ENHANCING EV CHARGING PERFORMANCE WITH ANN-CONTROLLED HYBRID (SOLAR/WIND) SYSTEMS

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ABSTRACT

This paper explores the enhancement of electric vehicle (EV) charging performance through the integration of an Artificial Neural Network (ANN) controller within a solar/wind hybrid power system. The study focuses on designing a robust, efficient system that makes use of the complementary qualities of wind and sun energy sources to guarantee a steady and dependable supply of power. By incorporating ANN control strategies, the system dynamically adjusts to fluctuations in energy production and demand, optimizing the charging process for EVs. The proposed hybrid system not only improves energy efficiency but also reduces dependency on the conventional grid, promoting sustainable and eco- friendly transportation solutions. Simulation results demonstrate significant performance gains in terms of energy utilization and charging speed, highlighting the potential of ANN-controlled hybrid systems in advancing the EV charging infrastructure.

Keywords: ANN Contoller, PI Controller,Buck converter,Boost converter, Electric vehicle charging station(EV charging station).

I. INTRODUCTION

Importance of Electric Vehicles (EVs)Electric Vehicles (EVs) are becoming an increasingly important part of the global transportation landscape due to their potential to address some of the most major environmental, economic,A. and technological challenges facing the world today. With growing concerns about Fossil fuel depletion, air pollution, and climate change EVs offer a promising an alternative to conventional gasoline and diesel-powered vehicles.

Electric cars, or EVs, are a viable way to lessen the impact on the environment. of transportation. The performance of EVs is affected by elements like cost, charging infrastructure, power systems, and battery capacity. As global warming accelerates and fossil fuel resources face depletion, the adoption of renewable energy sources, such as wind and solar has become increasingly essential. These energy sources are abundant, cost-effective, pollution-free, and widely accessible. Since EVs require charging, particularly for long-distance travel, charging stations equipped with renewable energy sources are strategically placed along highways. Efficient energy transfer is crucial, and power converters, particularly multiport DC-DC converters are essential components of managing the energy flow. In this study, In order to maximize solar energy use, a tracking technique called P&O MPPT is employed. This paper's primary goal is to create a system. that charges EVs using renewable energy both during the day and at night. The following is the structure of the paper: Section (1) Introduces a Wind energy system, and Section (2)Introduces the Solar energy system ,Section (3) details the proposed topology, Section (4) the presents characteristics of the solar/wind system, The simulation findings are discussed in Section(5), and the conclusion is given in Section(6).

II. CHARGING OF EV'S THROUGH RENEWABLE ENERGY RESOURCES

1) Wind Energy system
2) Solar Energy system

1. WIND ENERGY PLANT:

Wind energy is a vital part of the global transition to sustainable energy. Wind turbines harness the kinetic energy of the wind. using aerodynamic blades that rotate, driving a generator to produce electricity. The energy generated is then transmitted through cables and transformed into the appropriate voltage for distribution via the power grid. Turbines typically range from 1 to 10 MW in capacity, with offshore turbines reaching up to 12 MW. They can convert 35- 45% of available wind energy into electricity, and in optimal conditions, up to 50%. Wind energy is environmentally friendly, producing no greenhouse gas emissions during operation, and a single large turbine can offset the carbon emissions of 2,000-3,000 cars annually.

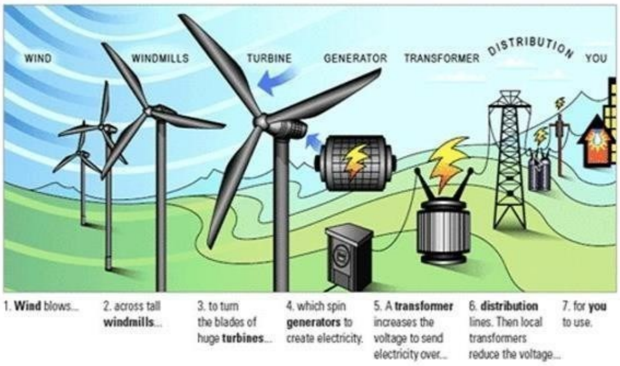

Figure 1: WIND POWER GENERATING SYSTEM

Wind energy is renewable, sustainable, and has low operational costs, while also creating jobs in manufacturing, installation, and maintenance. However, its effectiveness depends on location, with coastal and open areas being ideal, and the energy is intermittent due to varying wind speeds. These challenges can be addressed with energy storage solutions and grid management. The wind energy market is growing rapidly, expected to increase by 10- 15% annually over the next decade, contributing to a cleaner, more sustainable energy future.

