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Solar Powered Street Light with Sensor and Auto Intensity Control

Asan Nainar[1], Hariprasath[2], Layanya[3], Kathiravan[4], Sowmya[5]
Faculty, Department of Information Technology[1]
Students, Department of Information Technology[2,3,4,5]
SRM Valliammai Engineering College, Kanchipuram, Tamil Nadu, India

Abstract: *The goal of this work is to predict solar panel power output by utilizing machine learning techniques, such as neural networks and regression, and by examining variables such as panel orientation, temperature, and sun irradiation. Models with high forecast accuracy help with grid integration and solar energy management. The article also outlines an innovative LED street light system that runs on solar power and uses Internet of Things (IoT) technology for intelligent control. By adjusting brightness in response to motion detection and current conditions, the device improves both urban safety and energy economy. For continuous operation, it runs on a backup battery, encouraging intelligent and sustainable street lighting*

Keywords: Prediction, Internet of Things (IoT),Sensors, Backup Battery, Energy Economy

I. INTRODUCTION

Accurate solar panel power generation forecasts are more important than ever in order to maximize energy efficiency and improve grid stability. This is because solar energy technology is developing at a rapid pace. Effective grid integration, resource planning, energy management, and system optimization depend on these forecasts. Predictive models can be created to estimate solar panel power output under various environmental situations using past data from solar panel installations. By examining a variety of variables, including as solar irradiance, temperature, panel orientation, shading effects, and other climatic influences, machine learning algorithms and data analytics are essential for increasing prediction accuracy. This makes it possible for those involved in the solar energy ecosystem—such as legislators, system integrators, and energy providers—to decide on renewable energy subsidies and energy infrastructure with knowledge.

This research also explores creative approaches to street lighting systems. The conventional method of street lighting, which relies on Light Dependent Resistors (LDRs), has limitations when it comes to energy efficiency and adaptability to changing climatic conditions. In order to improve energy efficiency and public safety, the proposed street lighting system combines solar energy, Internet of Things (IoT) technology, and passive infrared (PIR) motion sensors to alter brightness based on detected movement. In order to ensure ongoing operation even in the event that the solar energy storage runs out, a backup battery is provided. This clever method of street lighting saves energy during times of low activity and adjusts to changing climatic circumstances, improving urban livability and sustainability all at the same time. All things considered, the goal of these developments is to redesign urban infrastructure with an emphasis on environmental responsibility and energy efficiency.

II. BENEFITS

- Predictive Models for Solar Energy Help Align Generation Capacity With Demand, Reducing Waste And Aiding In Resource Management.
- The System Uses Iot Technology to Adjust Solar-Powered Led Street Lights Based On Real-Time Conditions, Improving Energy Efficiency And Reducing Waste.
- Street Lights Are Designed to Operate Only at Night Or In Bad Weather, Turning Off During The Day, Which Is Especially useful In Regions With Electricity Shortages.

- Motion Sensors Trigger Lights to Brighten When Movement Is Detected, Enhancing Safety And Reducing Energy Use During Low-Activity Periods.

III. OBJECTIVES

Because solar energy technology is developing so quickly, it is becoming more and more crucial to estimate solar panel power generation accurately in order to maximize energy efficiency and enhance grid stability. This study examines the methods and strategies used in solar panel power prediction using datasets collected from solar panel installations. Predictive models can estimate solar panel power output under a range of climatic circumstances with a high degree of accuracy by using machine learning algorithms and historical data. In order to support the adoption of renewable energy sources and sustainability goals, the implications of accurate solar panel power prediction are discussed. This emphasizes the importance of data-driven insights in shaping the trajectory of solar energy technology.

Accurately estimating solar panel power generation is becoming increasingly important to maximize energy efficiency and improve grid stability since solar energy technology is advancing so quickly. Using datasets gathered from solar panel installations, this study investigates the approaches and techniques utilized in solar panel power prediction. Using machine learning algorithms and historical data, predictive models are able to estimate solar panel power output with a high degree of accuracy under a variety of climatic conditions. This paper discusses the consequences of precise solar panel power forecast to promote sustainability goals and the adoption of renewable energy sources. This highlights how crucial data-driven insights are in determining how solar energy technology develops.

IV. PROPOSED SYSTEM

Modern technology is included into the suggested solar LED street lighting system to increase sustainability and energy efficiency in metropolitan environments. To maximize energy consumption, it makes use of solar energy, motion detection, and automated brightness adjustment. Seamless connection between components is made possible by IoT infrastructure. By anticipating and resolving possible disturbances, predictive insights improve dependability and resilience by enabling real-time illumination level adjustments based on environmental circumstances. This proactive strategy guarantees steady illumination levels and reduces outages. Through the analysis of historical data to pinpoint inefficiencies, the technology also facilitates optimization and preventative maintenance techniques. Urban planners can make data-driven decisions with the support of predictive skills, which facilitate well-informed infrastructure upgrades and policy interventions that encourage energy-efficient practices.

