a sustainable and scalable solution for smart solar management, making it highly suitable for developing countries like Sri Lanka, where maximizing renewable energy utilization and reducing maintenance costs are critical objectives.

Keywords: Cloud Storage; Intelligent System; Internet of Things; Real-Time Monitoring; Self-Maintenance