IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ELECTRICAL VEHICLE CHARGING STATION USING SOLAR PANEL

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Abstract: As electric mobility continues to reshape the transportation landscape; the development of advanced EV charging infrastructure becomes paramount. This project introduces a groundbreaking EV charging station that combines state-of-the-art technologies to revolutionize the electric vehicle charging experience. At its core, the station incorporates high-efficiency solar panels, enabling clean and renewable energy capture, reducing environmental impact, and promoting sustainability.

The integration of an advanced Battery Management System (BMS) ensures the efficient utilization and longevity of lithium-ion batteries, while real-time data analytics and predictive maintenance algorithms, known as aging factor analysis, proactively manage the station's components for optimal reliability. A user-friendly mobile application, featuring unmanned QR code payment functionality, simplifies transactions, enhancing user accessibility and convenience.

This innovative EV charging station not only supports the transition to electric mobility but also sets new standards for sustainability, reliability, and user-centric design. Its seamless fusion of renewable energy, data-driven maintenance, and intuitive payment systems signifies a significant leap forward in the quest for a cleaner and smarter transportation future.

***Keywords* - EV charging infrastructure, Battery Management System (BMS), unmanned QR code payment, as aging factor analysis.**

I. INTRODUCTION

In recent years, the global automotive landscape has undergone a profound transformation, with an increasing shift towards electric vehicles (EVs) as a sustainable and environmentally responsible mode of transportation. This paradigm shift has prompted the need for a robust and forward-thinking charging infrastructure to support the growing EV fleet. Within this context, this project introduces a groundbreaking EV Charging Station, an embodiment of cutting-edge technology and sustainable innovation.

At the heart of this initiative lies the integration of solar power generation, redefining the concept of "green" charging. This solar panel system not only supplies renewable energy to the station but also reduces the burden on the grid, contributing to a cleaner and more sustainable energy ecosystem. Harnessing the power of the sun, this EV Charging Station aims to provide a tangible solution to the energy demands of electric vehicles while simultaneously reducing their carbon footprint.

Complementing the solar panel system is a state-of-the-art Battery Management System (BMS), a critical component that optimizes the utilization of energy and ensures efficient charging. The BMS not only monitors and controls the charging process but also safeguards the longevity of the batteries, making this charging station a testament to sustainability, efficiency, and reliability.

In line with the modern ethos of convenience and digitization, this project introduces an unmanned QR code payment method. This innovative approach eliminates the hassle of traditional payment methods, allowing users to seamlessly initiate and complete the charging process with a simple scan. This not only streamlines the user experience but also reduces operational costs and promotes contactless transactions, which are becoming increasingly important in our fast-paced, digital world.

Moreover, the project incorporates an Aging Factor Analysis, a cutting-edge approach that continually assesses the performance and health of the charging station components. By monitoring and analysing various factors such as battery life, solar panel efficiency, and system wear and tear, this analysis ensures the station's longevity and reliability, guaranteeing its continued operation over the years.

In essence, this project represents a pivotal moment in the evolution of EV charging infrastructure. By seamlessly integrating solar power, advanced battery management, user-friendly payment solutions, and continuous system analysis, it lays the foundation for a future where sustainable transportation and convenience harmoniously coexist. This EV Charging Station is not just a technological marvel; it is a beacon of hope for a greener, smarter, and more accessible future of transportation.