V. METHODOLOGY

A. Energy Harvesting Module:

Position high-efficiency solar panels strategically, taking into account sunlight exposure, tilt angles, and shading, while integrating energy storage systems like lithium-ion batteries with charge controllers and voltage regulators to store excess energy. Use a monitoring system to track performance and conduct regular maintenance for system reliability.

B. Energy Prediction Module:

Obtain historical solar radiation data from reliable sources, analyze trends to understand seasonal variations, and evaluate shading effects through on-site surveys. Use simulation tools and mathematical models to predict solar energy generation, incorporating panel characteristics, degradation rates, and machine learning algorithms trained on historical data. Continuously monitor real-world performance, validate prediction models with actual energy production data, and adjust as needed for ongoing accuracy and reliability.

C. Lighting Control and Sensing Module:

LED modules in solar-powered street lighting are energy-efficient and reliable, with low energy consumption, high brightness, and longer lifespans that reduce maintenance costs. These modules adjust brightness dynamically based on environmental factors, conserving energy while enhancing safety by increasing brightness during low ambient light conditions or upon motion detection. To implement auto intensity control, connect LEDs, Light Dependent Resistors

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(LDR), and Passive Infrared (PIR) sensors to a microcontroller like Arduino Uno, with proper wiring to ensure accurate functionality and safety.

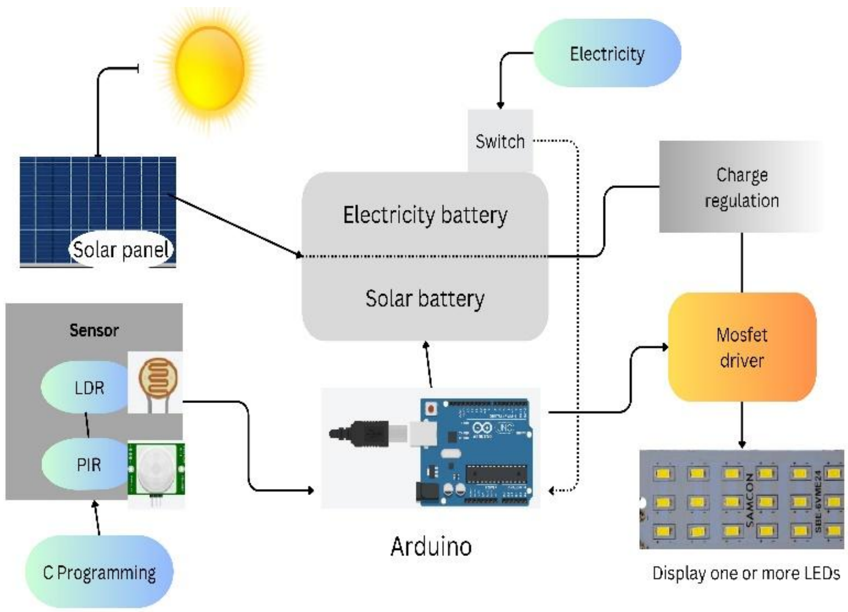
D. Implementation, Control and Communication Module:

The central processing unit in solar street lighting systems, often an Arduino or similar microcontroller, executes commands, monitors sensors, and adjusts LED brightness based on tailored algorithms. It connects with control systems or cloud platforms for remote monitoring, allowing stakeholders to track performance, energy usage, and system status in real-time. Protective housing and robust design ensure durability, while connectivity with central monitoring systems supports proactive maintenance and integration with broader smart city infrastructure.

VI. SYSTEM ARCHITECTURE

System Architecture

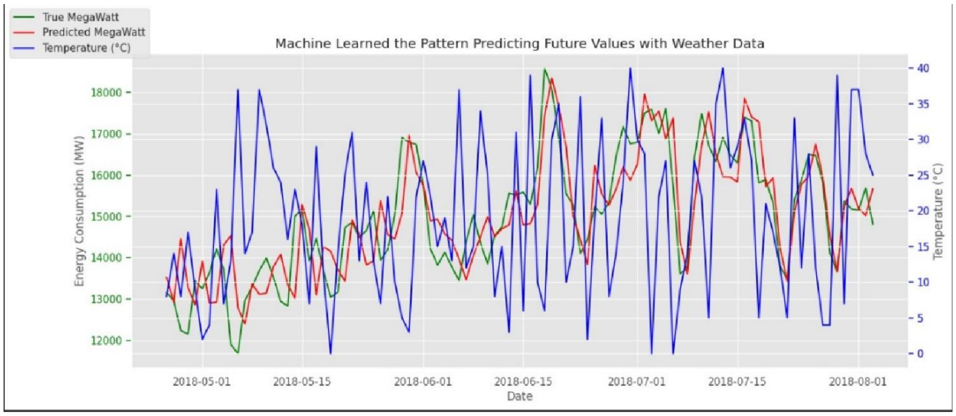
After prediction:



The architecture diagram for a solar-powered street light with sensor and auto intensity control depicts a hierarchical arrangement of components and their connections to illustrate the system's functionality. At the top, the solar panel is positioned to symbolize its exposure to sunlight, while beneath it lies the battery, signifying its role in energy storage. In the center, the Arduino board is placed as the central control unit, orchestrating the system's operations. Connected to the Arduino are the LDR and PIR sensors, denoted by arrows indicating the flow of data, illustrating their roles in detecting ambient light levels and motion, respectively. Positioned at the bottom is the LED light, connected to the Arduino, representing its controllable nature in providing illumination. Encasing these components is the auto intensity control circuit, depicted as a box surrounding the Arduino, LDR, PIR, and LED, symbolizing its function of regulating the LED intensity based on sensor inputs. Arrows between components denote the flow of data or power, with labels specifying the connections and their purposes. Together, this diagram visually conveys how each component interacts within the system to achieve efficient and adaptive street lighting.

