TEXAS A&M UNIVERSITY
Engineering

ESP: Booth 310

Automatic Solar Lighting System

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Problem Definition

In recent years, Texans have experienced unreliability within the state's power grid, which has failed in both extreme heat and cold.These issues stem from the grid's inability to meet the growing demand for electricity, resulting in more frequent and prolonged power outages. Such outages are, at best, a major inconvenience, and a worst, potentially fatal, especially when they lead to a lack of lighting.

Methodology

Our project is an automatic solar lighting system powered by solar panels and lead-acid batteries. It lights the foyer and exterior of a house, triggered by PIR sensors and controlled via a mobile app. The system has four subsystems: Power Generation, Power Distribution, Microcontroller & Sensors, and App & Database.

Power Generation

- Built custom solar charge controller for 100W solar panel to 12V Lead-Acid battery with overcharge protection and MPPT functionality.
- Implemented INA260 Power Monitor to read power ratings from battery and communicate with MCU.

Power Distribution

- Built a pair of Modified Sine Wave Inverters to efficiently provide power to each light socket, tested and validated with 40W, 60W, 100W LED light bulbs.
- Designed, coded, and manufactured an SPI Controlled Relay Driver to operate the Relay switches on each Modified Sine Wave Inverter.

Microcontroller & Sensors

- Built a custom microcontroller system with sensor inputs, power monitoring, app integration, and lighting control via UART, I2C, SPI, WiFi, and Bluetooth.
- Designed and tested interior/exterior PIR + ambient light sensors with PIC24 MCU and UART, achieving 100% trigger accuracy.

App & Database

- Android App with cloud database (Firebase) connected to microcontroller provides remote control, scheduling and data monitoring.

Figure 1. AI generated image of ASLS

Engineering Analysis

Our project had several engineering components, including power monitoring, energy conversion, and device communication critical for the entire system to function, communicate, and validate effectively.

a. Data is collected from the charge controller and uploaded to the app via MCU for real-time battery status monitoring.
b. The charge controller is used to measure current, voltage, and power from the charge controller output, ensuring accurate energy tracking.
c. The charge controller was tested and validated using analysis of the solar panel and power source emulating panel outputs with voltage monitoring.

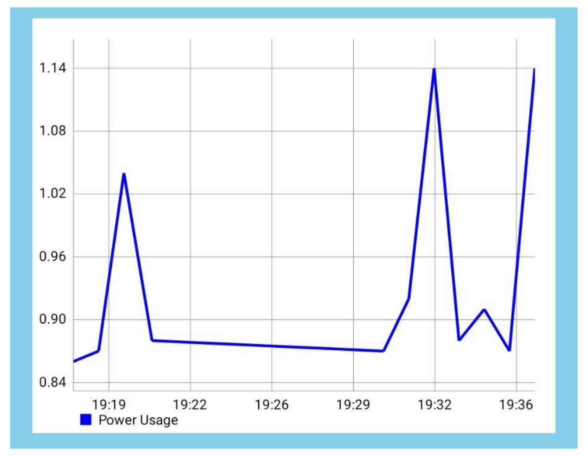

Figure 2 & 3. Charge controller data collected by the MCU and transmitted to the app for battery monitoring

9:30 AM- 10:00 AM			2:00 PM - 2:30 PM		
Start Voltage (V)	End Voltage (V)	Charged (%)	Start Voltage (V)	End Voltage (V)	Charged (%)
12.80	12.81	0.77	12.69	12.74	3.85
12.58	12.62	3.08	12.76	12.80	3.08
12.65	12.69	3.08	12.83	12.86	2.31
12.68	12.72	3.08	12.78	12.83	3.85
12.77	12.80	2.31	12.79	12.83	3.08
12:00 PM - 12:30 PM			**4:30 PM - 5:00 PM**		
Start Voltage (V)	End Voltage (V)	Charged (%)	Start Voltage (V)	End Voltage (V)	Charged (%)
12.77	12.84	5.38	12.83	12.85	1.54
12.82	12.88	4.62	12.80	12.82	1.54
12.69	12.76	5.38	12.76	12.79	2.31
12.73	12.79	4.62	12.81	12.83	1.54
12.79	12.86	5.38	12.77	12.81	3.08