II.FLOW DIAGRAM

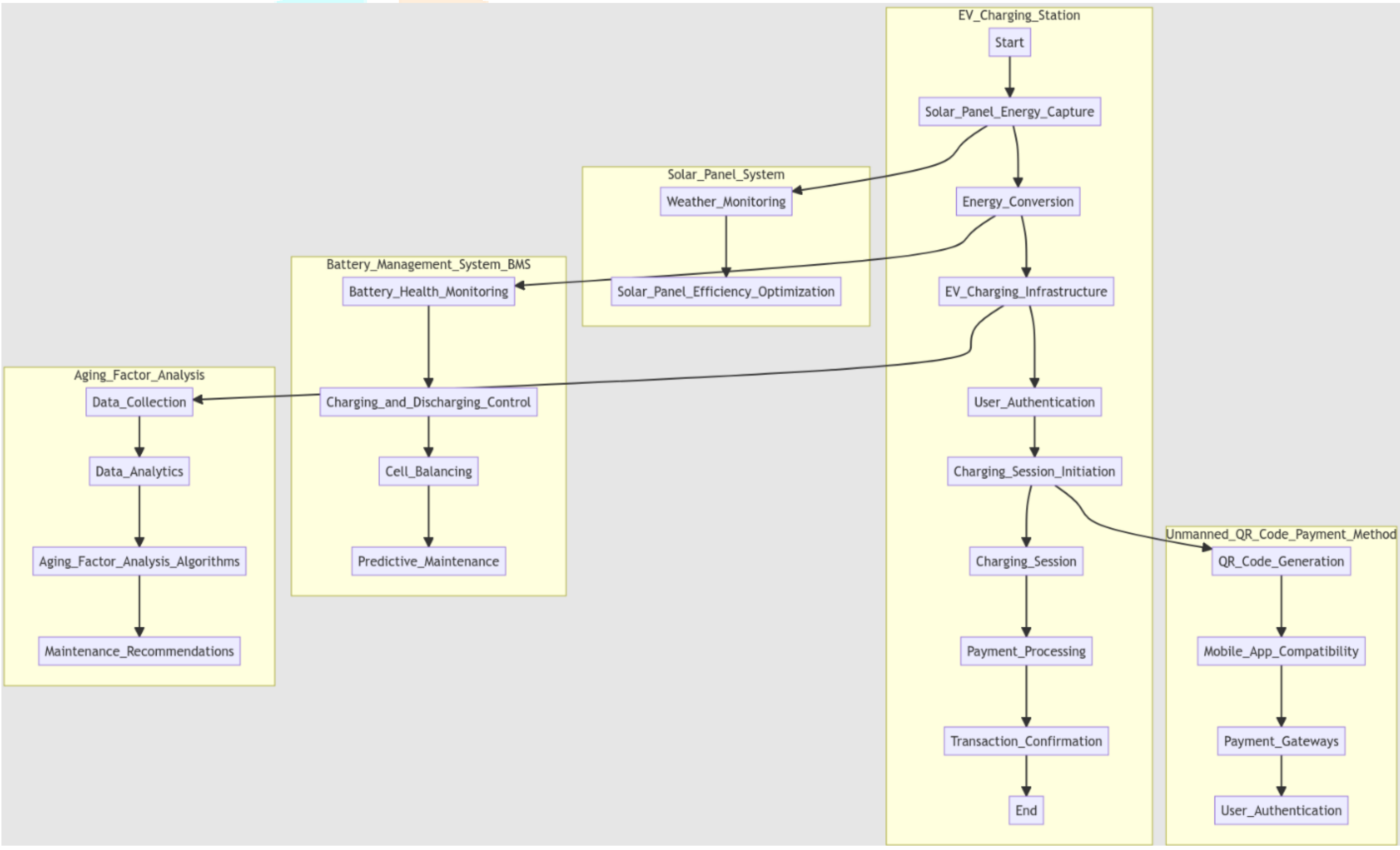

Fig. 1: Flow diagram of the proposed Electrical vehicle charging station

The flow diagram of the Electrical Vehicle (EV) charging station project that integrates a solar panel, battery management system (BMS), unmanned QR code payment method, and aging factor analysis is a visual representation of the key processes and interactions within this innovative project. It illustrates how these integrated components work together to create an efficient, sustainable, and user-friendly electric vehicle charging infrastructure. Here's a brief overview of the flow diagram:

1. **Start**: The flow diagram begins with the "Start" point, indicating the initiation of the charging station process.
2. **Solar Panel Energy Capture**: This step represents the capture of solar energy through high-efficiency solar panels. It showcases the importance of weather monitoring for optimizing solar panel efficiency.
3. **Energy Conversion**: Solar energy captured from the panels undergoes energy conversion, which is a crucial step in transforming solar power into a usable form for charging electric vehicles.
4. **EV Charging Infrastructure**: The diagram depicts the charging infrastructure, indicating the connection of converted energy to the EV charging points.
5. **User Authentication**: To ensure secure access to the charging station, users are required to authenticate themselves before initiating a charging session.
6. **Charging Session Initiation**: Users initiate charging sessions, and this step highlights the connection between the user authentication and the charging process.
7. **Charging Session**: The actual charging of electric vehicles takes place at this stage, emphasizing the core purpose of the charging station.
8. **Payment Processing**: Users can make payments for their charging sessions using the unmanned QR code payment method, as shown in the flow diagram.
9. **Transaction Confirmation**: After successful payment processing, the system confirms the transaction, providing assurance to the user.
10. **End**: The flow diagram concludes with the "End" point, signifying the completion of the charging session and the overall process.
11. **Solar Panel Efficiency Optimization**: In the Solar Panel System subgraph, it's highlighted that weather monitoring data is used to optimize the efficiency of the solar panels, ensuring maximum energy capture.
12. **Battery Health Monitoring**: In the Battery Management System (BMS) subgraph, the system monitors battery health, a critical aspect of efficient EV charging.
13. **Predictive Maintenance**: The Aging Factor Analysis subgraph focuses on data collection, analytics, aging factor analysis, and maintenance recommendations. This emphasizes proactive maintenance to enhance charging station reliability.
14. **Unmanned QR Code Payment Method**: Within the subgraph for the unmanned QR code payment method, the diagram shows the steps of QR code generation, mobile app compatibility, payment gateways, and user authentication for seamless and secure payments.

This flow diagram provides a clear visual representation of the interconnected components and processes that make up the EV charging station project, highlighting the integration of renewable energy, data-driven maintenance, user convenience, and efficient payment methods to create a forward-looking and sustainable charging infrastructure for electric vehicles.

III.PROPOSED METHODOLOGY

PARAMETERS:

Unmanned QR Code Payment Method	
Payment Gateway Integration	Stripe
QR Code Generation Library	QR Code Generator
Mobile App Compatibility	iOS, Android
Payment Currency	USD
QR Code Encryption	AES-256
Transaction Timeout	5 minutes
Aging Factor Analysis	
Data Collection Frequency	Hourly
Aging Factor Calculation	Arrhenius Equation
Threshold for Battery Replacement	80%
Predictive Maintenance Interval	6 months
Data Analytics Platform	Python with Pandas and Scikit-Learn
Charging Infrastructure	
Number of Charging Points	4
Connector Type	CCS (Combined Charging System)
Power Level	DC Fast Charging (50 kW)
User Authentication Method	RFID Cards, Mobile App

Parameter	**Value**
Solar Panel Integration	
Solar Panel Capacity	10 kW
Solar Panel Type	Monocrystalline
Solar Panel Efficiency	18%
Number of Solar Panels	30
Solar Panel Location	Rooftop
Tilt Angle	30 degrees
Battery Management System (BMS)	
Battery Type	Lithium-ion
Battery Capacity	50 kWh
Number of Battery Packs	2
Battery Voltage	400 V
BMS Protocol	CAN bus
Control Algorithm	State of Charge (SOC)

Physical Infrastructure	
Enclosure	Weatherproof
Charging Cables	Type 2
Safety Features	Emergency Stop, Overcurrent Protection
Lighting	LED for Night Visibility
Regulatory Compliance	
Standards	ISO 15118, IEC 61851
Data Privacy Compliance	GDPR (if applicable)
Electrical Codes	Local Regulations
User Interface	
Charging Status Display	LCD Touchscreen
Multilingual Interface	Multilingual
Payment Receipts	Email, Mobile App
Maintenance Plan	
Routine Maintenance Schedule	Monthly
Firmware Updates	Quarterly
Battery Health Checks	Annually
24/7 Monitoring and Support	Available

1. Site Selection and Preparation:
- Identify suitable locations for the EV charging station with easy access to sunlight.
- Prepare the site for the installation of solar panels and charging infrastructure.

