Novel Hybrid Optimization for MPPT-Based EV Charging Using Cat-Mouse and Honey Badger Algorithms

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KEYWORDS

MPPT,Battery Storage Systems (BSS),EVs,PV, Wind,Cat-Mouse and Honey Badger Algorithm

ABSTRACT

Abstract: To mitigate carbon emissions and curb the greenhouse gas effect, many countries are transitioning toward renewable energy-based power generation while simultaneously replacing conventional transportation with hybrid and electric vehicles. Given the critical need for efficient charging solutions for electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs), this research explores the growing demand on the traditional power grid, which results in increased costs and operational stress. To address these challenges, the integration of local renewable energy sources, such as solar photovoltaic (PV) and wind energy, into the grid is proposed. However, due to the inherent intermittency of PV power generation, battery storage systems (BSS) are necessary to enhance grid stability.

This paper presents a hybrid charging station concept that integrates solar and wind energy with the grid, ensuring efficient and safe charging for various EV scenarios. The proposed system incorporates on-site PV power generation, utilizing BSS to manage load fluctuations and reduce grid dependency. Additionally, the use of interleaved buck-boost converters within the BSS enhances power conversion efficiency. A battery charging model for solar PV-based systems is developed, featuring a Maximum Power Point Tracking (MPPT) mechanism implemented through a buck-boost converter to optimize efficiency. To further enhance MPPT performance, a novel hybrid optimization algorithm combining the Cat-Mouse and Honey Badger algorithms is introduced. The proposed approach ensures improved efficiency and stability throughout the charging process. Simulation results validate the effectiveness of the hybrid MPPT algorithm, achieving an efficiency rate of 99.99%, thereby optimizing battery charging while minimizing energy losses.

I. INTRODUCTION

Traditional energy costs have recently risen dramatically due to environmental deterioration, climate change, and a scarcity of fossil fuels. It is critical that fresh and clean energy be used globally. Everyone in the world is paying more and more attention to plug-in electric vehicles (PEVs) and electric cars (EVs) [1-3]. Most of the time, this is because they are typical of new energy cars. Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) have many advantages. These include lowering costs, stabilizing peak power, and moving peak load. When charging from the grid to the vehicle (G2V), both plug-in electric vehicles and battery electric vehicles (BEVs) can act as loads. When discharging from the vehicle to the grid (V2G), they can act as generators [4-6]. Broadly speaking, "V2G" can be used for both V2G and G2V uses. A one-way power converter is usually used for G2V, which covers both regular charging systems and fast charging systems. Standard electric cars use twice as much power as the average home, so charging them quickly will put a strain on the grid [7]. Should the G2V charger not perform cutting-edge conversion, it could cause grid problems like unwanted peak loads, harmonics, and a low power factor [8-10]. It is required for the V2G system to allow energy to be put back into the grid. Because it allows continuous input current and two-way power flow, a grid-connected AC/DC converter is an important part of the V2G system. There are three main areas of study that bidirectional AC/DC converters meant for V2G applications need to focus on: increasing power density, lowering ripple in the input and output current, and providing reactive power compensation options [11–13].In recent years, various AC/DC converter topologies have been utilized in the V2G system. These include single-stage single-phase and three-phase, two-stage single-phase and three-phase, ZVS inverter, and many more [14-16].

A single-phase interleaved AC/DC boost converter was used in reference [17] to power an electrical vehicle charger. Proposes a high-performance single-phase bridgeless interleaved PFC converter both [18-19] perform the same job of reducing battery charge and discharge current ripple, but none can work with a wide output voltage. The passage discusses the challenges associated with global greenhouse gas (GHG) emissions, emphasizing the human contribution to climate change. It cites the Fourth Assessment Report of the International Panel on Climate Change (IPCC), which highlights a 70% increase in GHG emissions between 1970 and 2004. Recognizing the urgent need for emission reduction, global efforts, such as the Copenhagen Accord, commit developed countries to mitigating emissions by 2020 [20-24]. The U.S., for instance, pledges a 17% reduction from 2005 levels. The text emphasizes the role of renewable energy in emission reduction but acknowledges economic constraints. It cites cost disparities, with solar and offshore wind being more expensive than conventional coal and natural gas [25-28]. Energy storage is proposed as a solution to enhance renewable energy utilization, but the high costs of storage systems, such as Lead-Acid batteries, pose challenges. This part also talks about earlier study that shows how distributed generation can save money and how it might cut down on the need for peaking power plants, which is another benefit. It suggests that the economic viability of renewable energy and storage technologies.

The paper makes a significant contribution by addressing the growing global concerns related to rising energy costs, environmental degradation, and the increasing demand for clean energy. Focusing on plug-in electric vehicles (PEVs) and electric cars (EVs), the paper explores the advantages of electric vehicles, such as cost reduction, peak power stabilization, and the potential for bidirectional energy flow between the vehicle and the grid (V2G). Emphasizing the importance of effective power conversion in grid-to-vehicle (G2V) charging and V2G applications, the paper discusses challenges associated with grid strain, harmonics, and low power factor. It then introduces various AC/DC converter topologies for V2G systems, highlighting the need for increased power density, reduced current ripple, and reactive power compensation. The paper's key contribution lies in proposing EV charging algorithms through hybrid optimization, offering a cost-effective solution to enhance the economic viability of renewable energy and storage technologies, ultimately contributing to the reduction of greenhouse gas emissions in the electricity generation sector.

II. RELATED WORK

Jingang Han et.al. 2020 [29] around the world, it is common for smart grid technologies and electric vehicles (EVs) to work together. The Vehicle-to-Grid (V2G) idea gets the most attention. Bidirectional grid-connected AC/DC converters are very important in V2G systems. Electric cars (EVs) and the grid can both get power from these converters, and the power quality standards are met at the same time. This article shows a three-phase AC/DC converter that is linked to the grid and can work in both directions. It was specially made for V2G systems. The converter can make up for reactive power, allow power to move in both directions, and smooth out power grid fluctuations. There is a sketch of how V2G devices are put together and a well-known mathematical model of an AC/DC converter. AC/DC converters that can work in both directions use a grid voltage feed forward decoupling device. Along with the controller design, an analysis of the Proportional-Integral (PI) control method is also given. In this project, a base for lab experiments is set up for the V2G bidirectional grid-connected converter. It is MATLAB/Simulink that is used to make the model for the system modelling. Both the simulation and the experiment gave us information about how well the model works and how well the control method works.

Ata Raziei1 et.al. 2014 [30] the goal of this study is to look into what would happen if solar power output and battery energy storage were combined. The goal is to lower the real-time cost of energy for residential customers. A linear optimization approach is used as part of a two-step process in the study. In the first step, the best mix of grid power, solar power, and battery power is found to meet load needs for a whole year. This is done by taking into account the size of the solar array and the amount of power that the batteries can hold. The second step is to look at the different combos of solar panels and battery capacities to find out how much each one will cost in capital. In the setting of real-time price information, the results show the most cost-effective way to get electricity to customers. It's interesting to know that the best system doesn't have any batteries because battery technology isn't very good yet, and solar alone can meet 29% of demand. That being said, the study suggests that if battery technology keeps getting better, the share of demand that can be met cheaply by solar power could rise to 39%. This is an example of how important it is to keep an eye on changes in battery technology to make using solar energy in homes less expensive.

The first study by Bo Al-Sahlawi et al. (2024) [31] introduces a novel methodological framework for optimizing the planning and design of electric vehicle (EV) charging stations with renewable energy resources. It considers the strategic self-interested nature of EV users in a fully liberalized market environment. The bilevel programming model with equilibrium constraints captures the interplay between the charging station owner's profit maximization and EV users' strategic charging decisions. The proposed methodology is demonstrated through case studies, showcasing its effectiveness in enhancing renewable energy utilization and overall system efficiency.

The second study by Ashish Kumar Karmaker et al. (2023) [32] focuses on an energy management algorithm for a hybrid solar and biogas-based electric vehicle charging station. This algorithm, designed for a 20-kW EV charging station, utilizes a fuzzy inference system to optimize real-time charging costs and renewable energy utilization. Simulation results indicate a significant reduction in energy costs compared to existing flat rate tariffs, highlighting the algorithm's potential for cost savings and environmental benefits.

In the third study by Dongxiang Yan et al. (2022)[33], a distributed online algorithm is proposed to promote energy sharing between EV charging stations, addressing the supply-demand mismatch caused by fluctuating renewable generation and unpredictable charging demands. The algorithm, based on the Lyapunov optimization framework, operates in a prediction-free manner and offers privacy protection while being suitable for online implementation. Theoretical bounds for the optimality gap between offline and online optimization are provided, demonstrating the effectiveness of the proposed method in reducing operating costs.

The fourth study by Alper Çiçek et al. (2022) [34] introduces a novel concept for integrating rail-based public transportation systems with EV parking lots using a "park and ride" strategy. The study includes the design of a photovoltaic-based carport for renewable energy production and develops an optimal energy management system. The proposed approach considers existing unused energy infrastructure capacity, regenerative braking energy from the railway system, and uncertainties related to EV demand. Case studies validate the efficacy of the proposed concept in effectively managing diverse energy inputs.

The fifth study by Tayenne Dias de Lima et al. (2023)[35] addresses the challenges of integrating distributed energy resources (DERs) in electrical distribution systems (EDS) for EV charging. A novel model for multi-period planning of EDS and DERs, considering conditional value at risk (CVaR) to manage uncertainties in generation cost and carbon emissions, is proposed. The model aims to minimize the net present cost related to investment, operation, and risk, offering a flexible tool for different purposes such as carbon taxes and budget limits.

The sixth study by Suyang Zhou et al. (2020)[36] proposes a pricing methodology for EV charging facilities, taking into account the charging facility service ratio, traffic flow, and renewable energy generation. The methodology aims to maximize the consumption of renewable energy and reduce traffic jams. Simulation results based on a road network test bed demonstrate the potential of the pricing methodology to significantly increase the consumption rate of renewable energy at charging stations.

The seventh study by Barman. P et al. (2023)[37] presents a charging infrastructure for electric vehicles using a common DC bus charging mechanism based on hybrid renewable energy sources, such as solar photovoltaic and fuel cell. The study highlights the bidirectional flow of power, enabling charging/discharging during grid presence/absence modes. The proposed system achieves satisfactory operation during grid availability/unavailability through current and voltage-based control mechanisms, improving power quality.

