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IoT-Enabled Self-Charging Electric Vehicle using Dynamo and Solar Power

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***Abstract*— As electric vehicles (EVs) become more prominent in the global shift towards sustainable transportation, challenges such as limited charging infrastructure, prolonged charging times, and range anxiety hinder their widespread adoption. This project proposes a novel solution through a hybrid self-charging system that integrates both dynamo based and solar energy harvesting mechanisms.**

Utilizing a dual battery setup where one battery is charged by a dynamo and the other by a solar panel the system ensures continuous and efficient energy recovery while in motion or stationery. An IoT-enabled monitoring platform, powered by ESP32 and the Blynk app, provides real-time data tracking and system alerts, enhancing operational transparency and user engagement. The solution aims to reduce dependency on external charging stations, extend battery life, and promote eco-friendly mobility through intelligent power management and self-sufficiency.

***Index Terms*— Blynk App, Dynamo, ESP32, IoT, Regeneration.**

I. INTRODUCTION

The transportation sector is rapidly shifting toward electric vehicles (EVs) as a cleaner, more sustainable alternative to traditional gas-powered cars, driven by the need to cut carbon emissions and reduce reliance on fossil fuels. Despite advancements in battery technology and charging infrastructure, challenges like range anxiety and lengthy charging times continue to slow widespread EV adoption. Limited access to charging stations, especially in rural areas, and the 30+ minute wait at fast-charging stations can frustrate users and strain power grids during peak demand, making it clear that innovative solutions are needed to improve the EV experience.

In order to tackle these issues, this project proposes a self-charging EV system that combines regenerative braking through a dynamo with solar power to charge the vehicle's batteries on the go or while parked. Integrated with IoT technology, the system uses an ESP32 module and the Blynk platform to let users monitor voltage, battery health, and temperature in real-time via a mobile app. This approach not only boosts energy efficiency and convenience but also enhances safety and reliability, paving the way for a more practical and user-friendly EV future.

This work has been divided into the sections. The literature review has been outlined in the section II and section III deals with methodology. The result and experimentation are carried out in section IV and conclusion is given in section V.

II. LITERATURE REVIEW

Recent advancements in self-charging electric vehicles (EVs) highlight innovative approaches to harnessing renewable energy sources for on-board power generation, addressing key limitations in traditional EV designs. For instance, Nithya Rani et al. **[1]** propose a dual-battery system integrating regenerative braking, solar, and wind energy with an automatic switching mechanism and DC-DC boost converter to optimize power distribution and extend vehicle range. Similarly, Tamim et al. **[2]** describe a closed-loop self-charging setup for smart electric bikes using a dynamo-motor-battery configuration, enhanced by GPS tracking, accident detection, and monitoring features to boost safety and reduce external charging needs. Rao et al. **[3]** employ Model-Based Development (MBD) with simulation techniques like SIL, MIL, and HIL to validate a dynamo-driven regenerative braking system incorporating Permanent Magnet Synchronous Motors (PMSM) and Field-Oriented Control (FOC) for improved performance. Complementing these, Kerur and S.H. **[4]** outline a control strategy for two 24V batteries paired with a dynamo and boost converter for dynamic charging and efficient energy management, while Bhoomika and Darshan **[5]** detail a fabrication process integrating a dynamo, BLDC motor, battery pack, and rectifier to convert mechanical energy into electrical power for sustained operation.

These system-level innovations are supported by foundational research into their core components and control strategies. Al-otaibi **[7]**, for example, presents a patent-level framework for self-charging electric cars, underscoring the novelty of integrating on-board generation. The viability of such systems relies on the underlying powertrain, with Schaltz **[9]** providing a general overview of electrical vehicle design and modelling. Motor control is particularly critical for optimizing energy recapture. Gopal B T **[8]** offers a comparison between direct and indirect Field-Oriented Control (FOC) of induction motors, a strategy central to the work of Rao et al. **[3]**. Similarly, Haddoun et al. **[10]** propose a loss-minimization Direct Torque Control (DTC) scheme to further enhance EV motor efficiency. Finally, the

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effectiveness of these charging systems hinges on efficient power electronics, as explored by Abdel-Gawad and Sood **[6]** in their detailed analysis of boost converters, which are essential for managing power flow from the dynamo and solar panels.