Table 1. Charge controller charging data at various times

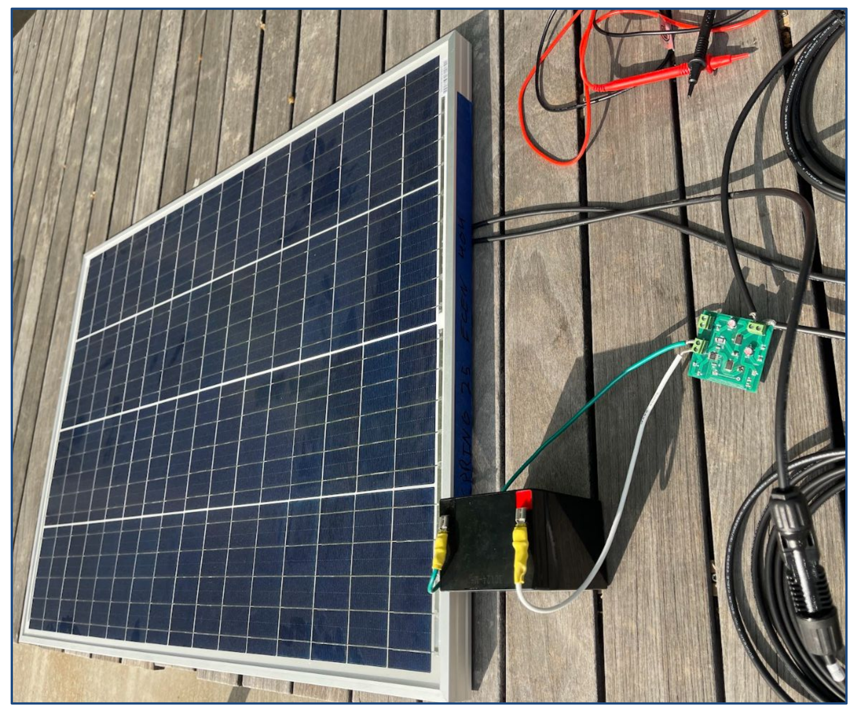

Figure 4. Solar Panel and Charge Controller Validation

Functional Block Diagram

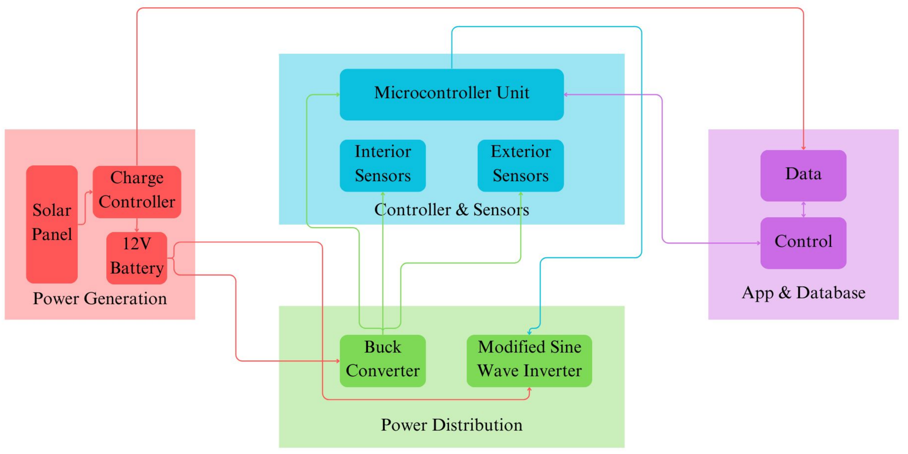

Figure 5. System architecture of subsystem interaction

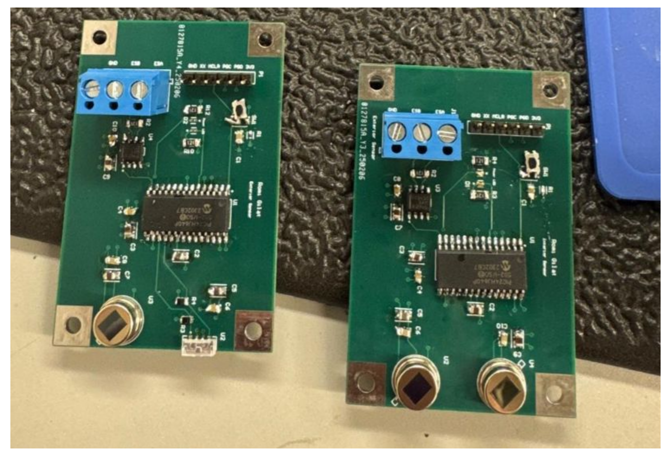

Figure 6. Interior and Exterior PIR sensors

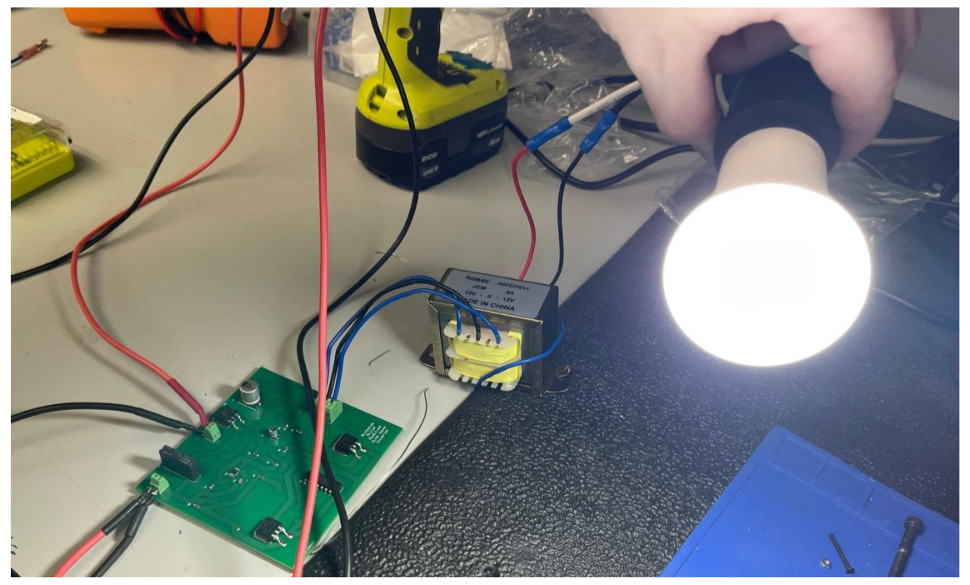

Figure 7. Light bulb lit using Modified Sine Wave Inverter

Outcomes

The Automatic Solar Lighting System successfully provided up to 8 hours of continuous lighting, controlled both manually through the app and automatically via sensor triggers. The system reliably illuminated both the foyer and exterior areas of the household, demonstrating effective off-grid power and smart control integration. The power monitor recorded power usage data, uploaded to Firebase via the MCU, and downloaded and displayed on the App.

As shown in Table 1, the solar component of the project has consistent charging levels throughout the day, despite lower sunlight levels. This highlights the MPPT's capabilities of being used as a charge controller.

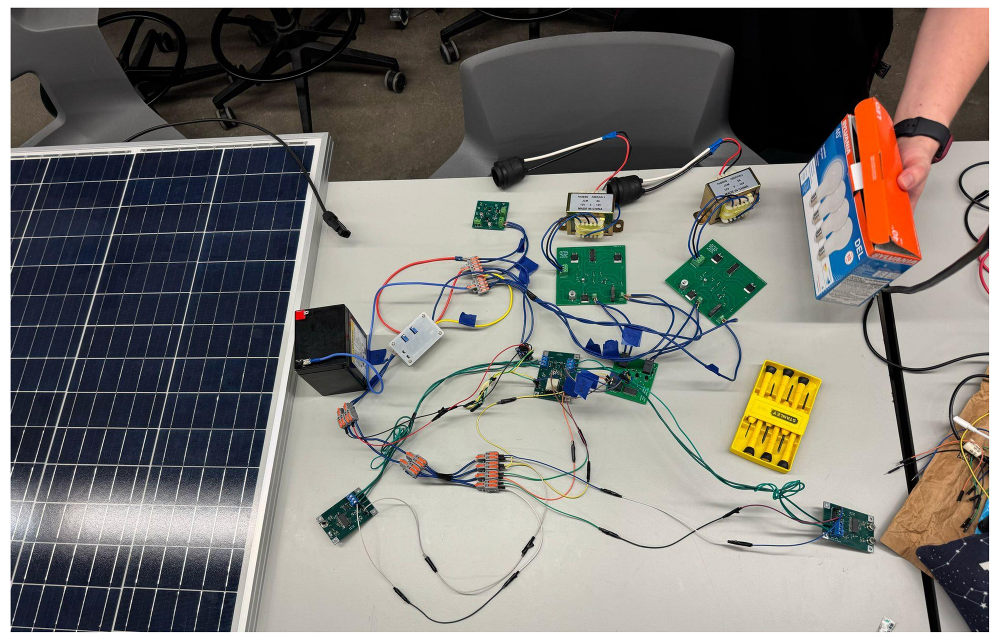

Figure 8: Fully functional system.

Impact

This automatic solar lighting system is designed to help homeowners become more energy-independent by reducing reliance on the power grid. It enhances safety and peace of mind, especially during emergencies when access to electricity may be disrupted. During the process of creating the Automatic solar lighting system, we explored:

- **Component Selection**
  We learned the importance of choosing components that are durable and weather-resistant, suitable for the device's intended use, and capable of long-term outdoor operation.
- **Planning Ahead**
  Proper planning in the early stages, such as anticipating the system's real-world usage and environmental challenges, helped guide design decisions and ensure better performance and reliability.
- **Prototyping Before Finalizing Design**
  Creating a prototype before committing to a final design allowed for smoother integration of components, more efficient use of space, and effective validation through testing, minimizing potential issues later in development.

References

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2.IEEE SCC21 - IEEE 1661-2019 – IEEE Guide for Test and Evaluation of Lead-Acid Batteries Used in Photovoltaic (PV) Hybrid Power Systems. New York, NY: IEEE, 2007. doi: 10.1109/IEEESTD.2007.4285867
3. Wellish, I., & Siepert, B. (2019, May 1). Adafruit INA260 Current + voltage + power sensor breakout. Adafruit Learning System. https://learn.adafruit.com/adafruit-ina260-current-voltage-power-sensor-breakout/arduino

Acknowledgements

We thank our sponsor, Dr. Wonhyeok Jang for his vision, consistent help and feedback on the project from Dr. Lusher II, and our teaching assistants Sabyasachi Gupta and Fahrettin Ay for guiding us along the way.