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# COOPERATIVE POWER EXCHANGE BETWEEN TWO ROOFTOP SOLAR PLANTS INTERFACED WITH ARDUINO IOT CLOUD

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*Cooperative power Exchange; IoT; Arduino IOT cloud, NodeMCU ESP8266; Thing Interactions; Switch Module*

A B S T R A C T

*The main aim of this paper is to develop a system which enables the sharing of excess power generated by the solar panels to maximize the use of renewable energy sources and reduce the reliance on traditional power grids. The monitoring system collects data from the two rooftop solar plants and transmits it to the cloud for visualization, retrieval, and data storage. The Arduino IOT Cloud provides a platform for the monitoring of power generation and consumption, and the Node MCU ESP8266 enables communication between the two solar plants. The system implements a cooperative power exchange algorithm that allows the two rooftop solar plants to exchange power based on their energy production levels. The system operates on a peer-to-peer instantaneous energy monitoring, where the two rooftop solar plants can share excess power to each other.*



## 1. INTRODUCTION

In order to minimize the negative environmental effects of conventional energy producing techniques, there has been an increasing focus on renewable energy sources in recent years. Rooftop solar power production has become one of the most popular renewable energy sources because of its accessibility, scalability, and potential for decentralization. The idea of cooperative power exchange (Yamaguchi & Matsumoto, 2023) between two rooftop solar plants has emerged as a workable solution to this problem. A network of linked solar power plants may be built, allowing excess energy from one plant to be shared with a plant that is facing a deficit, resulting in stable and balanced energy ecology. This collaborative strategy improves the overall efficiency and dependability of the renewable energy infrastructure while optimizing power use and reducing waste (Strielkowski et al., 2019). In this project, a sophisticated platform for monitoring, managing, and coordinating cooperative power exchange between two rooftop solar plants is provided by the combination of the Arduino IOT Cloud and NodeMCU ESP8266 microcontroller board. Real-time data from solar power plants can be collected and visualized using Arduino IOT Cloud, and NodeMCU ESP8266 allows communication and coordination between the plants to ensure effective power exchange (Li et al., 2020).

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## 2. LITERATURE SURVEY

A literature review of two rooftop solar plants cooperating to trade electricity using an Arduino IoT Cloud-enabled NodeMCU 8266 interface shows that interest in decentralized energy management systems is rising.It presents a concept for the implementation of Peer-to-Peer energy network based on the circuit-switching framework (Salvi et al., 2020). The proposed system also provides users with the ability to track and sell energy remotely using IoT architecture and cloud computing. They propose an integrated auctioning-scheduling mechanism that auctions the surplus energy and done by making using for Arduino IOT cloud as mainly the following features one is thing interaction and the other is Arduino IOT cloud web editor as features allow user to program and communicate. Schedules its consumption on a cloud datacenter. The auction part incentivizes the inter-datacenter cloud workload migrations, while the scheduling part ensures that migrated workloads do not exceed the destination datacenter capacity (Abada et al., 2022).