Collectively, these studies underscore the potential of hybrid energy recovery and smart controls to make EVs more autonomous. Despite these innovations, EVs continue to face persistent challenges that impede broader adoption, including heavy dependency on sparse external charging stations, inefficient recovery of kinetic energy during braking, and the absence of robust real-time monitoring systems. These issues often result in range anxiety for users, particularly in areas with limited infrastructure, while suboptimal power recapture and lack of oversight can lead to energy waste, battery degradation, and safety risks. Such gaps not only strain power grids but also undermine the environmental benefits of electrification, as highlighted in ongoing research emphasizing the need for integrated, self-sustaining solutions.

In order to overcome these hurdles, the proposed system aims to develop an advanced self-charging EV framework that leverages dynamo-based regenerative braking and solar power for continuous on-board charging, minimizing reliance on external sources. By employing separate batteries for dynamo and solar inputs, it ensures efficient power management and safe charging protocols to prevent overloads. Furthermore, integrating IoT capabilities via an ESP32 microcontroller and the Blynk platform enables real-time tracking of voltage, temperature, and battery health through a mobile app, empowering users with actionable insights for enhanced reliability, safety, and overall vehicle autonomy. This approach builds directly on prior methodologies while introducing seamless monitoring to bridge existing deficiencies.

III. METHODOLOGY

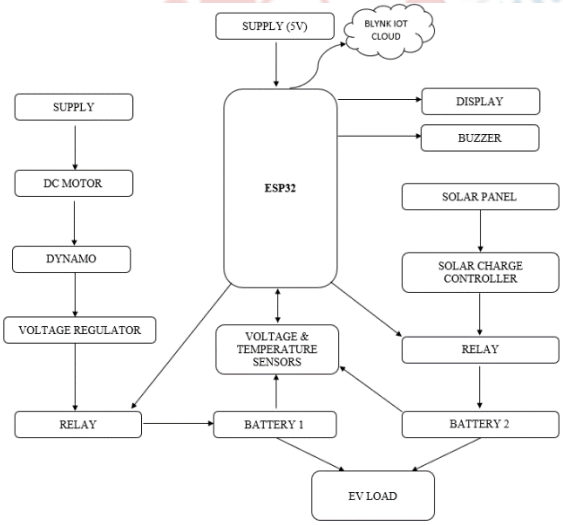


Figure 1. Block Diagram of the proposed system.

The system's architecture is centered around the ESP32 microcontroller, which acts as the central processing unit. It receives power from a 5V supply and connects to the Blynk IoT Cloud for remote monitoring. The ESP32 gathers real-time data from Voltage & Temperature Sensors that monitor the system's power sources and batteries. Based on this sensor data, the ESP32 manages all outputs: it sends operational status and alerts to a Display and a Buzzer, and it controls the Relay modules to manage the flow of power to the batteries.

This design features two independent, self-charging circuits. The first path is a dynamo system, where a DC Motor (driven by the vehicle's motion) turns a Dynamo. The resulting power is conditioned by a Voltage Regulator and fed through a Relay to charge Battery 1. The second path is a solar system, where a Solar Panel captures energy, which is managed by a Solar Charge Controller and sent through another Relay to charge Battery 2. Both batteries are connected to the main EV Load, it can be switched to the desired battery by using a SPDT switch, providing a dual-source, sustainable power solution.

The system's methodology and validation centered on integrating a dual-source, self-charging framework controlled by an ESP32 Dev Kit. The dynamo charging path was successfully validated using a 775 DC dynamo, which generated a stable 11–12V; this was regulated by an LM2596 buck converter and a 3S BMS module to deliver a safe 13.8V to the primary battery. Concurrently, the solar path was verified, demonstrating that the 12V, 10W solar panel, producing up to 17V, could effectively charge a secondary battery via its PWM solar charge controller. These tests confirmed the successful hardware integration of both the regenerative and solar charging pathways.