Output for Prediction:

COMPARISION OF PREDICTED AND ACTUAL VALUE



The graph displays the relationship between true megawatt production, predicted megawatt production, and temperature over a given time period. A strong correlation is observed between temperature and true megawatt production, suggesting that higher temperatures often align with increased energy output. The predicted megawatt values closely track the true megawatt values, indicating a high level of accuracy in the prediction model. Discrepancies between true and predicted megawatt outputs are minimal, signifying effective predictive accuracy despite temperature fluctuations. Overall, the graph underscores the reliability of the predictive model in forecasting energy generation across varying temperature conditions

VII. CODE THAT WE USED FOR FUTURE PREDICTION

```
Machine_Df
True_MegaWatt = TestData["AEP_MW"].to_list()
Predicted_MegaWatt  = [x[0] for x in Predicted_MegaWatt ]
dates = TestData.index.to_list()
fig = plt.figure()
ax1= fig.add_subplot(111)
x = dates
y = True_MegaWatt
y1 = Predicted_MegaWatt
plt.plot(x,y, color="green")
plt.plot(x,y1, color="red")
# beautify the x-labels
plt.gcf().autofmt_xdate()
plt.xlabel('Dates')
plt.ylabel("Power in MW")
plt.title("Machine Learned the Pattern Predicting Future Values ")
plt.legend()

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
# Read weather data from CSV file
weather_df = pd.read_csv('/content/weather_data (2).csv')
weather_df.head(20)
# Convert 'Date' column to datetime type and set it as index
```

```
weather_df['Date'] = pd.to_datetime(weather_df['Date'])
weather_df.set_index('Date', inplace=True)

# Plot energy consumption and weather data
fig, ax1 = plt.subplots()

# Plot energy consumption
ax1.plot(Machine_Df['Date'], Machine_Df['TrueMegaWatt'], color='green', label='True MegaWatt')
ax1.plot(Machine_Df['Date'], Machine_Df['PredictedMeagWatt'], color='red', label='Predicted MegaWatt')
ax1.set_xlabel('Date')
ax1.set_ylabel('Energy Consumption (MW)')
ax1.tick_params('y', colors='green')

# Create a secondary y-axis for weather data
ax2 = ax1.twinx()
ax2.plot(weather_df.index, weather_df['Temperature_Celsius'], color='blue', label='Temperature (°C)')  # Change
'Weather' to 'Temperature_Celsius'
ax2.set_ylabel('Temperature (°C)')  # Change 'Weather' to 'Temperature (°C)'
ax2.tick_params('y', colors='blue')

# Show legend
fig.legend(loc='upper left')

plt.title("Machine Learned the Pattern Predicting Future Values with Weather Data")

plt.show()
```

VIII. RESULT

A complete solution for sustainable energy consumption is produced when solar panel power generation forecast is combined with Internet of Things-driven solar-powered LED street lighting. Grid stability and solar energy system optimization can be achieved by energy suppliers by using machine learning algorithms to predict solar panel output. Intelligent control, including auto intensity adjustment and motion detection to improve energy efficiency and safety, is made possible by integrating IoT technology into street lighting. By utilizing IoT automation for street lighting and predictive accuracy for solar power, this dual strategy reduces energy waste. The integrated system provides a solid example for towns looking to increase energy efficiency while advancing sustainability and security.

IX. FUTURE WORK

In the future, solar-powered street lights with sensor and auto intensity control are poised to undergo significant advancements, shaping the landscape of urban lighting solutions. Enhanced energy efficiency will be a hallmark, with ongoing developments in LED technology and energy storage systems leading to longer operating times and reduced energy consumption, even in low sunlight conditions. Moreover, integration with a variety of renewable energy sources such as wind or kinetic energy harvesting will ensure uninterrupted power supply, bolstering resilience against adverse weather conditions or sunlight scarcity.

X. CONCLUSION

The intelligent Solar Street Lighting Control System integrates solar panels with advanced energy prediction models for enhanced street lighting efficiency and sustainability. By utilizing historical data and weather forecasts, the system predicts energy generation, allowing for optimized energy usage. The circuit design incorporates Light Dependent Resistors (LDR) and object sensors to control street light illumination, with Arduino UNO managing the central control. This smart system significantly reduces power consumption while promoting energy conservation and long-term cost-effectiveness. Overall, the project underscores the potential of smart control systems in urban infrastructure and contributes to the advancement of renewable energy technologies.

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