2. Solar Panel Installation:
- Install monocrystalline solar panels on rooftops or suitable platforms.
- Optimize panel positioning and tilt angle for maximum energy capture.
- Connect the solar panels to a solar inverter for energy conversion.

3. Battery Management System (BMS):
- Deploy a lithium-ion battery system with a capacity of 50 kWh.
- Monitor the health of the battery packs using BMS sensors.
- Implement a State of Charge (SOC) control algorithm for efficient charging and discharging.

4. Charging Infrastructure:
- Set up DC fast-charging stations with a power output of 50 kW.
- Install CCS (Combined Charging System) connectors for compatibility.
- Implement RFID card and mobile app-based user authentication for charging.

5. Unmanned QR Code Payment Method:
- Integrate a secure payment gateway such as Stripe.
- Develop a QR code generator library for generating unique QR codes.
- Ensure compatibility with iOS and Android mobile apps for payments.
- Implement AES-256 encryption for secure transactions.
- Set a transaction timeout of 5 minutes for payment processing.

6. Aging Factor Analysis:
- Collect data on battery performance at hourly intervals.
- Utilize the Arrhenius Equation to calculate aging factors.
- Set a threshold of 80% for recommending battery replacements.
- Predictive maintenance is scheduled every 6 months.
- Analyse data using Python with Pandas and Scikit-Learn for insights.

7. User Interface and Monitoring:
- Provide an LCD touchscreen display for users to check charging status.
- Create a multilingual interface for user instructions.
- Send payment receipts via email and mobile app notifications.
- Implement 24/7 monitoring and support for users and system health.

8. Regulatory Compliance and Sustainability:
- Ensure compliance with industry standards such as ISO 15118 and IEC 61851.
- Address data privacy requirements, including GDPR if applicable.
- Use recyclable and sustainable materials in construction.
- Offset carbon emissions by purchasing Renewable Energy Credits (RECs).

9. Maintenance Plan:
- Conduct routine maintenance checks on a monthly basis.
- Perform firmware updates quarterly to ensure system security and efficiency.
- Conduct annual battery health checks to assess performance.
- Provide 24/7 support for troubleshooting and emergency response.

10. Environmental Impact:
- Evaluate the environmental impact of the charging station.
- Monitor energy savings and reduced carbon emissions due to solar integration.

This proposed methodology outlines the steps involved in designing, implementing, and maintaining an EV charging station that integrates solar power generation, advanced battery management, secure payment methods, and predictive maintenance through aging factor analysis. It aims to provide sustainable and efficient charging solutions for electric vehicle users while minimizing environmental impact and ensuring regulatory compliance.

IV EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Offline Application

4.1.1 Experiment Setup

To evaluate the power and energy generated by a 10 kWp PV array in the station, an accurate measurement of weather data is required. For this purpose, the meteorological data from that department is used, which has a resolution of 1 min . Global horizontal irradiance (*S*GHI), Diffuse Horizontal Irradiance (*S*DHI), Direct Normal Irradiance (*S*DNI) and ambient temperature (*Ta*) are obtained from the meteorological department for the years 2011–2013. A 10 kWp PV array was modelled in MATLAB using 30 modules of Sun power E20-327 modules rated at 327 W , whose specifications are shown in Table 1.