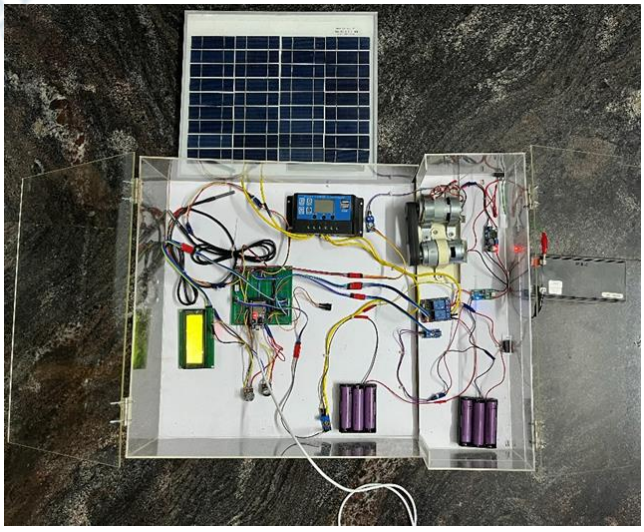


Figure 2. Prototype of the proposed system.

Real-time monitoring, a key objective, was achieved by integrating three REES52 analog voltage sensors to track dynamo, solar, and battery input voltages, alongside two

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DS18B20 temperature sensors for thermal safety. The ESP32 reliably processed this data and transmitted it over Wi-Fi to the Blynk IoT platform. This implementation provided a clear, synchronized user interface on both a 20x4 LCD and a mobile app, successfully validating the system's capacity for remote diagnostics and live monitoring of voltages and temperatures.

Intelligent control logic and safety features were also confirmed. The ESP32 successfully managed 5V 2-channel relay modules, activating charging only when source voltage exceeded 13V and deactivating below 10V to prevent battery damage. Safety protocols were proven effective: a buzzer and "Low Dynamo Voltage" warning were immediately triggered on the LCD and Blynk app when the dynamo's output fell below 7V. This, combined with the 60°C thermal cutoff, demonstrates a robust, automated system that optimizes charging while prioritizing battery health and user safety.

IV. RESULT AND EXPERIMENTATION

A. Hardware Results

Based on the initial testing and component validation, the individual hardware components performed as follows:

1. **Central Controller (ESP32):** The ESP32 successfully integrated with the Arduino IDE. All code compiled, and it was able to accurately read sensor data, control the relays, and transmit real-time data to both the 20x4 LCD display and the Blynk mobile application, confirming a "seamless hardware–software integration".
2. **Dynamo System (775 DC Motor):** When mechanically driven, the dynamo generated a stable output voltage between 11V and 12V. This voltage was successfully regulated by the LM2596 buck converter and stepped up to a 13.8V charging voltage by the 3S BMS module, which then successfully charged the first battery.
3. **Solar System (12V, 10W Panel):** Under sunlight, the solar panel generated an open-circuit voltage of up to 17V. The PWM solar charge controller effectively managed and stabilized this voltage to safely charge the second battery.
4. **Sensors:**
   a. Voltage (REES52): The three analog voltage sensors accurately monitored the dynamo output, solar charging line, and battery input terminals. The readings were correctly converted and displayed, as shown in Figures
   b. Temperature (DS18B20): The two temperature sensors provided accurate digital readings for the dynamo and solar modules, allowing the system to monitor for potential overheating.

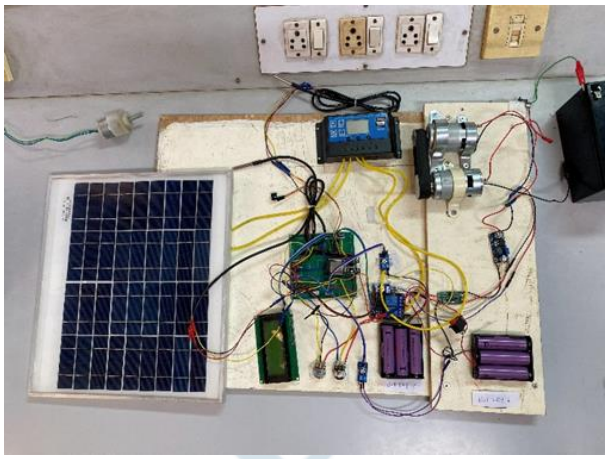


Figure 3. Hardware of the proposed system

B. Experimentation

During the full system experiment, the integrated components were tested for charging control, safety, and real-time monitoring:

1. Charging Control Logic: The 5V 2-channel relay modules functioned correctly. The system was programmed to automatically start charging when the dynamo or solar voltage exceeded 13V and to stop charging if the voltage dropped below 10V to prevent damage. The status of the relays (e.g., "D: Chg" for Dynamo Charging or "S: Full" for Solar Full) was correctly shown on the LCD.
2. Fault Alert Mechanism: The safety system was validated by simulating a low-voltage fault. When the dynamo voltage was dropped below the 7V threshold, the buzzer was immediately "triggered". Simultaneously, a "Low Dynamo Voltage" warning was displayed on the LCD and a push notification was successfully sent to the Blynk app, as seen in Figure 4.
3. Final System Output: The final assembled prototype demonstrated that it could successfully charge itself using both mechanical (dynamo) and renewable (solar) energy sources. When powered on, the LCD and Blynk app both provided a complete, simultaneous display of all critical data: voltages, temperatures, battery status, and fault alerts.

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Figure 4. Low Dynamo Voltage Alert.



Figure 5. Solar Charging Indication.

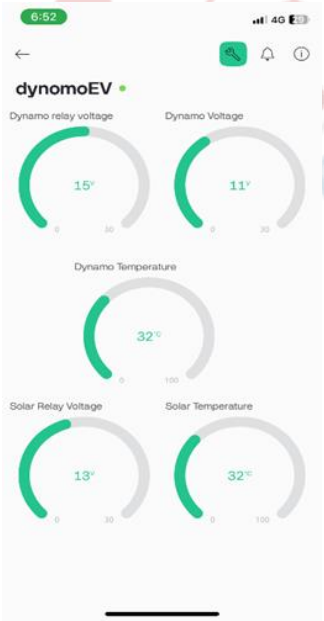


Figure 6. Blynk App Interface.



Figure 7. LCD Display.

C. Comparison of Battery SoC with and without Dynamo Regeneration.

The performance evaluation of the proposed system was conducted by recording the battery State of Charge (SoC) variations under different loading and regenerative conditions. Tables 1 to 4 and Figure 3 to 5 illustrate the comparative behavior of the EV battery with and without the integration of the dynamo-based regenerative system. The data reveal clear distinctions in discharge duration, voltage stability, and energy recovery effectiveness.

Table 1: Battery Discharge Without Dynamo (0.8 A Load)

Serial No.	Time (HH:MM)	EV Load (A)	Battery SoC (%)
1	10:00	0.8 A	100%
2	10:15	0.8 A	89.50%
3	10:30	0.8 A	80%
4	10:45	0.8 A	71%
5	11:00	0.8 A	62%
6	11:15	0.8 A	53%
7	11:30	0.8 A	43.50%
8	11:45	0.8 A	33%
9	12:00	0.8 A	19.50%
10	12:15	0.8 A	4%

As shown in Table 1, when the 3.3 V, 2000 mAh battery was subjected to a constant 0.8 A discharge current without any regenerative input, the SoC dropped from 100% to nearly 0% within approximately 2 hours and 15 minutes. The decline was nearly linear, indicating a direct proportional relationship between load current and energy depletion. This scenario represents a conventional EV discharge profile where no recovery mechanism is active. The absence of regenerative input leads to faster exhaustion, confirming the typical short operational duration of standard battery-only systems.

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Table 2: Battery Discharge Without Dynamo (1A Load).

Serial No.	Time (HH:MM)	EV Load (A)	Battery SoC (%)
1	10:00	1.0 A	100%
2	10:15	1.0 A	88.00%
3	10:30	1.0 A	76.50%
4	10:45	1.0 A	64.00%
5	11:00	1.0 A	51.00%
6	11:15	1.0 A	37.50%
7	11:30	1.0 A	23.00%
8	11:45	1.0 A	7.50%
9	12:00	1.0 A	0%
10	12:15	1.0 A	0%

In Table 2, when the load current was increased to 1.0 A, the SoC depletion became significantly faster, reaching full discharge in about 2 hours. The data show that a higher current draw results in accelerated chemical depletion inside the battery cells, which also causes a mild temperature rise and reduced efficiency. The SoC curve associated with this dataset (illustrated in Figure 3) exhibits a steeper gradient, confirming that discharge time inversely depends on load current magnitude.