2. SOLAR ENERGY PLANT:

Introduction to Solar Power for Charging Electric Vehicles

As the world increasingly shifts towards sustainable energy solutions, combining electric vehicles (EVs) with solar power offers an innovative and eco-friendly way to reduce carbon footprints and reliance on fossil energy sources.

The integration of solar energy into electric vehicle charging systems is a powerful step toward creating a more sustainable transportation ecosystem. This approach not only supports the growing demand for electric vehicles but also leverages the abundant and renewable energy of the sun to power them.

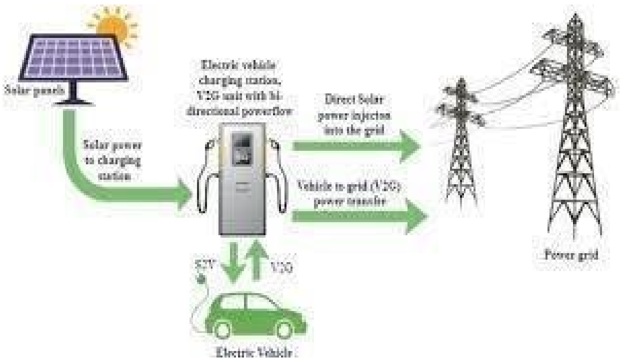

Figure 2: SOLAR POWER GENERATING SYSTEM

Electric Vehicle Charging with Solar Power

Electric vehicles are powered by electricity, typically charged through conventional grid-connected charging stations. However, when combined with solar energy, EVs can be directly charged using electricity produced by solar panels, reducing their environmental impact and reliance on the grid. The process involves installing a solar panel system that captures sunlight and converts it into electricity, which can be used to charge the EV's battery.

Solar-powered EV charging systems consist of solar panels that generate DC electricity from sunlight, an inverter to convert it into AC electricity, an EV charger to connect the vehicle, and optional battery storage to store excess energy for later use. During the day, solar panels generate power, either charging the vehicle directly or storing energy for nighttime use. If more energy is produced than needed, the excess can be sent back to the grid.

The advantages of using solar power for EV charging include sustainability, reduced carbon footprint, cost savings, energy independence, and increased adoption of renewable energy. However, challenges like high upfront costs, dependence on weather and location, space requirements, and system maintenance exist. As solar technology improves and becomes more affordable, solar-powered EV charging is expected to grow, becoming a mainstream solution in the future.

3. SECTION DETAILS TOPOLOGY:

Charging Electric Vehicles (EVs) with Hybrid Wind and Solar Energy:

A hybrid wind and solar energy system for EV charging combines both renewable sources to provide a reliable and sustainable energy supply. Solar panels capture sunlight, while wind turbines generate power from wind, with both sources converting their energy into electricity for EV charging through an inverter. Excess energy can be stored in batteries for later use or sent back to the grid.

Figure 3: HYBRID POWER GENERATING STATION TO CHARGE ELECTRIC VEHICLES

This system offers increased reliability, reduced carbon footprint, energy independence, and cost savings. However, it requires a significant initial investment, is weather-dependent, and needs regular maintenance, especially for wind turbines. Despite these challenges, it provides a scalable, environmentally friendly solution for EV charging.

4. SOLAR PV SUB SYSTEM:

The photovoltaic effect is how solar PV systems convert solar energy into electricity. P-N junction semiconductor semiconductors use this process to produce energy when they come into contact with light. The comparable circuit for a solar cell is depicted in Fig. 4.

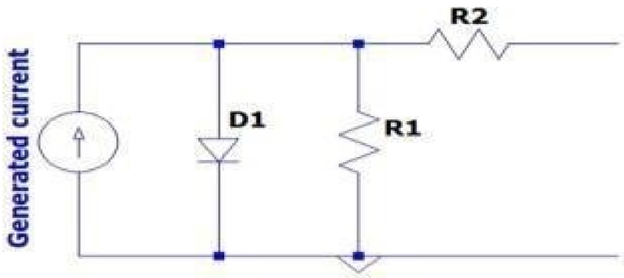

Figure 4: SOLAR PV SUB-STATION

The following is the current that is generated in each solar panel's secondary side:

$$I_0 = I_{sh} - I_s \left(\exp\left(\frac{V+IR_2}{nV_t}\right) - 1\right) - \frac{V_0+IR_2}{R_2} \qquad (1)$$

where the voltage and current generated are denoted by Vo and Io. Solar cell I-V curves display the relationship between voltage as well as current in a photovoltaic system. Features on solar cells. I-V Curve are basically a graphic representation of how a module functions, illustrating the relationship between current and voltage under various temperature and irradiation conditions. The I-V and P-V curves for the suggested solar module are shown in Fig. 5.