The ninth study by Fareed Ahmad et al. (2023) [38] focuses on the optimal location and capacity planning of charging stations, considering the integration of renewable energy sources and energy management strategies. The study utilizes Monte Carlo Simulation to address uncertainties related to PEV charging demand and PV power generation. Energy management strategies, including battery storage and vehicle-to-grid (V2G), are applied to improve grid reliability and reduce peak power demand.

The tenth study by M. Chapana et al. (2023) [39] proposes a mathematical formulation for optimal operation scheduling of a remote photovoltaic farm and distributed electric vehicle charging stations. The model maximizes the profit of the private investor by coordinating EV charging and pricing mechanisms. The inclusion of a remote PV farm and considerations for ancillary services and risk management make the proposed model comprehensive and applicable to real-world scenarios.

III. PROBLEM FORMULATION AND SOLUTIONS

A. Problem Formulation:

The paper addresses several critical issues in the realm of electric vehicles (EVs) and renewable energy integration into the grid. Key problem areas include the management of EV charging loads, the cost of EV batteries, thermal stability concerns, grid stability, and the need for effective demand-side management. These challenges are pivotal for the widespread adoption of electric vehicles and the efficient utilization of renewable energy sources in the context of a micro grid (MG).

B. Proposed Model and Solution:

The proposed model employs a comprehensive approach to tackle the identified issues. A buck-boost converter and a solar screen are integrated into the system to optimize power extraction from the photovoltaic (PV) panel for efficient battery charging. To enhance the charging process, a hybrid cat-mouse and honey badger algorithm is employed, utilizing an isolated buck converter and a proportional integral derivative (PID) controller to regulate the current flow to the battery.

The circuit diagram in Figure 1 illustrates the configuration, showcasing the integration of components for effective power management. The maximum power point tracking (MPPT) method is implemented to ensure optimal power levels are obtained from the PV panel. A novel hybrid method, named the hybrid cat-mouse and honey badger algorithm, is introduced to enhance the MPPT process, contributing to improved energy extraction efficiency.

Furthermore, a fractional-order proportional integral derivative (FOPID) controller is utilized to manage both the battery system and the isolated buck converter, enhancing control precision. The overarching goal is to minimize the total cost of energy, and as part of the optimization process, a focus is placed on the power grid. The study incorporates the concept of a micro grid (MG), consisting of distributed renewable energy resources (DERs) operating at low power levels.

The research also explores strategies for effective management of an MG's energy, considering various constraints. Specifically, the study delves into planning the generation of DERs at specific times or intervals to reduce fuel costs, manage peak loads, and mitigate petrol emissions. The inclusion of energy storage capabilities in the MG version's battery further enhances the flexibility and resilience of the proposed solution. Overall, the project presents an integrated model addressing EV-related challenges and contributing to the efficient operation of micro grids with a focus on cost optimization and sustainability.

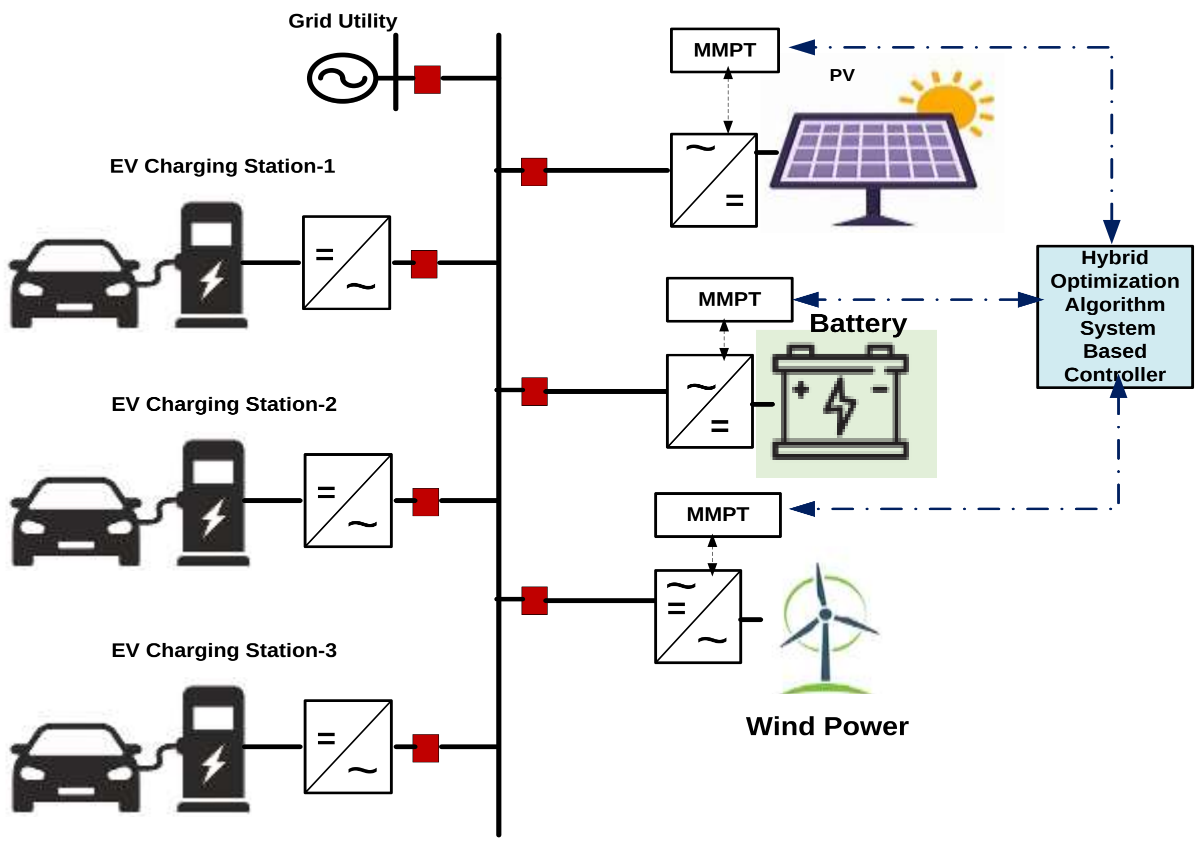

Fig.1 Proposed flow diagram.

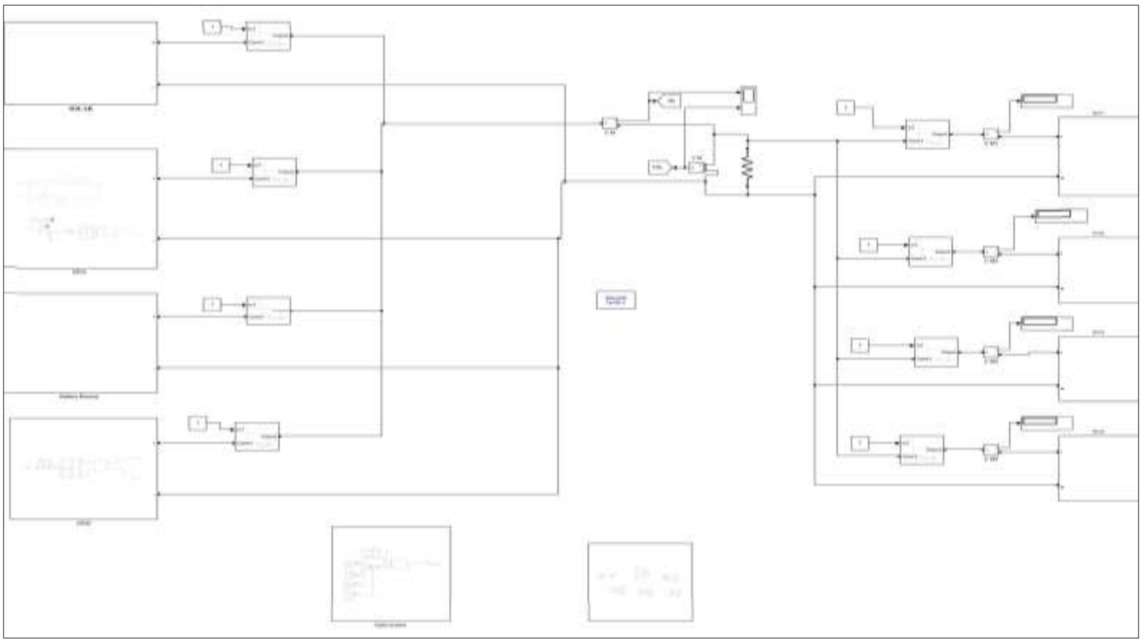

Fig.2 MATLAB Simulink model

In this integrated renewable energy system simulation, solar power and wind turbine energy sources are harnessed with Maximum Power Point Tracking (MPPT) algorithms to optimize their efficiency [20-21]. A boost converter is employed to enhance the voltage output from the solar panels. The energy generated is then fed into a bidirectional converter, allowing for a seamless connection to the grid and enabling energy flow both ways. A battery storage system is integrated to store excess energy for later use or discharge during high demand periods. The simulation incorporates Pulse Width Modulation (PWM) switching for precise control of the bidirectional converter. The system's overall performance and reliability are enhanced through the implementation of the cat and mouse and honey badger optimization algorithms. This comprehensive simulation is conducted using MATLAB, providing a holistic analysis of renewable energy generation, storage, and bidirectional power flow, emphasizing the importance of advanced control strategies for efficient and sustainable energy utilization.