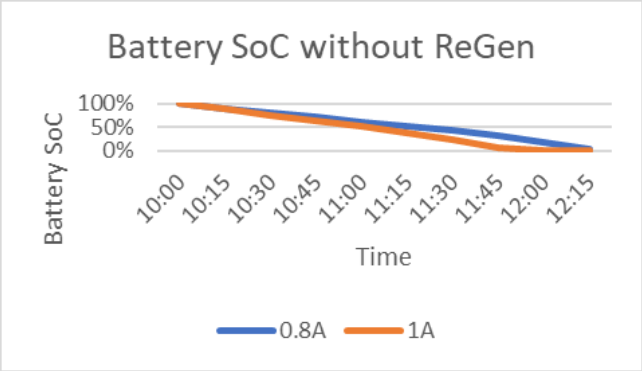


Figure 8. Plot of Battery SoC vs Time (without ReGen)

Figure 8 compares SoC versus time for two non-regenerative cases (0.8 A and 1.0 A loads). The graph shows a steep and nearly linear decline, confirming rapid battery depletion when no regenerative system is present.

In the third scenario, as presented in Table 3, the battery was subjected to a load of 0.8 A while simultaneously receiving a regenerative charge of 0.2 A from the dynamo. This reduced the net discharge current to 0.6 A, effectively extending the discharge period. The SoC decreased much slower, maintaining around 34% even after 2 hours of continuous operation. The recorded SoC curve (depicted in Figure 9) demonstrates a gentler slope compared to the non-regenerative case, indicating improved charge retention due to energy feedback from the dynamo during motion. This proves that regenerative charging effectively compensates for part of the consumed current, thus enhancing total usable time.

Table 3: Battery Discharge with Dynamo Integration (0.8A Load + 0.2A Regeneration)

Serial No.	Time (HH:MM)	EV Load (A)	Regen Charge (A)	Net Current (A)	Battery SoC (%)
1	10:00	0.8 A	0.2 A	0.6 A	100%
2	10:15	0.8 A	0.2 A	0.6 A	92%
3	10:30	0.8 A	0.2 A	0.6 A	84.50%
4	10:45	0.8 A	0.2 A	0.6 A	77%
5	11:00	0.8 A	0.2 A	0.6 A	69.50%
6	11:15	0.8 A	0.2 A	0.6 A	62%
7	11:30	0.8 A	0.2 A	0.6 A	54%
8	11:45	0.8 A	0.2 A	0.6 A	45%
9	12:00	0.8 A	0.2 A	0.6 A	34%
10	12:15	0.8 A	0.2 A	0.6 A	19%

Table 4: Battery Discharge with Dynamo Integration (1.0 A Load + 0.2 A Regeneration)

Serial No.	Time (HH:MM)	EV Load (A)	Regen Charge (A)	Net Current (A)	Battery SoC (%)
1	10:00	1.0 A	0.2 A	0.8 A	100%
2	10:15	1.0 A	0.2 A	0.8 A	89.50%
3	10:30	1.0 A	0.2 A	0.8 A	80%
4	10:45	1.0 A	0.2 A	0.8 A	71%
5	11:00	1.0 A	0.2 A	0.8 A	62%
6	11:15	1.0 A	0.2 A	0.8 A	53%
7	11:30	1.0 A	0.2 A	0.8 A	43.50%
8	11:45	1.0 A	0.2 A	0.8 A	33%
9	12:00	1.0 A	0.2 A	0.8 A	19.50%
10	12:15	1.0 A	0.2 A	0.8 A	4%

Table 4 depicts the discharge performance when the battery experienced a 1.0 A load along with 0.2 A regenerative input. The net effective current was 0.8 A, and the SoC remained at about 19% after 2 hours and 15 minutes of operation. Compared with Table 2, this shows a significant performance improvement, with roughly 25–30% higher residual SoC over the same duration. The regenerative current slowed the discharge rate and stabilized the voltage drop, confirming that even moderate dynamo assistance yields measurable gains in operational efficiency and range extension.