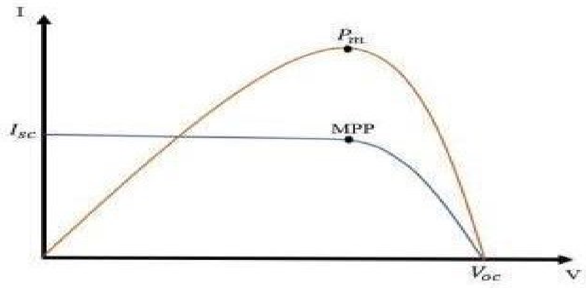

Figure 5: I-V AND P-V MODULE CHARACTERISTIC

Using a buck-boost converter in conjunction with an MPPT method is necessary to maximize solar energy. The greatest amount of power points at various times of the day are tracked in this research using the P&O technique. If the system's output power exceeds the energy required for the power source, the excess power can be fed into the power grid as a demand-side control technique using a multilevel inverter.

5. WIND TURBINE SYSTEM:

Wind energy has emerged in recent years as a result of the rapid advancement of novel developments and wind turbines. A windmill system uses a rotor, a number of blades, & a generator to convert wind energy into electrical power. A combination of wind speed and therotating blade surface determines the quantity of available wind energy. It is unnecessary to state that MPPT is required in order to optimize wind energy utilization. Both of these MPPT algorithms track the greatest power under different wind conditions. This approach measures the power that is generated in real duration and tracks the pace at which power varies with speed in order to maximize the power that the array of wind turbines can produce. MPPT can be accomplished by altering the rotor speed or duty cycle of the converter. The tip pitch ratio (TSR) is represented by the equation below.

$$\lambda = \frac{R_w}{Velocity} \qquad (2)$$

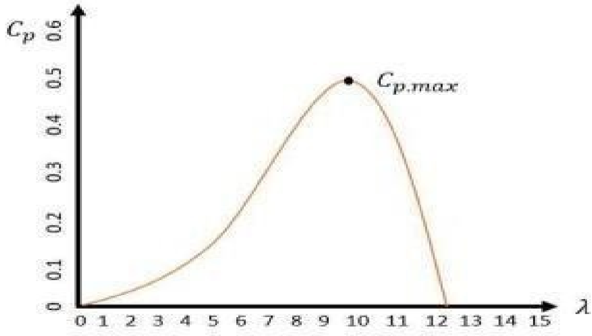

Figure 6: C_p vs λ

The generator's electromechanical frequency and wind speed provide the term of tip speed ratio, which is a crucial concept as seen in Fig. 6.

Additionally, the wind turbine's maximum power may be obtained as follow:

$$P_{max} = \frac{1}{2} C_p \rho V^3 \qquad (3)$$

where ρ is the density of air. The equation above and Fig. show that the maximum value for authority Pmax is produced with the biggest amount of λ_{max} and C_{pmax}.

III. CHARGING STATION BLOCK DIAGRAM:

The EV battery is recharged during the day using wind and solar power. To ensure effective energy management, a boost converter raises the solar panel's output voltage to 400V. At night, when wind energy is available, it helps charge the DC bus. A buck converter is then used to charge the EVs through the battery. Despite being plentiful and cost-free, solar energy can have erratic output. This issue is addressed by combining it Using an additional energy source, like wind.

In this study, a hybrid solar/wind system is proposed, where solar energy charges the battery in sunny conditions, and wind energy charges it when wind is present. If the hybrid system cannot generate sufficient energy, the battery's storedenergy is used to charge the EVs, providing a reliable and sustainable solution. With the help of hybrid power (wind/solar) 4 Electric vehicles were charged. Assuming the cars initial charging as:

1. Electrical vehicle 1 with the charging 20%
2. Electrical vehicle 2 with the charging 30%
3. Electrical vehicle 3 with the charging 40%
4. Electrical vehicle 4 with the charging 50%

20,30,40 and 50 percent.The electrical vehicles was charged at the charging station, where we used a buck converter with an ANN controller to enhance charging performance.