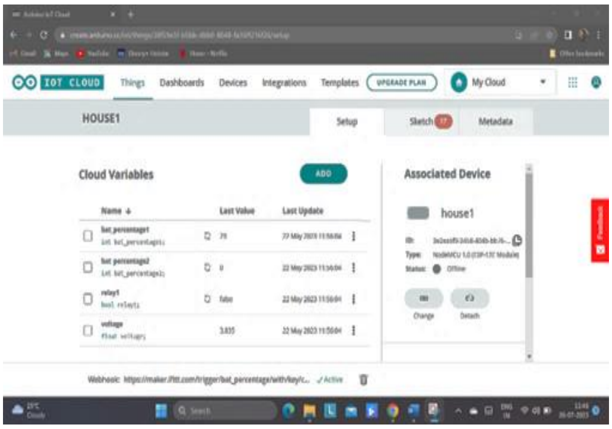


**Figure 1**. Cloud variables of house 1

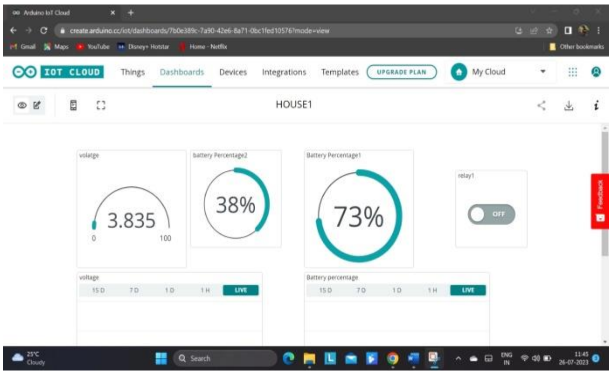


**Figure 2.** Dashboard of house1

## 3. ARDUINO IOT CLOUD

The cloud-based (Atlam et al., 2017) Arduino IoT Cloud platform enables users to safely connect to, manage, and control their IoT projects and devices. For creating IoT apps and connecting them with the Arduino ecosystem, it offers a combination of tools and services. The platform makes it easier to remotely manage and update devices, gather and analyze data, and connect to and operate IoT devices (Oton et al., 2021).

### 3.1 Thing Interactions

The Arduino IoT Cloud offers a simple interface for defining interactions between objects. Devices may react to events or changes in other devices thanks to these interactions (De Oliveira Cavalcanti & Pimenta, 2023). For instance, you may set up a device such that it performs a given action when it gets a certain message or when a property value reaches a predetermined level.

### 3.2 Arduino IoT Cloud Web Editor

The Arduino IoT Cloud Web Editor provides community support, accessibility, integrated IoT capability, cloud integration, collaboration tools, and device management capabilities. For creating, deploying, and administering IoT applications utilizing Arduino boards, it offers a comprehensive and user-friendly environment (Panagiotakis et al., 2022).

## 4. EXPERIMENTAL SETUP

A cutting-edge combination of hardware elements including NodeMCU ESP8266, TP4056 charging module, lithium-ion battery, voltage divider circuit, and relay module, all smoothly interfaced with the Arduino IoT Cloud platform can be shown in the experimental setup for the solar power exchange project as shown in fig 3 (Salvi et al., 2020). This technological convergence represents a fundamental change in the way we organize and distribute renewable energy sources.

The NodeMCU acts as a link between the actual hardware parts and the digital world thanks to its integrated Wi-Fi capabilities, enabling bidirectional communication and control. The proper operation of the Lithium-Ion battery (Abu et al., 2023) is maintained by the TP4056 charging module. This module makes sure the energy storage component is secure and lasts a long time by controlling and managing the battery charging process. Along with the visual indications, the TP4056 charging IC ensures effective charging and protects against overcharging or undercharging of the lithium-ion battery. Speaking about batteries, the Lithium-Ion kind, often the 18650 types, is in charge of both storing and supplying energy. This arrangement is perfect for its high energy density and rechargeable design. Using a voltage divider circuit, the Analog-to-Digital Converter (ADC) of the NodeMCU is cleverly used to monitor the battery voltage level and translate it into a readable range.

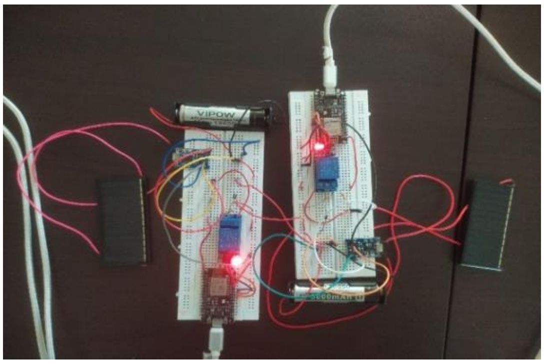

**Figure 4**. Prototype model of P2P connection between two solar power plant

## 4.1 SOFTWARE SETUP

The ArduinoCloud.update () method is used in the loop () function to update the cloud variables and attributes. The analogRead() method is used to read the sensorValue from the analog input pin A0. By translating the sensor data to voltage and adding a calibration factor, the voltage is computed. By converting the voltage value to a % between 0 and 100 while considering the battery cut-off voltage and maximum voltage, the bat_percentage1 variable is created. For monitoring reasons, the computed values are then output to the serial monitor. Using the digitalWrite() method, the relay pin is set to HIGH or LOW depending on the bat_percentage2 and bat_percentage1 values.