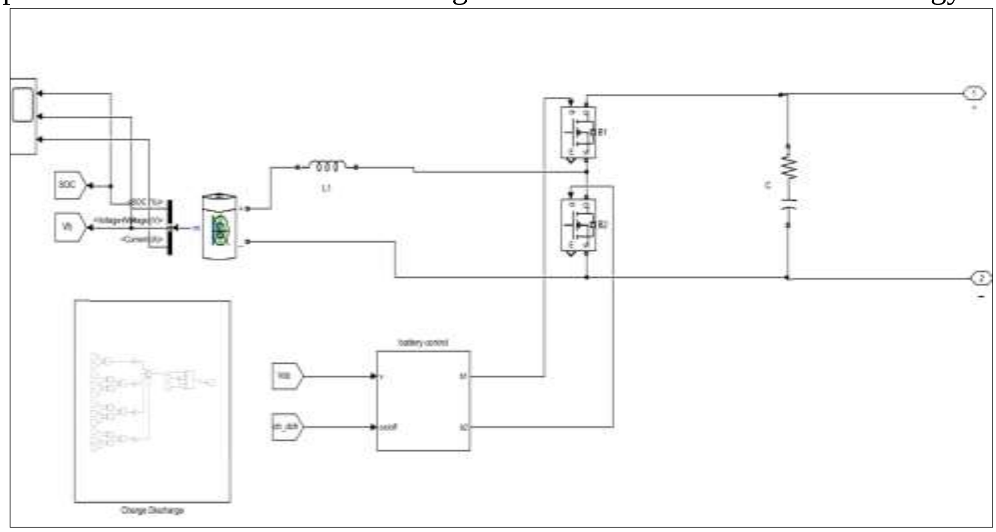

Fig.3 Battery subsystem

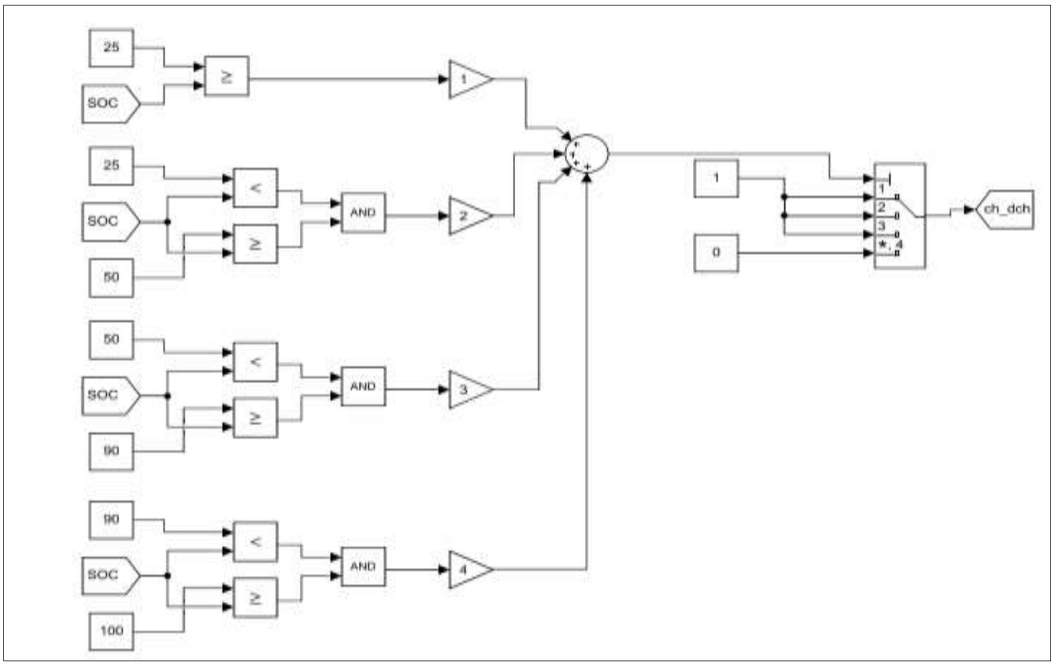

Fig.4SOC control circuit

There are four cases has been considered and discussed such as

- If soc less than 25, it will charge
- If soc between 25 to 50, it will charge
- If soc between 50 to 90, it will charge
- If soc between 90to 100, it will charge

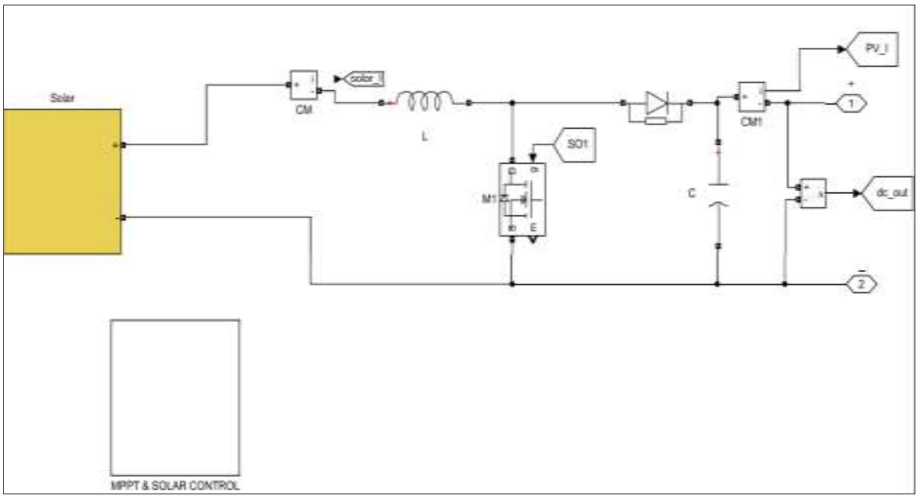

Fig.5 Solar Subsystem

An exponential diode, a parallel resistor Rp, and a resistance Rs are linked in series with each other to make a model that can be used to investigate how well a solar cell works. The output current (I) is determined by factors such as the solar current (hIph), diode saturation currents (Is and2Is2), heat voltage (Vt), and quality factors (N and 2N2). The mathematical expression for I includes terms related to the diode characteristics and the parallel resistor. The model allows for the representation of how the solar cell responds to light intensity (Ir), measured in W/m², and computes the solar-generated current (h0Iph0) based on the input light intensity. The use of a mask is mentioned, likely for simplifying the model description, and a quality factor specific to amorphous cells is introduced [22-26]. This model provides insights into the intricate factors influencing the solar cell's output current, offering a tool for understanding and analyzing the performance of such cells under varying conditions.

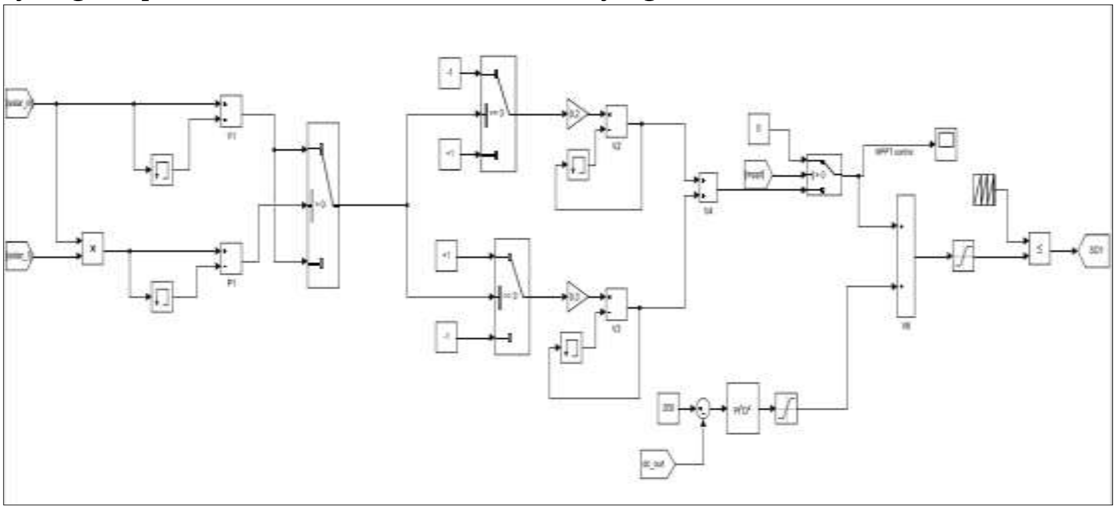

Fig. 6 MPPT Control

The MPP algorithm is an indefinite process that matches the impedance of a solar PV system with the load side's impedance, adjusting the duty cycle accordingly. Measurements and calculations are made to control actions, ensuring the maximum power point is reached for the current environmental conditions.

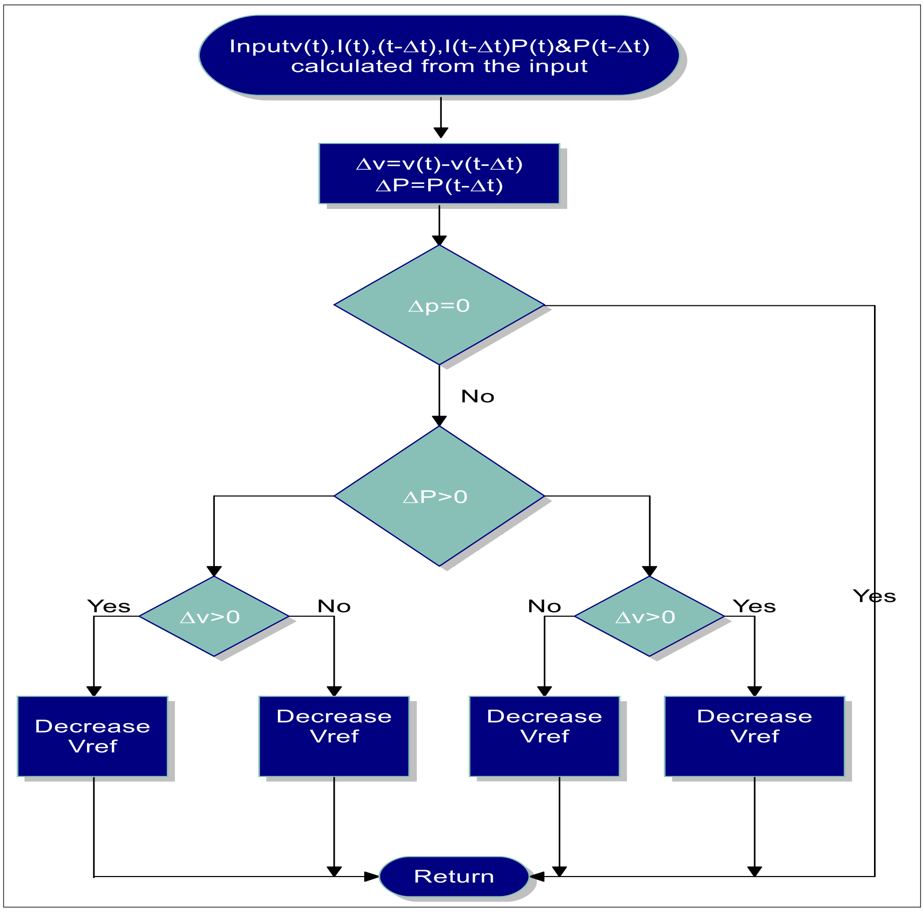

Fig. 7: The Flowchart of the P&O Algorithm

The steps of the algorithm are detailed below.