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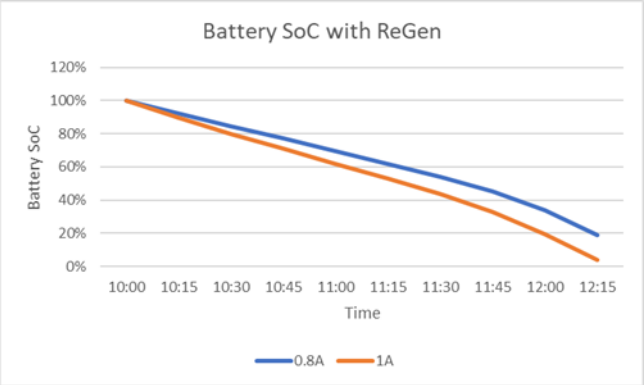


Figure 9. Plot of Battery SoC vs Time (with ReGen)

Figure 9 illustrates the corresponding regenerative cases with dynamo assistance. Here, the SoC curve declines gradually, with a smoother slope and longer time to reach lower SoC levels. This graph clearly demonstrates how the inclusion of dynamo-generated charge extends battery endurance.

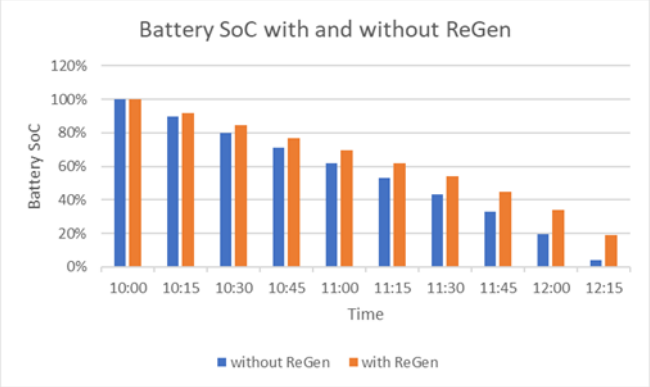


Figure 10. Plot of Battery SoC vs Time (with and without ReGen)

Figure 10 provides a comparative overlay of SoC curves for all four conditions. The two upper curves (dynamo-assisted) remain consistently above their non-regenerative counterparts across the entire time interval, with visible separation after the first 45 minutes. This confirms the efficiency of the regenerative mechanism, showing that the self-charging configuration effectively conserves energy and increases runtime.

In addition to the dynamo-based regeneration, the proposed system incorporates a solar charging setup dedicated to Battery 2, ensuring continuous power availability even when the vehicle is stationary. The solar panel, rated at 12 V and 10 W, delivered up to 17 V under optimal sunlight conditions and was regulated through a PWM solar charge controller. This arrangement maintained stable voltage and prevented overcharging. The solar system acted as a supplementary charging source, particularly effective during daylight parking or low-speed driving conditions when dynamo output was minimal. Over time, the solar contribution ensured that Battery 2 remained at a higher SoC level, typically maintaining 10–15% more charge than Battery 1 during idle periods. This dual-source approach where Battery 1 benefits from dynamo regeneration during motion and Battery 2 gains from solar charging during rest enhances the overall energy sustainability and autonomy of the EV system. The combination minimizes reliance on external grid charging, enabling near-continuous operation and improved energy efficiency.

V. CONCLUSION

The proposed IoT-enabled self-charging EV system demonstrates an efficient and sustainable method to extend EV range by combining dynamo-based regenerative charging during motion with solar charging during idle periods. Experimental results show that regeneration improves battery SoC by 25–30% compared to non-regenerative operation, while the solar subsystem maintains 10–15% higher SoC for the auxiliary battery, reducing dependence on external charging. IoT integration via ESP32 and Blynk enables real-time monitoring of voltage, temperature, and charge status, ensuring safe and efficient power management. Overall, the prototype proves to be a practical, scalable, and eco-friendly solution, offering continuous energy availability and strong potential for application in commercial electric two-wheelers and compact urban vehicles.

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