The relaypin is set to HIGH if the bat_percentage2 is less than 40 and the bat_percentage1 is more than 60. The default setting is LOW. The mapfloat() method is designed to translate values across ranges. It is used to determine the bat_percentage1 variable's value. Finally, anytime the relay1 variable from the IoT Cloud changes, the onRelay1Change() method is invoked. Using the digitalWrite() method, the relaypin is set to either LOW or HIGH depending on the value of the relay1 variable and vice versa.

## 5. RESULTS

A revolutionary approach to increase energy efficiency and promote sustainable energy sharing is the cooperative power exchange system. It uses the ESP8266 and automated relay operation on the Arduino IoT Cloud platform. This system enables power transfer from one rooftop solar plant to another when one of the batteries reaches the critical 40% voltage barrier, ensuring a continuous energy supply and efficient energy management. This comprehensive summary of the implementation's results will include the key findings involving power transfer, automatic relay operation, monitoring on the Arduino IoT Cloud platform, and real-time Gmail alerts through web hooks.

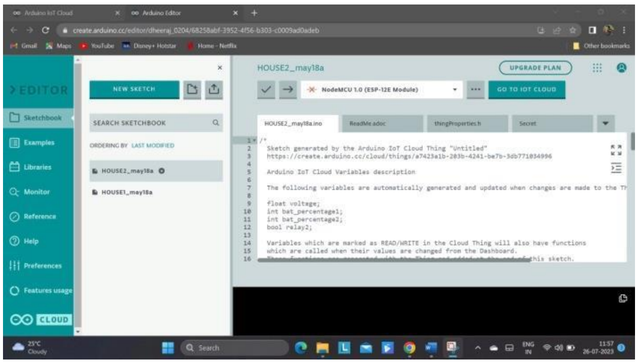


**Figure 5**. Arduino Web Editor

### 5.1 Transfer of Power at Low Battery Voltage

One of the remarkable results of the cooperative power exchange system is the seamless power transfer between the two rooftop solar plants when one of the batteries reaches a low voltage level. The power exchange procedure begins at the preset critical voltage level of 40%. Once the power from input is low, then for an instance the battery voltages show 1% as shown in figure 6, which may indicate an energy deficiency, which indicates one plant requires outside energy support. The system activates the automatic relay function to make the power transfer from the second solar plant, which has surplus energy. This real-time decision-making ensures that energy is continuously exchanged, and it also promotes energy balance and reduces energy waste.