Proposed Algorithmic implementation steps:	
Step 1:	Take two readings at regular intervals to get an accurate picture of the voltages and currents produced by the PV system
Step 2:	Perform the calculations to determine the powers P(n) and P(n-1).
Step 3:	In the event that the abilities are growing, the duty cycle should be lowered.
Step 4:	If the powers are going down, then you should up the duty cycle.
Step 5	Go to step 1.

Wind Turbine-

There is a machine called a wind turbine that uses the motion of the wind to make electricity. Another type of clean energy is wind machines. Comprising rotor blades attached to a central rotor hub, the turbine captures wind energy as the blades rotate around a horizontal or vertical axis. This rotational movement is transmitted through a main shaft to a generator housed within a nacelle, where mechanical energy is transformed into electricity. Positioned atop a tower to access higher wind speeds, the turbine's control system, equipped with anemometers and wind vanes, optimizes blade orientation for maximum energy capture. As a key component in wind power systems, wind turbines contribute significantly to sustainable energy production, particularly in wind farms where multiple turbines work in concert to generate clean and efficient electricity.

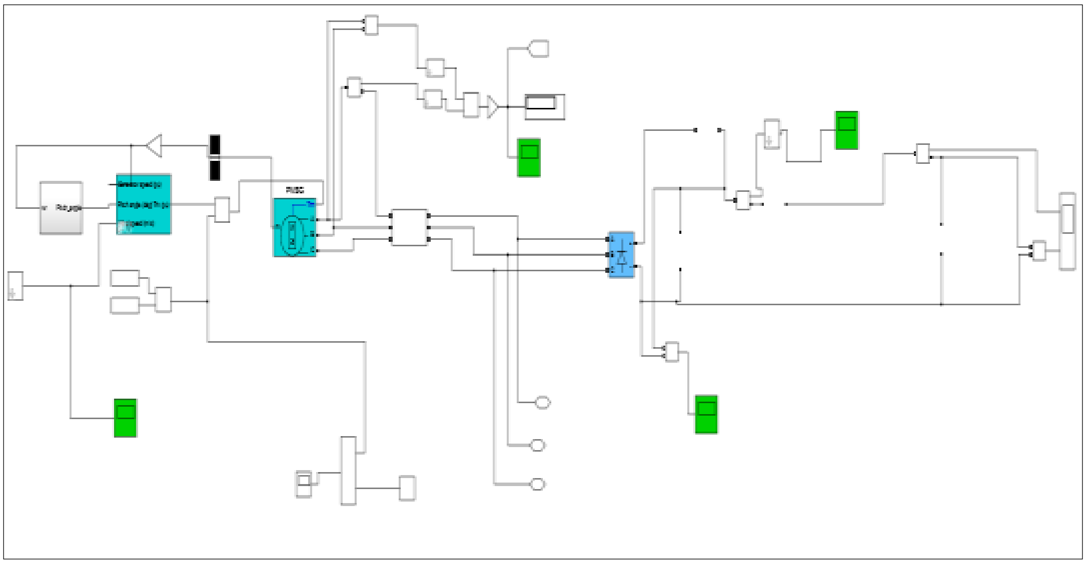

Fig. 8 Wind Turbine Model

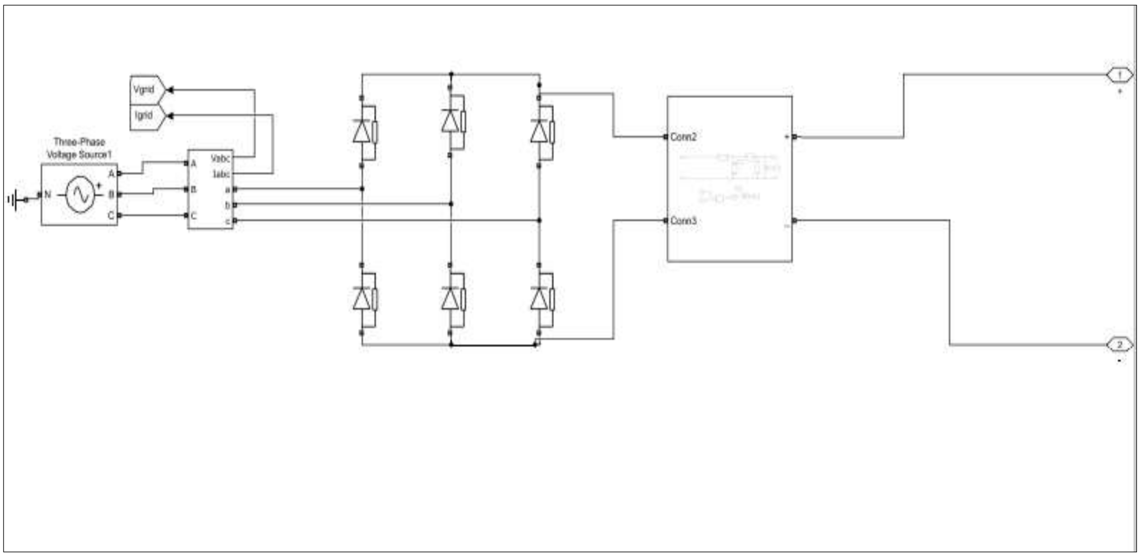

Fig.9 Grid System

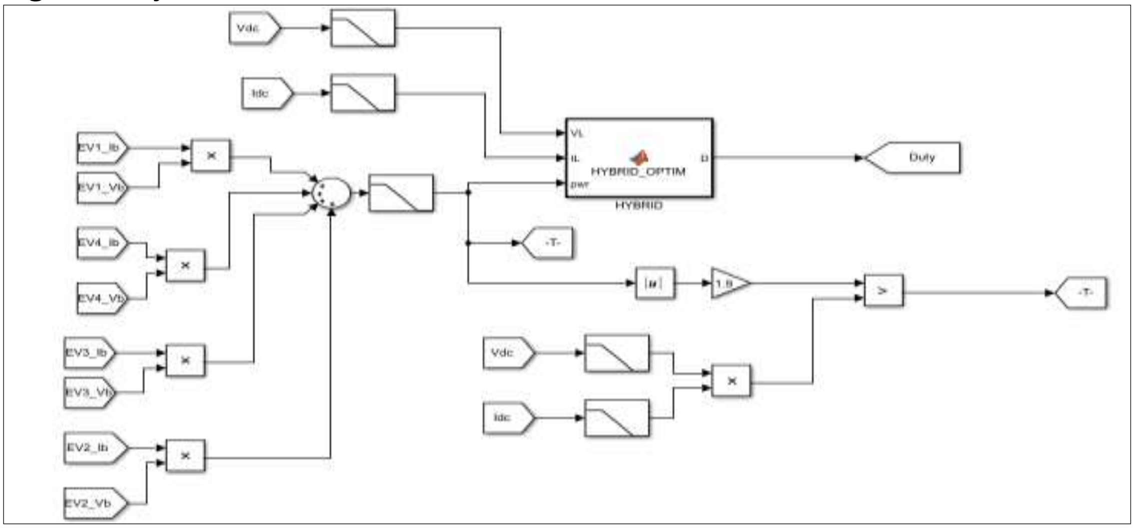

Fig.10 Hybrid optimization

All four EV stations connect with the HBA algorithm, after optimization power from algorithm duty cycle output of HBA given to the battery control of all EV station battery control.

IV. IMPLEMENTATION OF PROPOSED METHODOLOGY

The proposed methodology combines the strengths of the Honey Badger Algorithm (HBA) and Cat Mouse Optimization (CMO) to optimize the deployment of renewable energy resources in Electric Vehicle (EV) charging stations. The algorithm begins with the initialization of parameters, including duty cycles, velocities, and historical performance metrics. The objective function is designed to balance the power generated by renewable sources with the power consumed by EV stations, and it continuously evaluates and updates the optimal duty cycles to achieve this balance. The hybrid nature of the algorithm involves a switching phase where it alternates between updating duty cycles based on velocity information and evaluating the objective function to ensure a comprehensive optimization strategy.

During the optimization process, the algorithm leverages the HBA to dynamically explore the solution space and identify potential improvements to the duty cycles. Additionally, the Cat Mouse Optimization component introduces further diversity by exploring alternative solutions [27-30]. The velocities and duty cycles are continuously updated based on the best-performing positions and historical information, ensuring adaptability and responsiveness to changing conditions. This hybrid approach enhances the algorithm's ability to converge towards optimal solutions while maintaining diversity in the search space. The final result is a set of optimized duty cycles that maximize the utilization of renewable energy sources in EV charging stations, contributing to sustainable and efficient energy practices.

A. Optimization Techniques

a. Honey Bee Algorithm (HBA):

The HBA is a nature-inspired optimization algorithm based on the foraging behavior of honeybees. The algorithm involves the following key elements:

- **Employed Bees:** Employed bees explore the solution space and share information about food sources with other employed bees.
- **Onlooker Bees:** Onlooker bees select food sources based on the information provided by employed bees.
- **Scout Bees:** Scout bees explore new food sources to discover potentially better solutions.

b. Cat Mouse Optimization Algorithm

The Cat Mouse Optimization Algorithm is another nature-inspired algorithm that simulates the hunting behavior of a cat and the evasive behavior of a mouse. The algorithm involves the following aspects:

- **Cat:** Represents the predator searching for the prey (optimal solution).
- **Mouse:** Represents the prey trying to evade the cat.
- **Density Factor:** Influences the cat's ability to locate the mouse.