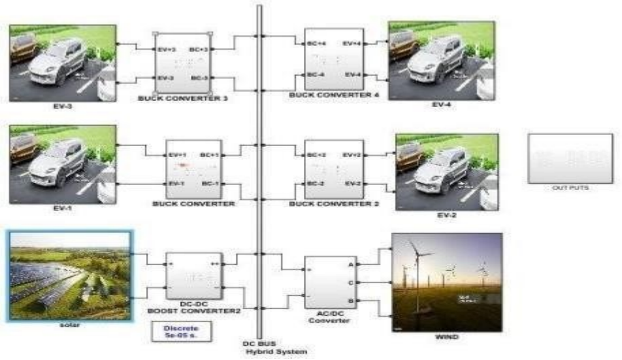

Figure 7: BLOCK DIAGRAM OF HYBRID CHARGING STATION

IV. SIMULATION RESULTS:

Simulation results of BOOST Converter:

Once power is generated by the solar system, a boost converter is used to step up the voltage to 400V for the DC bus. Figure 8 shows the output voltage of the solar system and the corresponding output voltage from the boost converter.

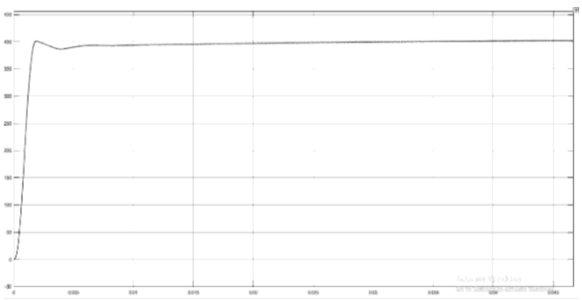

Figure 8: OUTPUT VOLTAGE OFTHE UTILIZED BOOST CONVERTER

ANN CONTROLLER

An Artificial Neural Network (ANN) controller can be used to control the error signal generated by a Proportional-Integral (PI) controller in a control system to improve performance, adapt to changes, or optimize the system.

ANN controller can be applied in conjunction with a PI controller:

1. PI Controller Output:

A PI controller is often used to minimize the error signal in control systems. The PI controller output is based on two components: Gains that are proportionate to the current error and integral to the cumulative error over time). The result of the PI controller is a control signal designed to reduce the error.

2. Error Signal Generation:

The error signal for the system is typically the variation between the true output (feedback) and the intended output (set point). PI controller uses this error signal to adjust the control effort. However, in systems with nonlinearities or time-varying characteristics, the PI controller might not always achieve optimal performance.

3. Role of the ANN Controller:

The ANN controller can take over or complement the PI controller to fine-tune the control effort. Neural networks can learn from the system's behavior over time and adapt to nonlinearity or disturbances that might affect the performance of a traditional PI controller.

4. Refine the control signal:

The ANN can adjust the output of the PI controller, enhancing its ability to cope with complex dynamics, nonlinearities, or time-varying conditions. For instance, the ANN could modify the proportional and integral gains based on the evolving error characteristics, optimizing the control response.

5. Learn from the error signal:

The ANN can learn to predict future errors or disturbances by training on the error signals over time, providing anticipatory control actions, thus improving system stability and reducing oscillations or overshoot.

6. Compensate for limitations of PI control:

The PI controller works well for systems with relatively linear behavior, but it can struggle with systems that have significant nonlinearities. The ANN controller can provide compensation for these nonlinearities by learning from past data, improving accuracy and response time.

7. Implementation of ANN in the Control Loop:

Training the ANN: The ANN can be trained using past data previous system responses, or control efforts to learn patterns that improve the control action. This training can be done offline or online, depending on the specific implementation.

ANN OUTPUT:

Once trained, the ANN will provide an output that is combined with the PI controller's output, either by adjusting the controller gains (making the PI ripples dynamic) or by directly modifying the control signal to fine-tune the response.

The ANN controller is used to enhance the error signal control generated by the PI controller by adapting to system dynamics and correcting limitations in the PI control strategy. The ANN can provide a more dynamic, flexible, and optimized control signal, improving overall system performance.

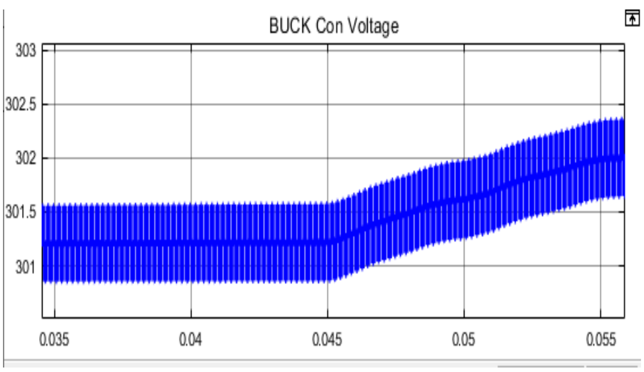

Figure 9:Zoomed results of Electrical Vehicle Battery

Voltage with Buck converter Controlled with PI controller.