Quantity	Value
Area of module (*A*pv)	1.63 m2
Nominal power (*Pr*)	327 W
Avg. panel efficiency (η)	20.4%
Rated voltage (*V*mpp)	54.7 V

Rated current (*I*mpp)	5.98 A
Open-circuit voltage (*V*oc)	64.9 V
Short-circuit current (*I*sc)	6.46 A
Nominal operating cell temperature (*T*NOCT)	45 °C ± 2 °C
Power temp coefficient (λ)	−0.38%/°C

To estimate the solar irradiance on a module (*Sm*) with a specific azimuth (*Am*) and tilt angle (θm) as shown in above table, an estimation of the position of the sun throughout the year is required. A solar position calculator is hence built using by which the azimuth (*As*) and altitude (*as*) of the sun throughout the year at the location of the station observatory can be determined. With the sun's position, the irradiance on a panel with specific orientation (*Am*, θm) can be estimated using the geometric models in and the Isotropic sky diffused model where *S*DNI*m*, *S*DHI*m* are the components of DNI and DHI which is incident on the panel:

$$S_m^{\mathrm{DNI}} = S^{\mathrm{DNI}}(\sin\theta_m \cos a_s \cos(A_m - A_s) + \cos\theta_m \sin a_s)$$

$$S_m^{\mathrm{DHI}} = S^{\mathrm{DHI}}\frac{1+\cos\theta_m}{2}$$

$$S_m = S_m^{\mathrm{DHI}} + S_m^{\mathrm{DNI}}$$

4.1.2. Experimentation Findings

SOCestimate(t0) further indicates the value of the SOC estimated at the moment t0. This estimate is calculated using the initial state of charge value SOCinit and the energy meter data, which are measured every dt equal to 2 minutes. It is the shortest amount of time required by many charging stations to access data without experiencing any synchronization or timestamp issues. The energy meters' readings at the time t0 under consideration, denoted Ew(t0), and Q dt minutes before to, denoted Ew(tQ), are used to estimate the power withdrawn by the car Pw(t0). The following formula is used to calculate the power Pw(t0):

$$P_w(t_0) = \frac{E_w(t_0) - E_w(t_{-Q})}{Q \times dt}$$

Q is a parameter chosen equal to 3 to obtain an accurate value of the power as quickly as possible (i.e., every 6 min). We consider that if the car does not withdraw energy during the six minutes before t0, the measured withdrawn power Pw(t0) is equal to zero. This phenomenon occurs because the car battery is fully charged, and then the SOCestimate is equal to 100%.

If Pw(t0) is not equal to zero, we compute SOCtemporary(t0) according to Equation (3). In this equation, we consider tinit being the time at the start of the charging process, and Y being the yield of the charging process (supposed to be equal to 95%).

$$SOC_{temporary}(t_0) = SOC_{init} + Y \times 100 \times \frac{E_w(t_0) - E_w(t_{init})}{E_{Max}}$$

If the car continues to charge (i.e., Pw(t0) > 0) while SOCtemporary(t0) equals a threshold value (usually 99%), we believe that SOC temporary's value is overstated in comparison to the true SOC. Without knowing anything else about the actual SOC, we assume that SOCestimate is still equal to the threshold value. In other situations, we assume that SOCestimate and SOCtemporary are equivalent.

Online Application

4.1.1 Experiment Setup

This experimental setup allows for the deployment and continuous improvement of the DRL-based EMS in real-world HEVs. It ensures that the EMS controller remains adaptive and effective in various driving scenarios, ultimately optimizing fuel efficiency and emissions reduction over time**.**