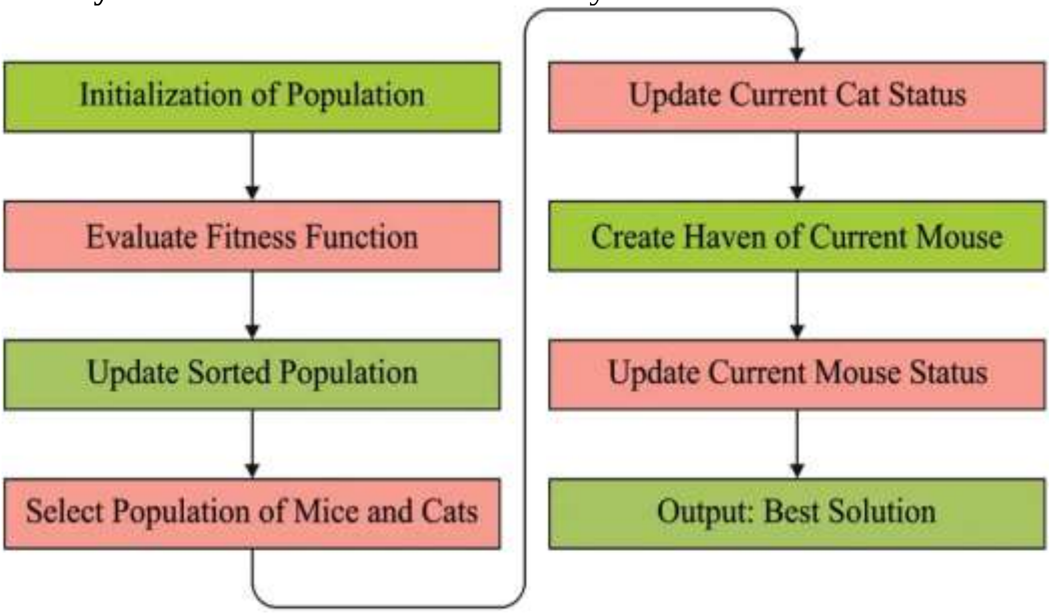

Fig. 11 Cat-Mause algorithm flow chart [27]

c. Hybridization:

In the provided code, the HYBRID_OPTIM function integrates elements of both algorithms. Here's a summary of its functionality

- **Initialization:** Initializes persistent variables and parameters.
- **Objective Function:** Evaluates the objective function, involving power balance calculations.
- **Update Duty Cycle and velocity:** Updates duty cycles (dc) and velocities (v) based on the hybrid approach.

- **HBA Component:** Incorporates an HBA-like strategy with onlooker and scout bees. The best position found using HBA (D2) is combined with the best position found so far (D1).
- **Update Velocity and Duty Cycle Functions:** Implement specific logic for updating velocities and duty cycles.
- **Cat Mouse Component:** Utilizes the Cat Mouse Optimization Algorithm within the velocity update process.

C. **Mutation and Selection Functions:** Perform mutation on the binary representation of a solution and select solutions based on their fitness.

D. **Other Supporting Functions:** Implement various utility functions for binary-to-decimal conversion, roulette wheel selection, and objective function evaluations.

- **Objective Function (p):**

  $|p(u)=|\text{pin}(u)-\text{pout}(u)|$

  Where pin and pout are calculated based on voltage, current, and power.

- **HBA Component:**

  The HBA involves mathematical expressions related to density factors, intensities, and solution exploration.

- **Velocity Update:**

  Velocity is updated using mathematical expressions involving inertia weight, personal and global learning coefficients, and randomization.

- **Duty Cycle Update:**

  Duty cycles are updated based on the current duty cycle and the updated velocity.

- **Mutation Function:**

  Involves mutation of the binary representation of a solution using randomization.

- **Cat Mouse Optimization:**

  The algorithm utilizes concepts of cat and mouse optimization involving density factors and solution exploration.

V. SIMULATION RESULTS AND DISCUSSION

How quickly electric current is added to or removed from electric batteries is governed by the state of charge control circuit. This is done to avoid voltage imbalance, overcharging, and electrical overload. By doing this, anything that might have an impact on how well the battery charges or how long it lasts and pose a risk to your safety is eliminated. In order to prolong the battery's life, battery technology may also prevent the battery from being totally discharged (a process known as "deep discharging") or perform regulated discharges. A "charge controller" or "charge regulator" could be a separate device or control circuits built into a battery pack, portable battery, or battery charge. After all, these words mean the same thing, so this is possible.

The SoC is a ratio that indicates how much battery life is remaining in relation to how much power the device can currently consume.

$$\text{So}C_t = \text{S0}C_o - \int_o^t \eta_i I_{L,} d_T \ / \ C_a \quad (1)$$

When you look at a graph, you can see how the current, temperature, and capacity all work together to figure out how efficient the battery is at doing what it's supposed to do. For example, when you look at a graph, you can see how the current, temperature, and capacitance all work together to figure out how efficient the battery is at doing what it's supposed to do.

$$\text{So}C_k = \text{So}C_{k-1} - \eta_i I_{L,k} \Delta_t \ / \ C_a \quad (2)$$

Where t is the number of hours between samples. In the form of a state equation, (2) tells us how to figure out the SoC from the SoCk21 and the current IL,k at the kth sample time.

Then, the battery model will be different because the state vector will have more parts and f(x, u) and g(x, u) will have a different functional form (x, u).

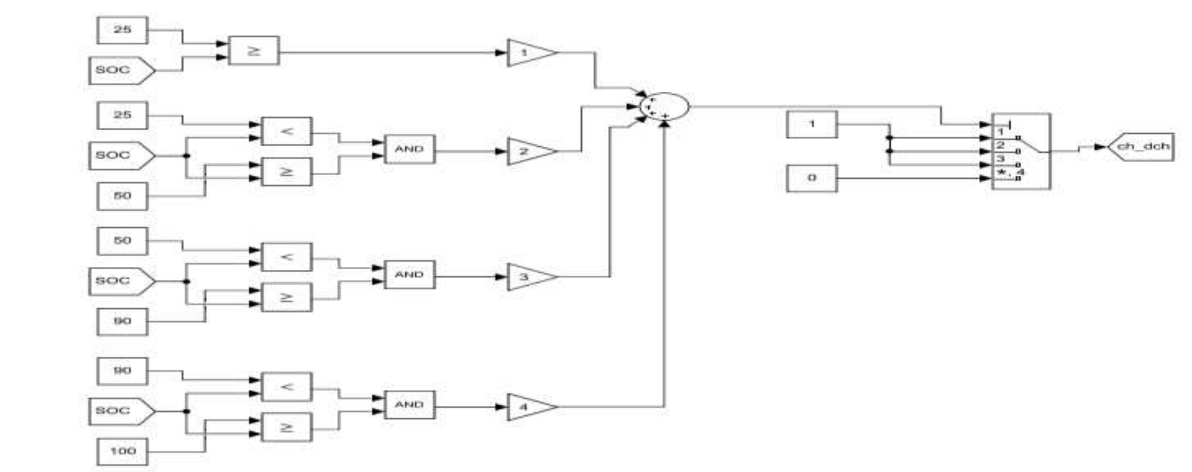

Fig.12SOCControl Circuit

Case Study

Different soc charging condition performed in the simulation

If soc less than 25, it will charge

If soc between 25 to 50, it will charge

If soc between 50 to 90, it will charge

If soc between 90to 100, it will discharge

Table 1 SOC Charging Condition

NO.1	SOC	Status	Action
1	Less than 25%	Charge	Disconnected from load only charging of battery
2	25 % < SOC < 50%	Charge	V2G avoided charging done
3	50% < SOC < 50%	Charge	Vehicle to gridperform ,charging
4	SOC = 100%	Discharge	Grid perform,no charging

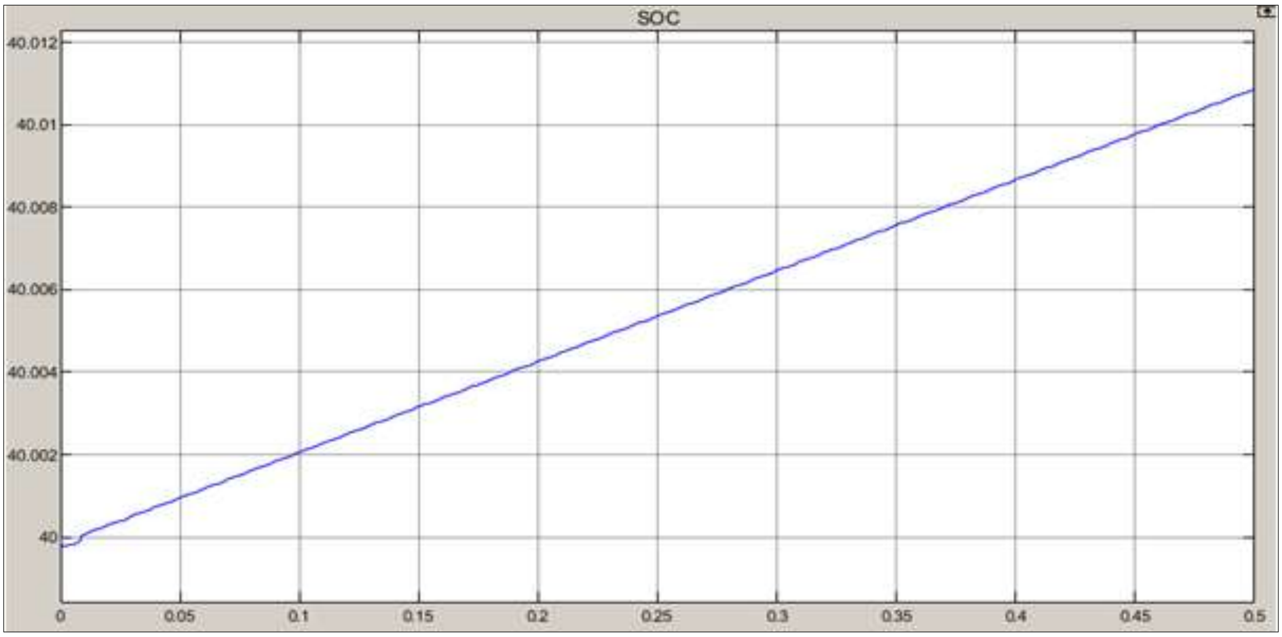

Fig.13SOC charging at 40%

To check the battery's SOC in the first example, the simulation's fourth SOC status check was performed. If the soc is between 0 and 25%, the charge is shown in fig. 12.