In the suggested DC fast charging station, the voltage is increased from 25V to 400V using a boost converter. The EV batteries must have their voltage stepped down by a buck converter in order to be charged.

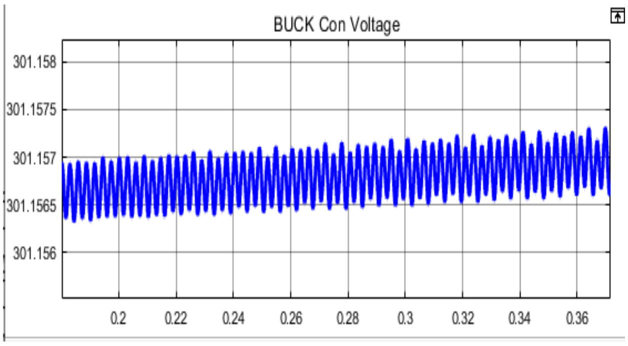

Figure 10:Zoomed results of Electrical Vehicle Battery Voltage with Buck converter Controlled with ANN controller

Figures Fig (9) and Fig (10) illustrate the zoomed-in results of an Electric Vehicle (EV) battery voltage controlled by a Buck converter using both a PI Controller and an ANN Controller. Observations indicate that when the Buck converter is managed by the output voltage and the PI Controller.The EV exhibits significant ripple content and more disturbed outputs.In contrast, utilizing the ANN Controller for the Buck converter results in a much smoother output voltage with minimal ripple. The reduced ripple content and smoother voltage levels achieved with the ANN Controller enhance battery performance and longevity. Excessive ripple and disturbed voltage outputs can lead to rapid battery degradation. Thus, the ANN Controller provides superior performance compared to the PI Controller, ensuring a more stable and reliable power supply for EV batteries.