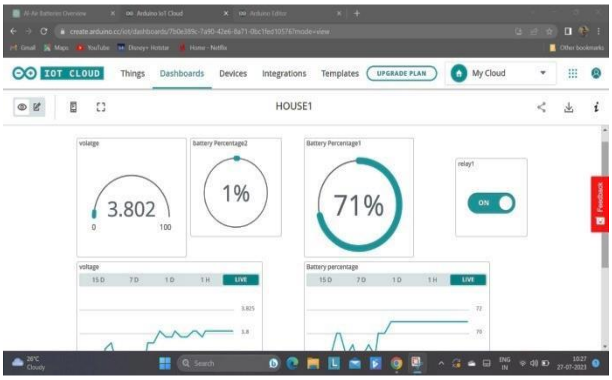


**Figure 6.** Power transfer from house 2 to house 1

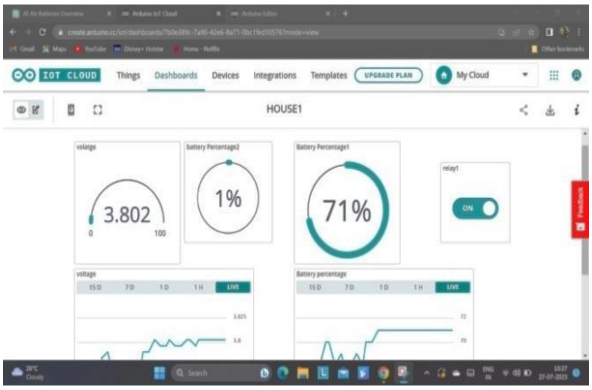


**Figure 7**. Power transfer from house1 to house 2

## 5. 2 Operation of Automatic Relays

The cooperative power exchange system, which regulates the power flow between the two rooftop solar systems, is very dependent on the automated relay functioning. The ESP8266 microcontroller (Lal et al., 2022), which serves as the control point, continuously monitors the battery voltage levels and energy needs. When the battery percentage in one plant drops below the predetermined level, the Arduino IoT Cloud platform activates the relay, allowing power transfer.

The automatic relay operation, which ensures a smooth transmission of power, allows the two solar plants to operate together independently. The quick activation and deactivation of the relays maximizes energy efficiency and minimizes energy waste throughout the exchange operation (Lee, 2019). By requiring less human involvement, this automated procedure improves system efficiency and simplifies energy management.

## 5. 3 Monitoring in the IoT Cloud Platform

The integration of the Arduino IoT Cloud platform has given the cooperative power exchange system considerable monitoring features. The user-friendly interface allows users to get real-time data on voltage levels, battery percentages, and relay statuses for both rooftop solar plants (Chen et al., 2018). This real-time monitoring helps users to make educated choices by allowing them to view the system's performance and the ongoing power exchange process.


**Figure 8.** Live data of battery voltage and percentage

## 5. 4 Webhook notifications for Gmail

A unique feature of the cooperative power exchange system is the incorporation of Gmail notifications through web hooks, as shown in Figure 9. The Arduino IoT Cloud platform sends real-time time alerts to a selected Gmail account (Cheng et al., 2019) when certain events occur, such as the turning on or off of the relay or critical battery levels. The ESP8266 and Arduino IoT Cloud-based cooperative power exchange system promises promising results in terms of optimizing energy utilization, stimulating the sharing of renewable energy, and creating a sustainable energy ecosystem. When the power transfer mechanism is activated and when one of the batteries hits a vital 40% voltage level, it ensures steady energy delivery and minimizes potential energy shortages. Automated relay operation controls power flow, maximizes energy efficiency, and minimizes energy loss.

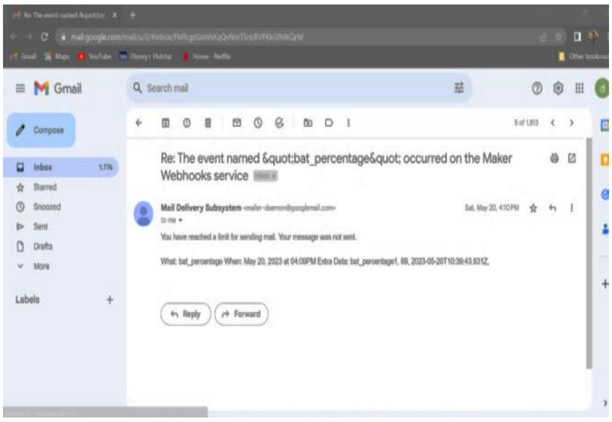


**Figure 9.** Webhook notification through Gmail

## 6. CONCLUSION

The cooperative power exchange system between two solar rooftop plants, enabled by ESP8266 and Arduino IoT Cloud, with a focus on Thing Interaction and Gmail notifications through web hooks, represents a remarkable advancement in renewable energy utilizations (Hannan et al., 2020) and sustainable energy sharing. This method has shown to be effective in developing a greener and more robust energy infrastructure, improving energy distribution, and encouraging energy self-sufficiency. We have examined the technique, application, and outcomes of this ground-breaking system throughout this project, and it is clear that it has enormous potential for influencing the direction of energy management in the future. The system's performance in fostering energy self-sufficiency, improving energy distribution, and lowering carbon emissions highlights its potential to fundamentally alter the energy landscape.

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