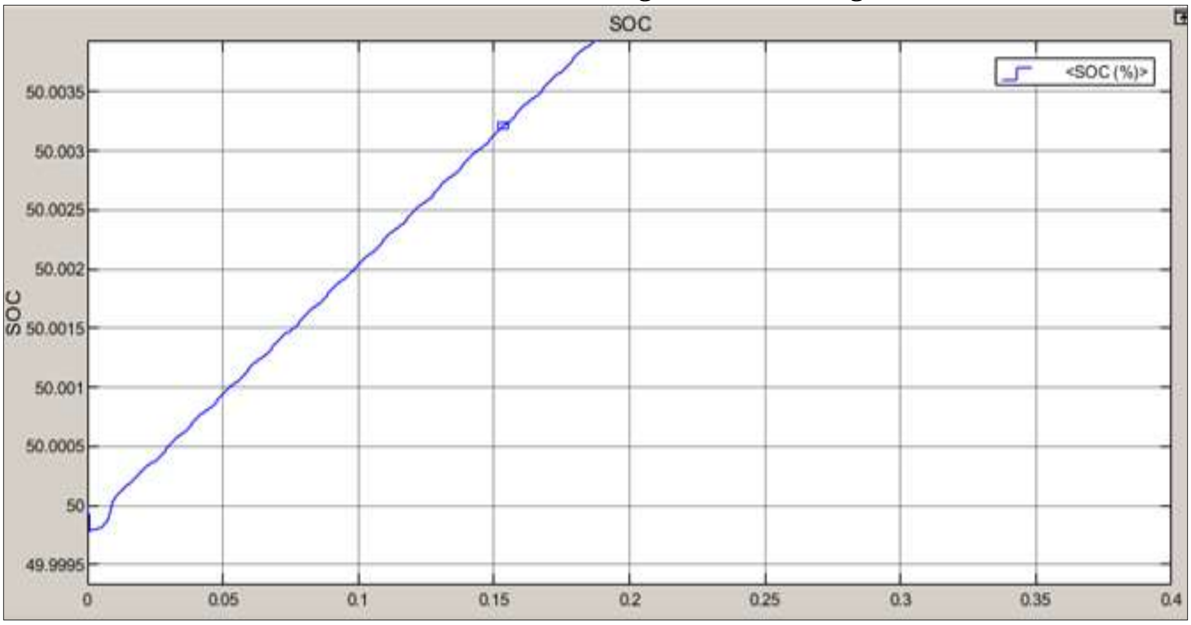

Fig.14SOC charging at 50%

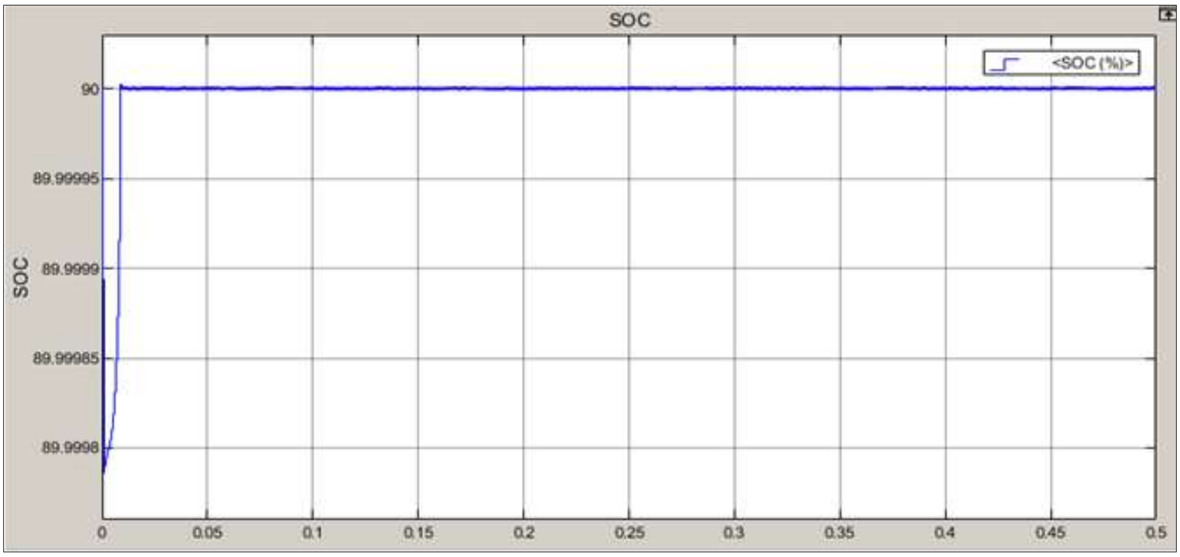

Fig.15SOC Charging At 90%

In the third case If soc between 50% to 90%, it will charge showing in fig.15

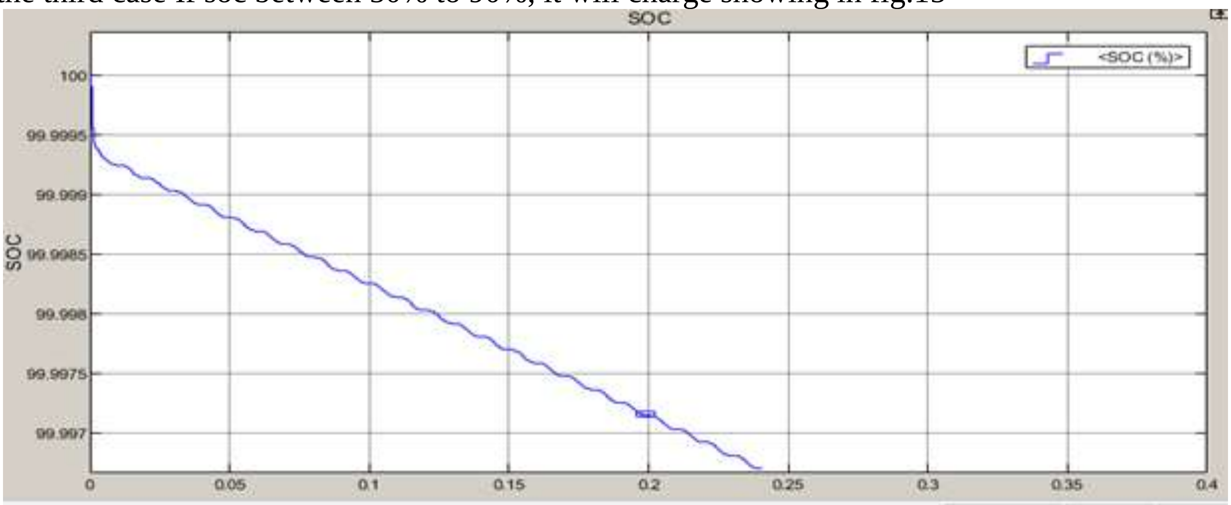

Fig.16SOCDischarging At 100%

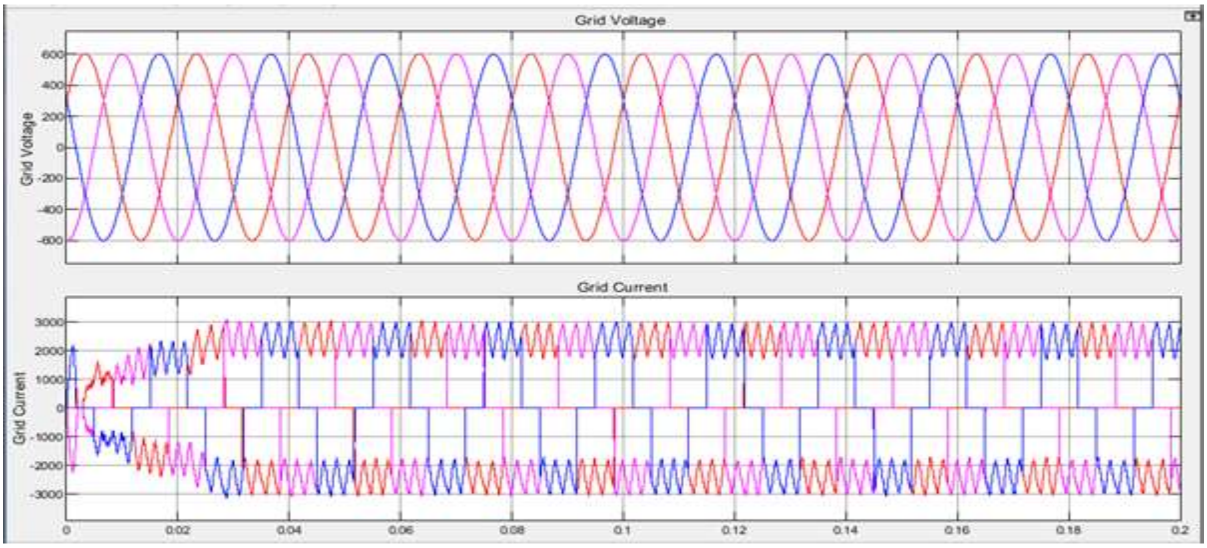

Fig.17 Grid Voltage and Current

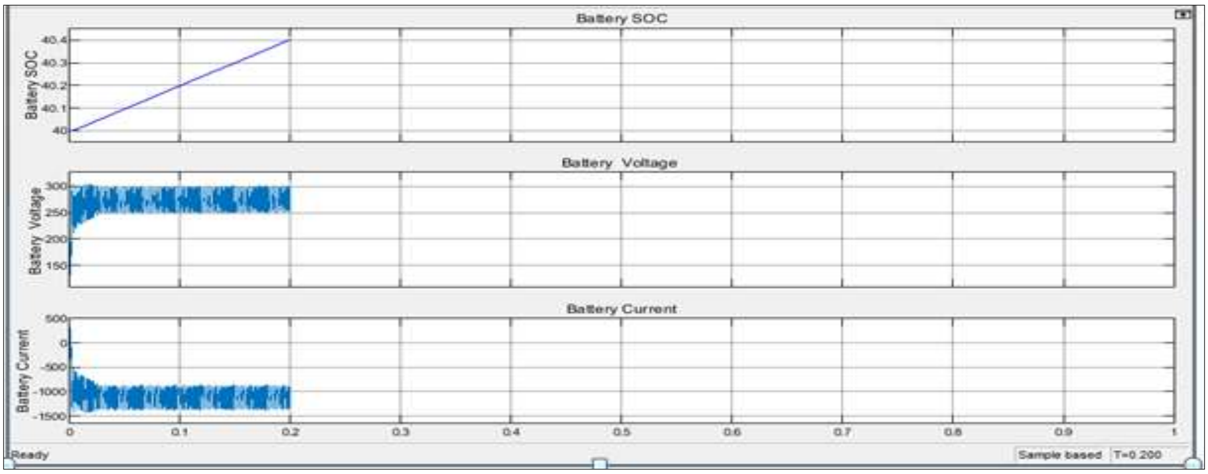

Fig. 18 BatterySOC, Battery, Voltage and Battery Current forEV1 Station

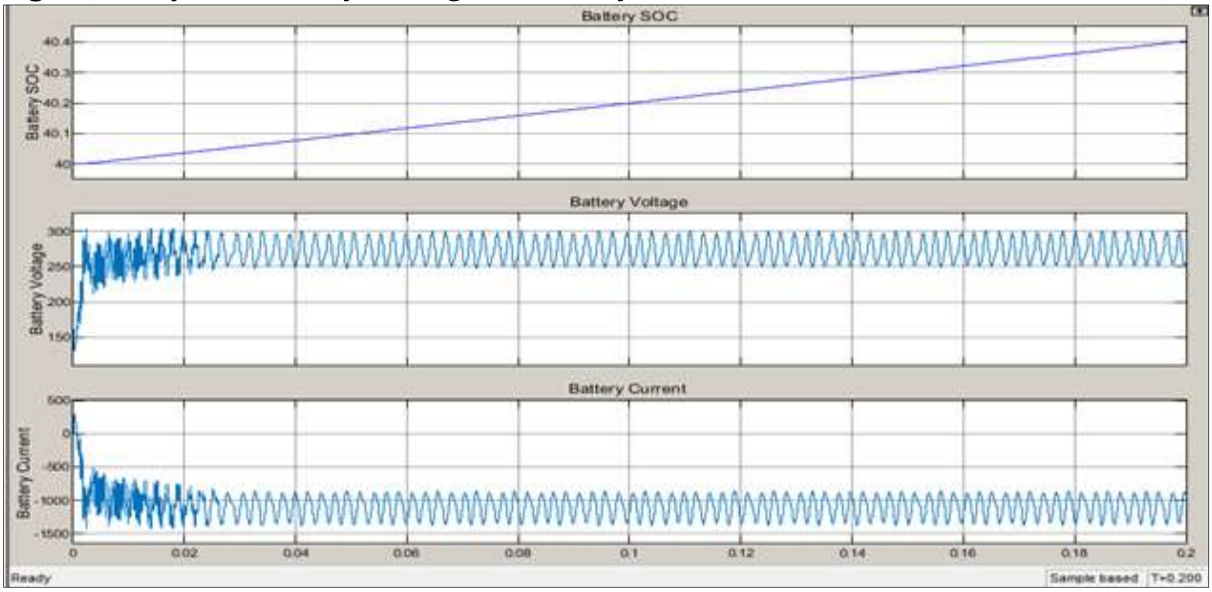

Fig. 19 Battery SOC, Battery, Voltage and Battery Current forEV4 Station

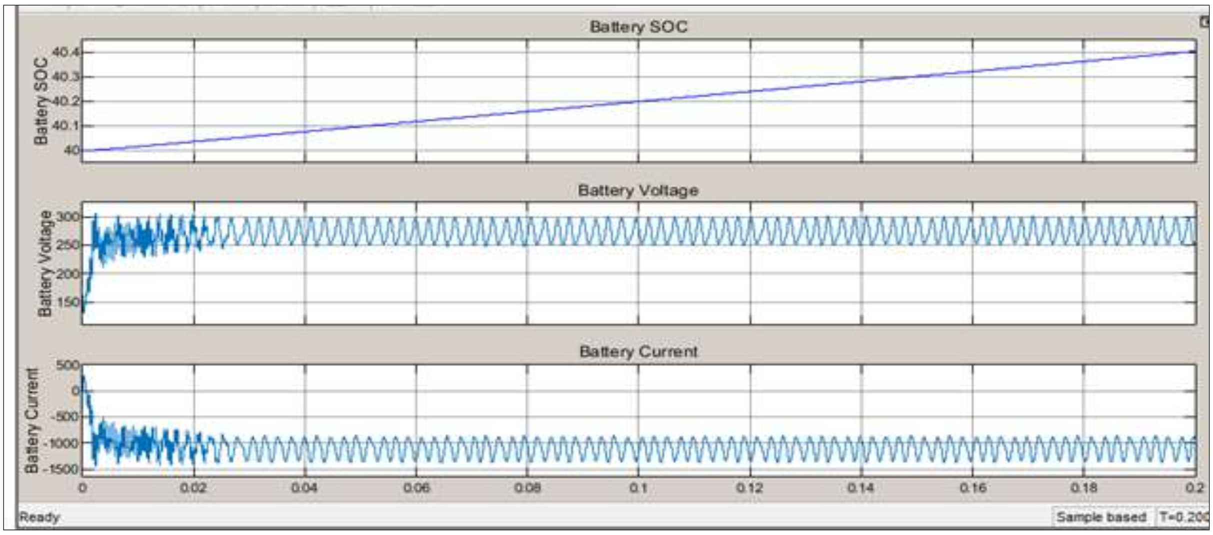

Fig.20 BatterySOC, Battery, Voltage and Battery Current forEV3 Station

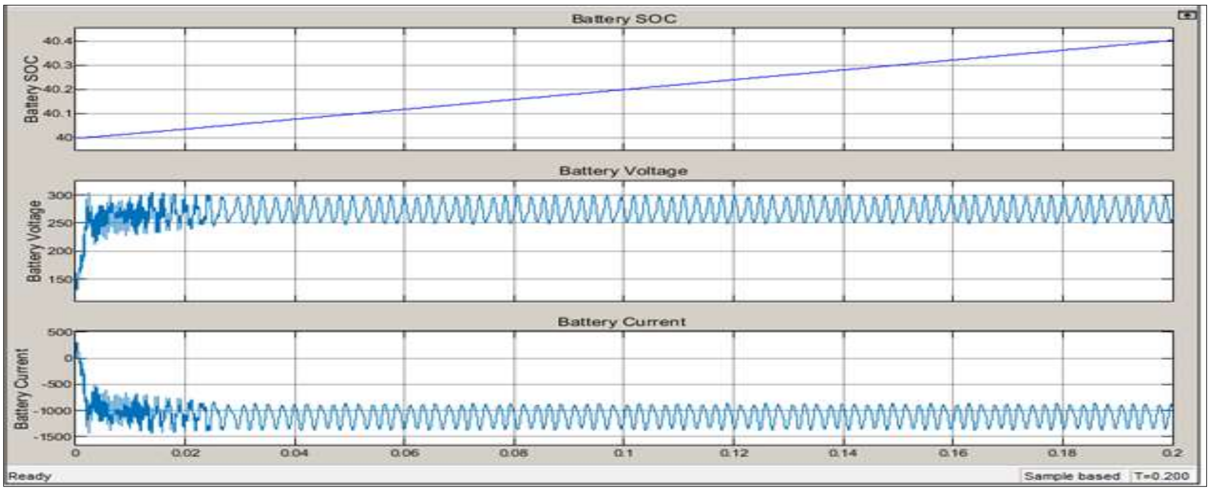

Fig.21 Battery SOC, Battery Voltageand Battery Current forEV2 Station

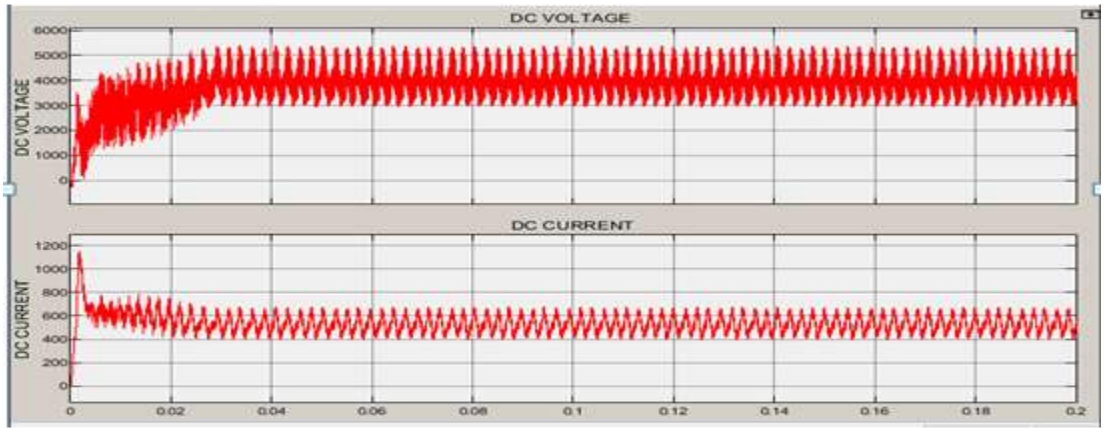

Fig.22DC Voltage and Current

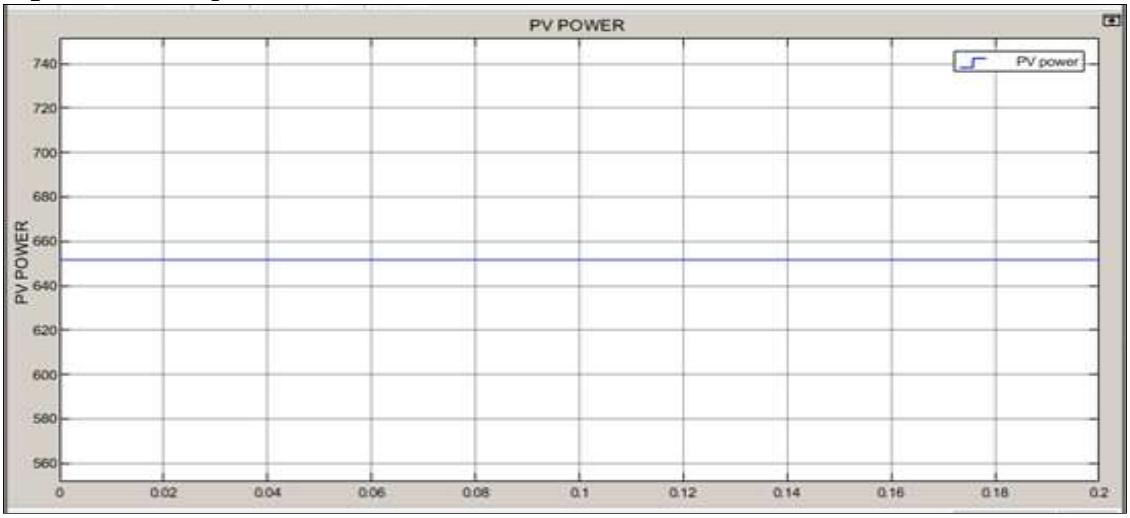

Fig.23PV Power

In fig.22 y axis showing PV power 655w with respect to time