V. SIMULATION RESULTS OF ELECTRIC VEHICLE CHARGING USING HYBRID (SOLAR&WIND) POWER

1.Simulation result of electric vehicle 1 with initial 20% charging

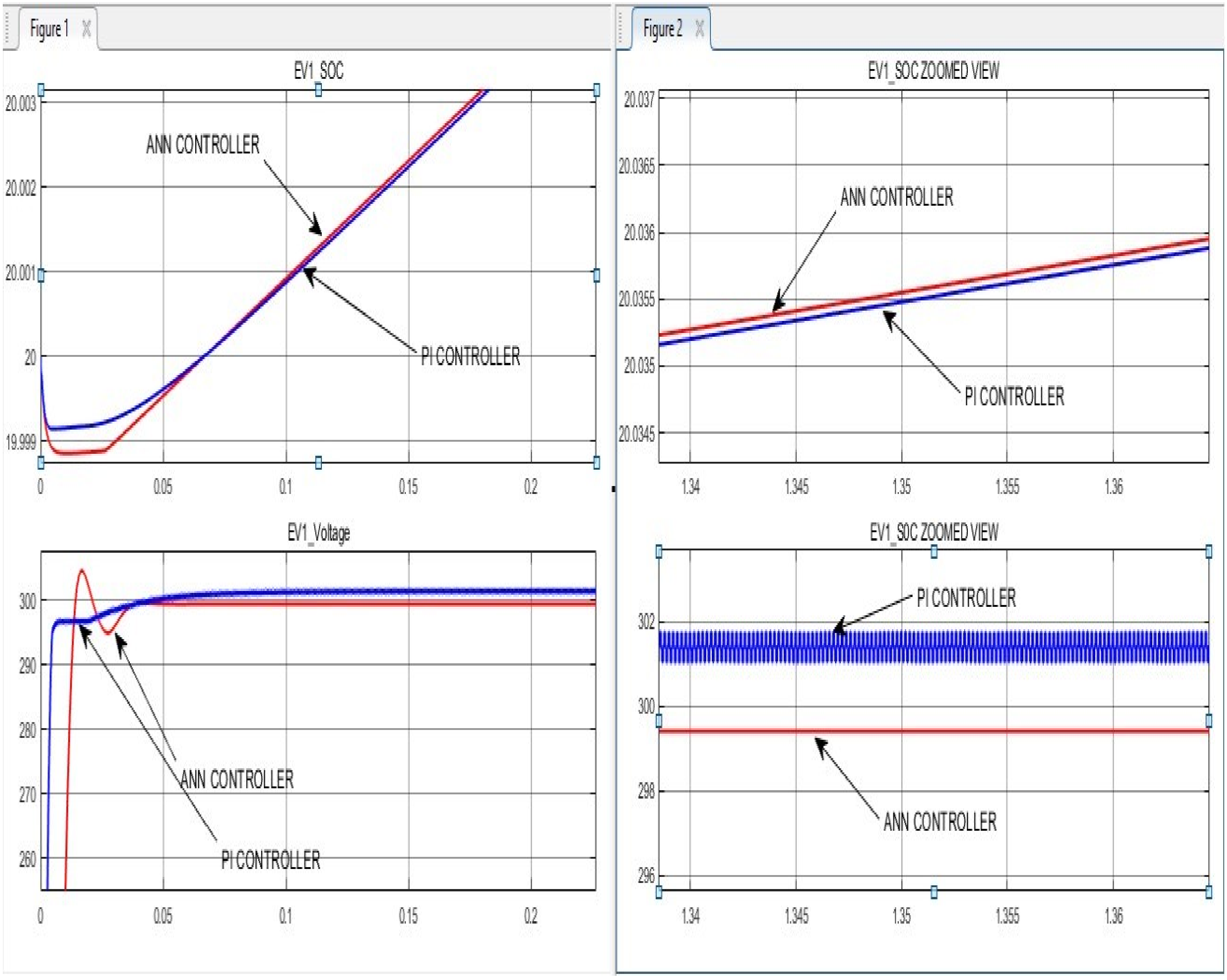

Figure 11: SOC and VOLTAGE of EV1

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2. Simulation result of electric vehicle 2 with initial 30% charging