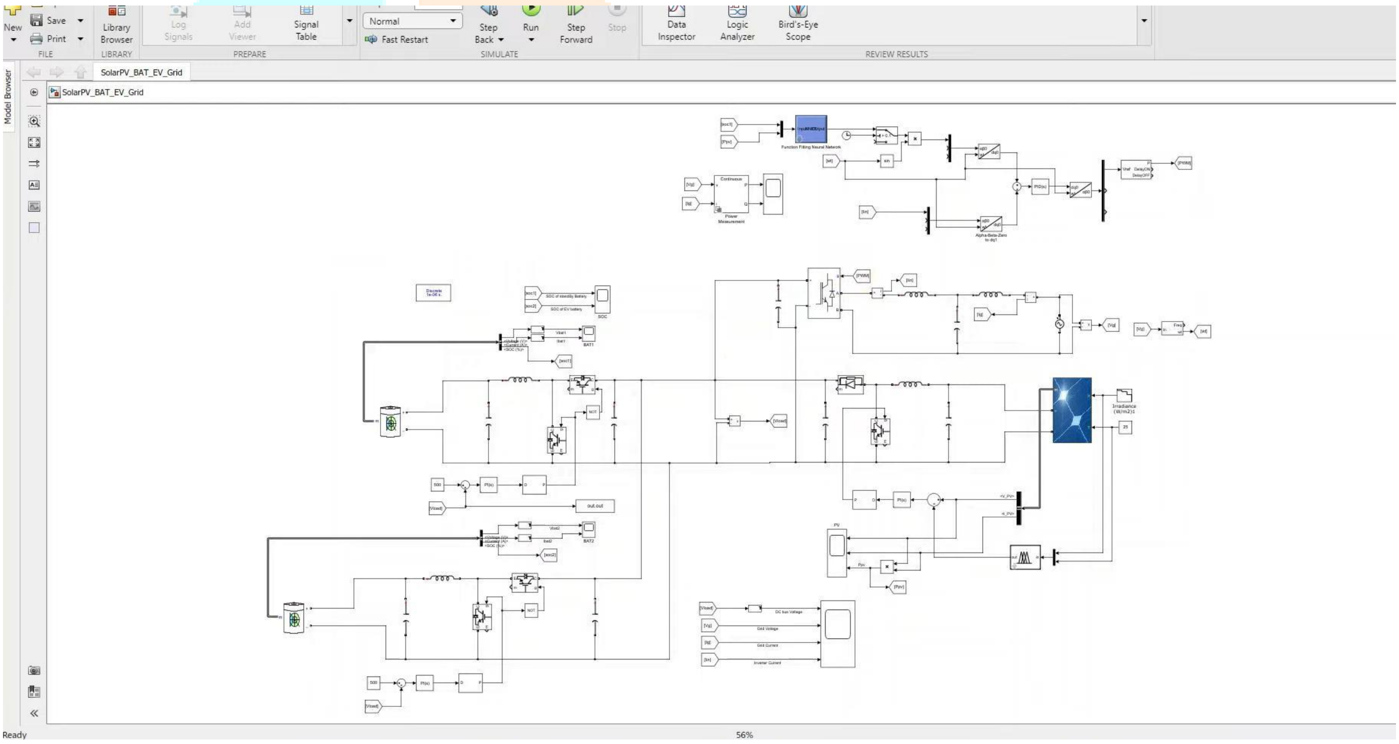

Figure 7. Simulation in the matlab software

4.2.2 Experimental Results

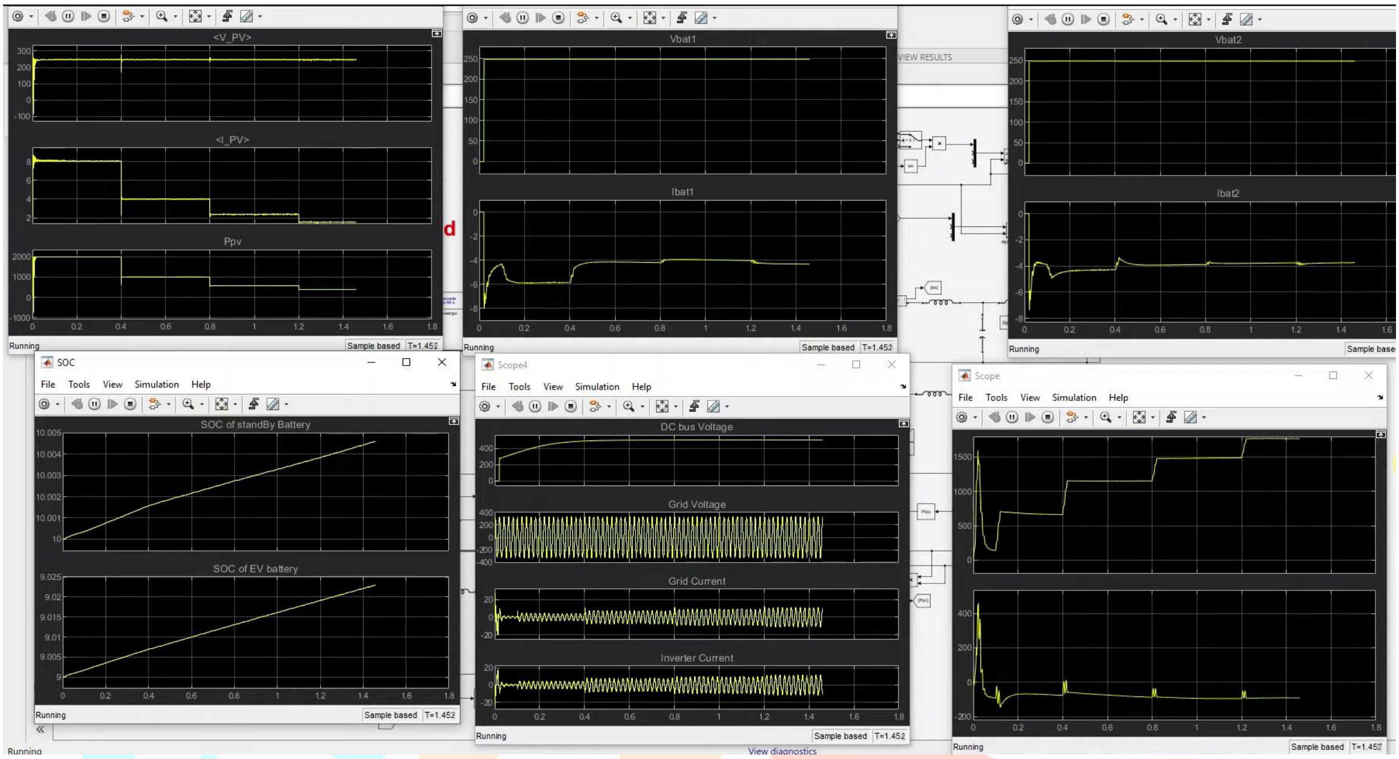

Figure 8. Simulation results of the model design in matlab

IV. CONCLUSION

The varieties of EVs, the technology employed, the benefits compared to internal combustion engine vehicles, the evolution of sales over the past few years, as well as various charging methods and potential future technologies, were all examined in this article. We also discussed the main research obstacles and untapped potential.

Batteries for EVs are important since they determine the autonomy of the vehicle. In light of these characteristics, we looked at a variety of battery types. We also discussed potential technologies for usage in the future, including graphene, which is anticipated to be a tool for storing greater amounts of power and enabling faster charging.

With this kind of technology, the EV might also get greater range, which might encourage drivers and users to adopt it.

Higher capacity batteries will encourage the usage of the quickest, most powerful charging methods as well as more advanced wireless charging techniques. Another factor that can help with the spread of electric vehicles is the development of a special connector that can be used everywhere. Future Smart Cities will have a significant impact on the EV industry, so it will be especially crucial to have flexible charging techniques that can respond to consumer needs. Future BMS should therefore take into account the new scenarios brought about by new batteries and the demands of Smart Cities.

Future works to be implemented

The future work of this study includes:

- Electric car popularity is influenced by a number of factors, including cost, range, and recharge time. For these things to matter, EV charging stations must be accessible. Below, we list some of the challenges and suggestions related to EV charging.
- Testing the three features with some other features to be combined in real world.

- It is currently popular to use interchangeable batteries, and such a station might be created. Additionally, depending on the environment, the system can be integrated with additional renewable energy sources and chargers that can accommodate different vehicle types.

V. ACKNOWLEDGEMENT

This is a great pleasure and immense satisfaction to express my deepest sense of gratitude and thanks to everyone who has directly or indirectly helped me in completing our paper work successfully. We express my gratitude towards my team and encouraged me in completing the work in scheduled time.We would like to express our sincere gratitude to our supervisor, Professors, for their valuable guidance and support throughout the research process. Their expertise and insights were invaluable in shaping our research and helping us to overcome challenges.

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