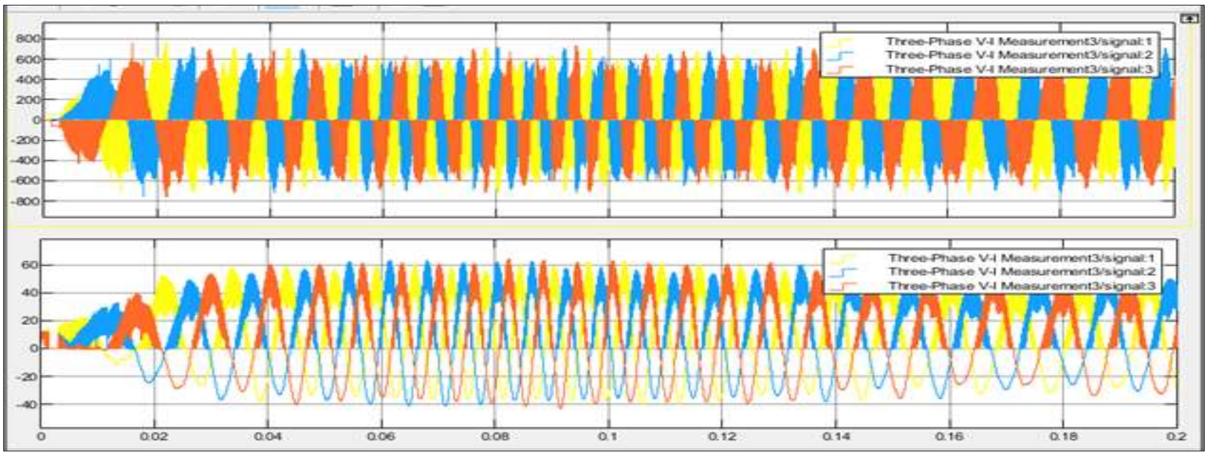

Fig.24 Three Phase Voltage and Current Measurement of Wind Generation System

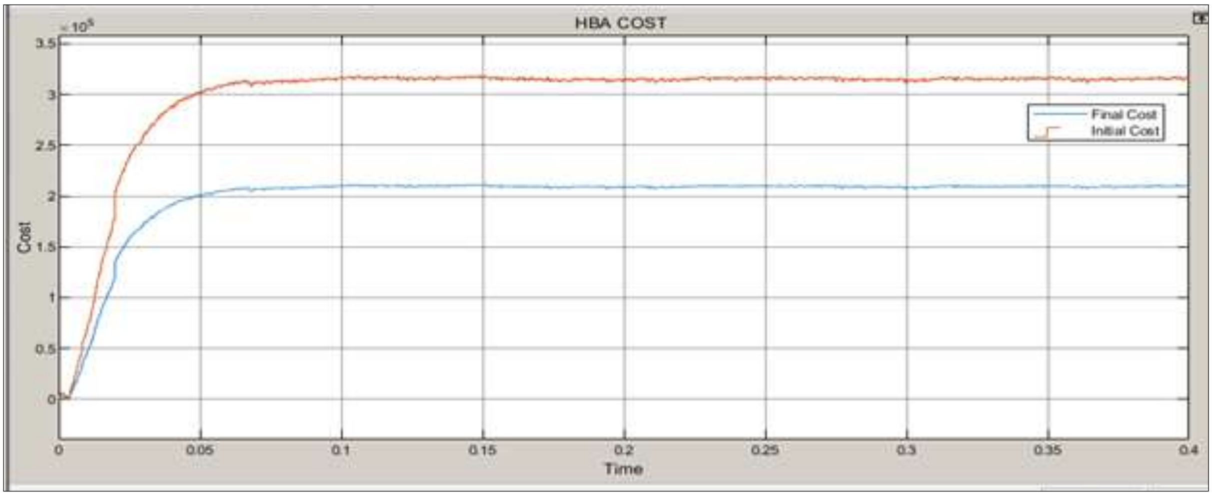

Fig.25 Initial and Final Optimization Cost

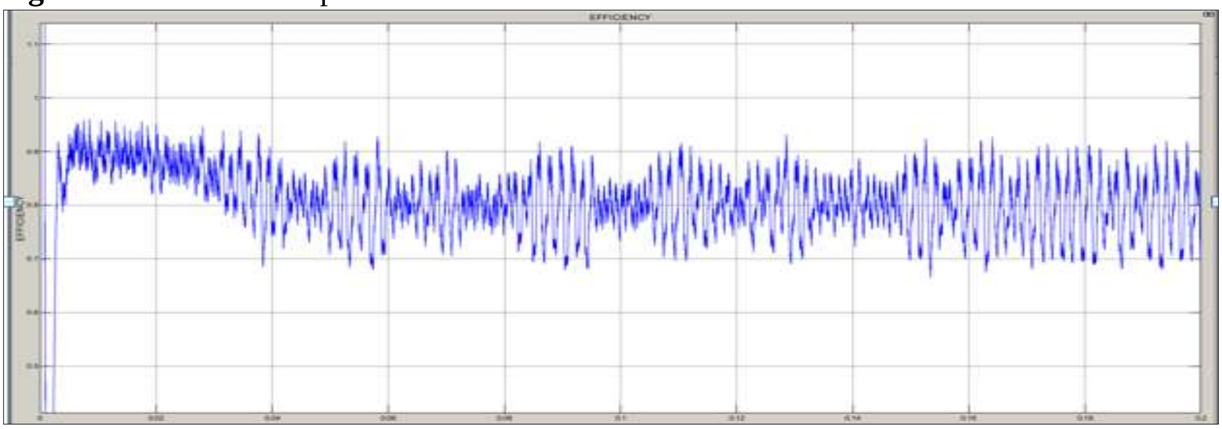

Fig.26 Efficiency

Table 2 Cost Comparison with Existing Work and Proposed Work

Study	Cost (Cent)
Proposed work	6
Previous work Ata Raziei[29]	10

Table 3 Comparison Result with Existing System

Approaches	Techniques	Efficiency
Existing Approach	Bidirectional Grid-Connected AC/DC	95.98 %
Proposed Approach[30]	EV Optimization –Honey Badger Algorithm	96.12%

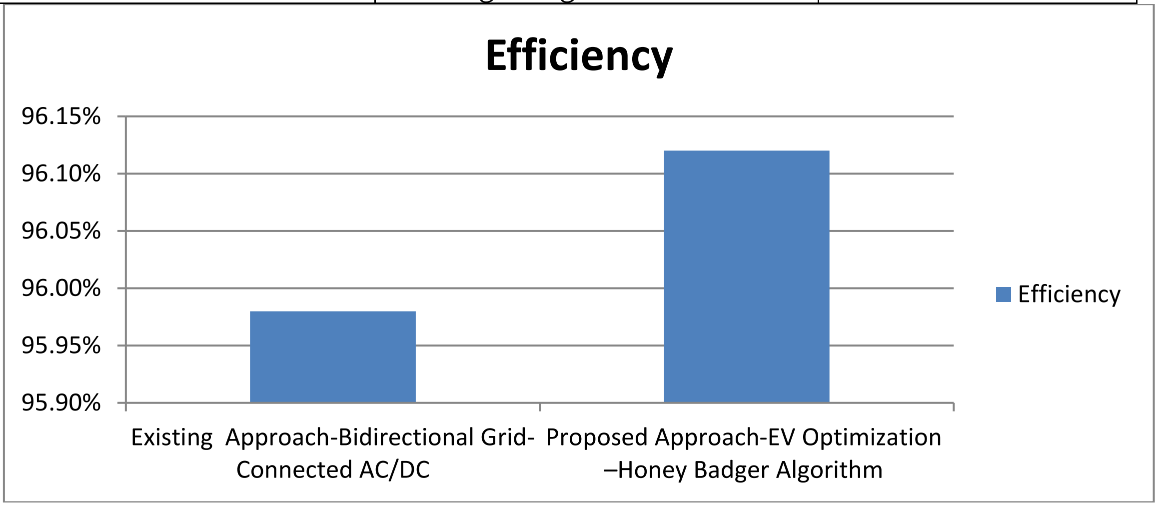

Fig.27 Efficiency Comparison of Existing and Proposed Approach

VI. CONCLUSION

Optimizing the performance of solar panels is crucial for enhancing efficiency and minimizing costs in solar energy applications. Factors like temperature significantly impact PV panel performance, requiring a delicate balance between surface operating temperature and solar irradiance penetration to maximize energy production. Dust accumulation on panels poses another challenge, emphasizing the need for optimization methods considering various environmental conditions. Cost optimization in photovoltaic (PV) systems involves addressing efficiency losses during DC to AC power conversion and implementing effective load management and solar irradiation strategies. Maximum Power Point Tracking (MPPT) systems play a vital role in optimizing energy capture from solar PV modules, requiring efficient algorithms to adapt to changing environmental conditions. In the realm of electrical vehicles (EVs), energy storage and management are central to cost optimization, with converters and advanced algorithms regulating charging supply and reducing operational costs. Integrating EVs with the grid demands careful energy management to leverage them as shared storage resources, offering a more sustainable and cost-efficient transportation solution.

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