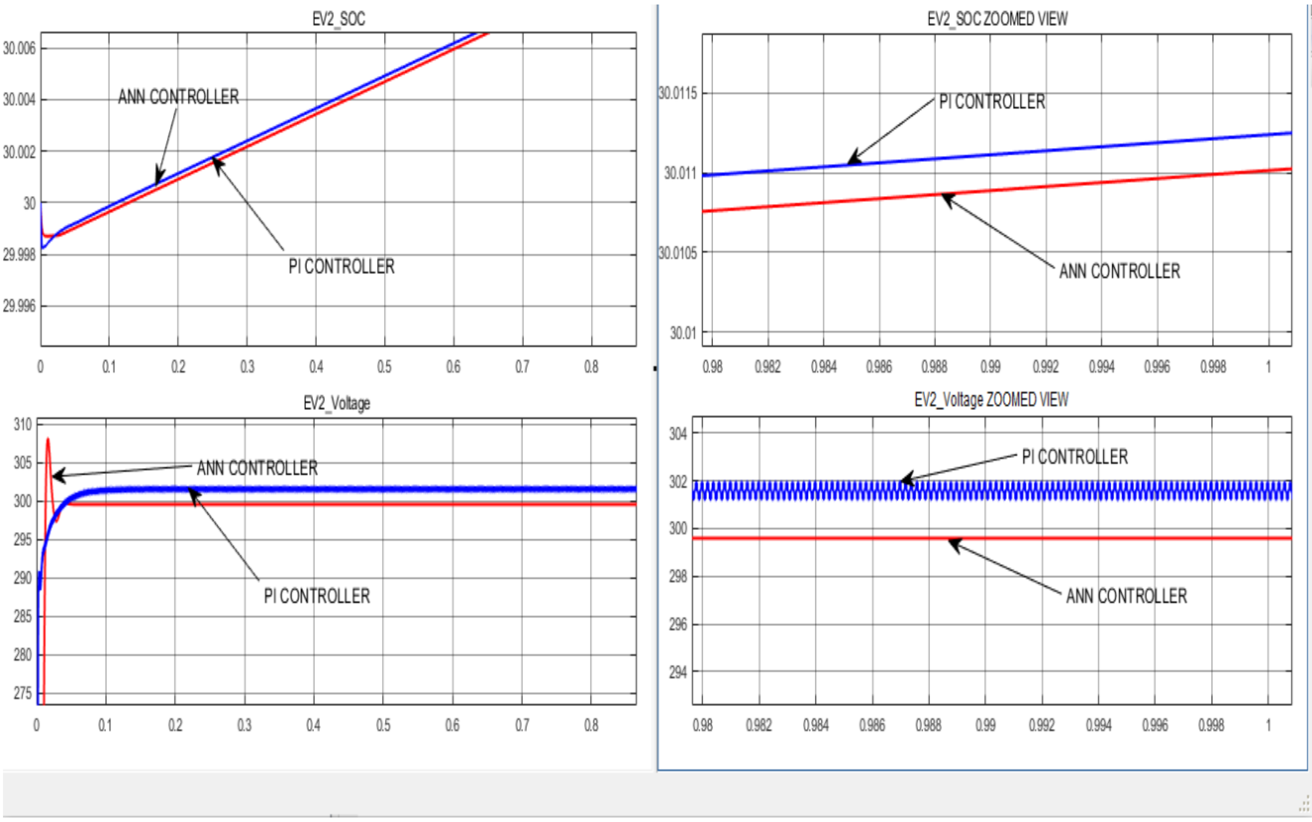

Figure 12: SOC and VOLTAGE of EV2

3. Simulation result of electric vehicle 3 with initial 40% charging

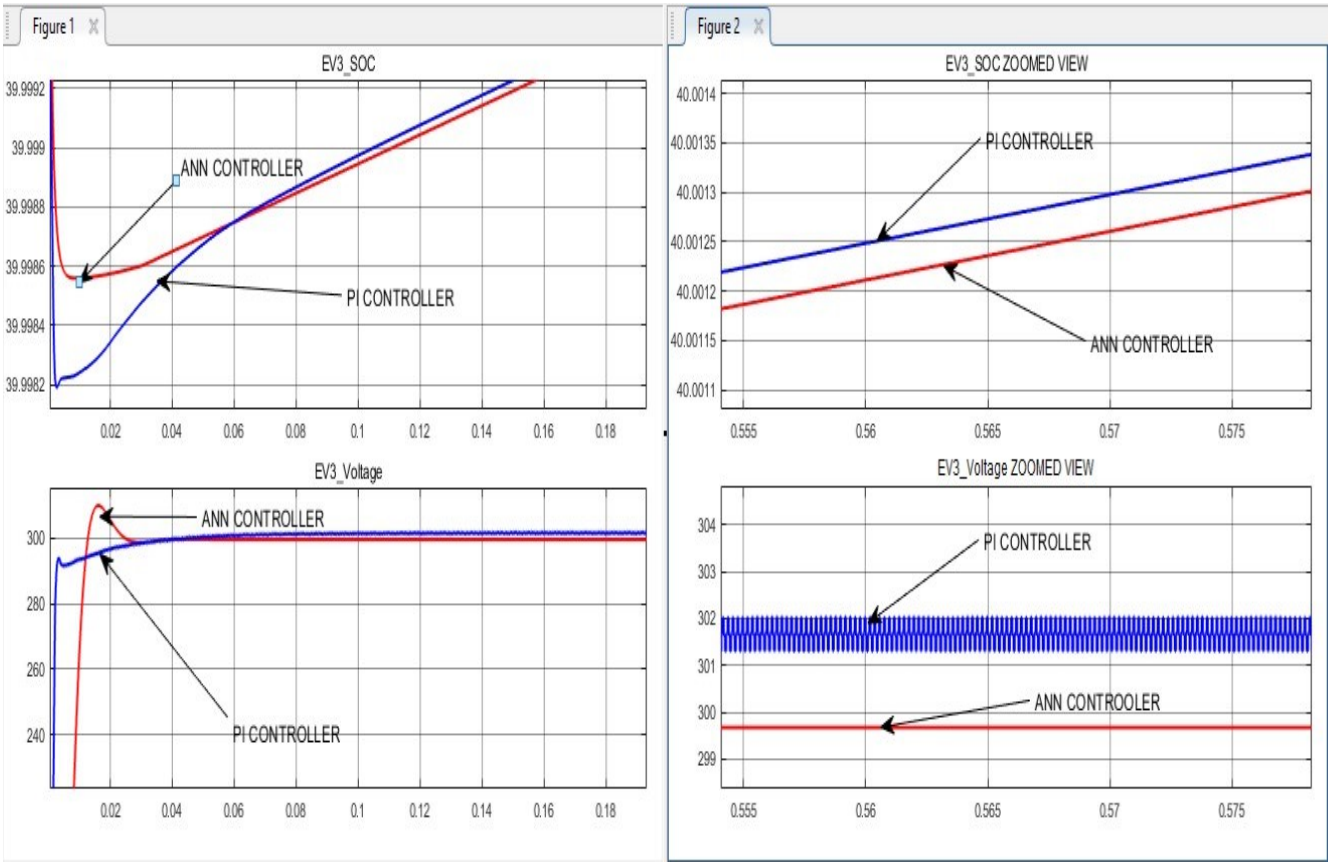

Figure 13: SOC and VOLTAGE of EV3

4. Simulation result of electric vehicle 4 with initial 50% charging

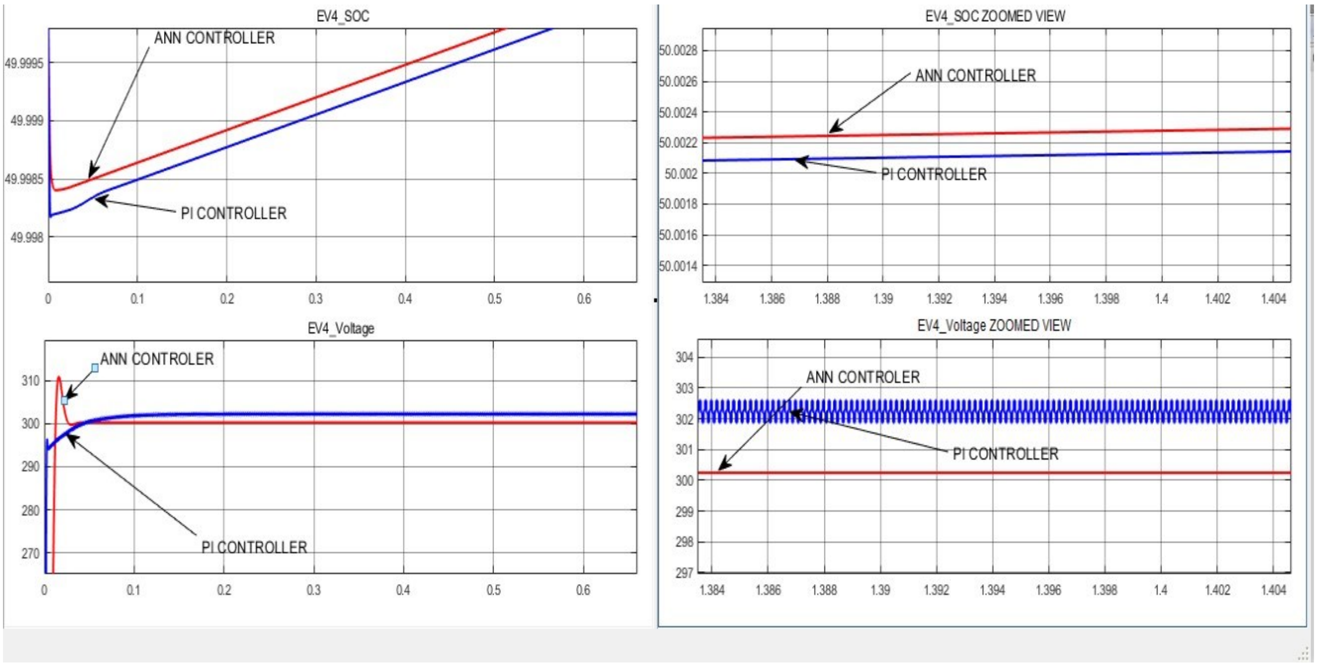

Figure 14: SOC and VOLTAGE of EV4

The electric vehicle (EV)initial charging starts with (20)%,(30)%,(40)%,(50)% charge and is fully charged using a hybrid solar and wind energy system. The charging process is carried out at a constant voltage of 400 volts through the DC- Bus to the BUCK Converter. And It reduces the voltage to 400volts To charge electric vehicles connected to the charging station. During this process, the voltage follows a sinusoidal waveform, which is generated with high accuracy to track the charging behavior. The purest DC waveform helps visualize how the voltage fluctuates over time, providing a detailed representation of the entire charging cycle.

VI. CONCLUSION:

The growing adoption of electric vehicles (EVs) has resulted in a surge in energy demand, which the current power infrastructure is unable to fully meet. This paper introduces a hybrid renewable energy charging station that operates without relying on external electricity sources and incurs no maintenance costs. The station harnesses renewable energy to charge storage batteries, which are then used to charge the electric vehicles. This setup not only reduces energy costs but also provides an easy-to-use power solution.

Simulation results indicate that using a combination of wind and solar energy systems, four electric vehicles were successfully charged. A buck converter, controlled by an Artificial Neural Network (ANN), was used to minimize voltage ripples during the charging process. And purest form of DC is generated. The system also contributes to a significant reduction in CO_2 and SO_2 emissions and lowers fuel costs.

VII. AUTHOR'S CONTRIBUTION

Conceptualiation: B Sai Prasanth Naik**,**
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Investigation: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam
Discussion of results: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam
Writing –Original Draft: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam
Writing – Review and Editing: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam
Resources: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam
Supervision: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam
Approval of the final text: B Sai Prasanth Naik, Dr. M. Ramasekhara Reddy, K.Nagabhushanam

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