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Single Phase Grid Connected Solar Charging Station For Electrical Vehicles Using ANFIS-Neural Network Control Approach

Abstract: This work presents a new system architecture for low-cost photovoltaic (PV) battery charging stations that can balance: 1) the cumulative charging time of each battery and 2) the overall charging time of all battery power sources. The new system's first control strategy is to rapidly charge each battery at the same voltage or SOC level before charging multiple batteries in parallel at the same time. The solar PV system is integrated with ANFIS MPPT to extract maximum power. From the PV module, the static battery storage and the EV battery are controlled by a feedback voltage control scheme to maintain a constant DC bus voltage. The neural network means that the NN receives two inputs: PV power and Soc of constant battery and the generated output is the actual current reference signal of grid inverter control. The simulations are then discussed under,several situations where the radiation conditions change and the,battery remains constant and EVs have different social,EV charging stations where the energy is processed successfully,using neural networks.

Keywords: PV array, Battery charging station, ANFIS-MPPT, Neural network, Stationary battery, EV Battery.

I.

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This section of the research presents the problem statement that has informed existing and previous research work.

28 1. The low controlling ability of the buck/ boost converter is achieved through the use of Zero Voltage Switching (ZVS).

2. Harmonic Losses in control of the PWM by using the PI control strategy and high THD.

3. Small signal ripple will appear at primary side again more signal ripple in secondary side in single phase output by Using high step-up DC-DC conversion.

Objective

1. To thereby control the buck and boost converter by using a bidirectional power flow in the battery unit

2. After analyzing these observations, the following objectives were set to control the PWM by using ANFIS- MPPT and Neural network.

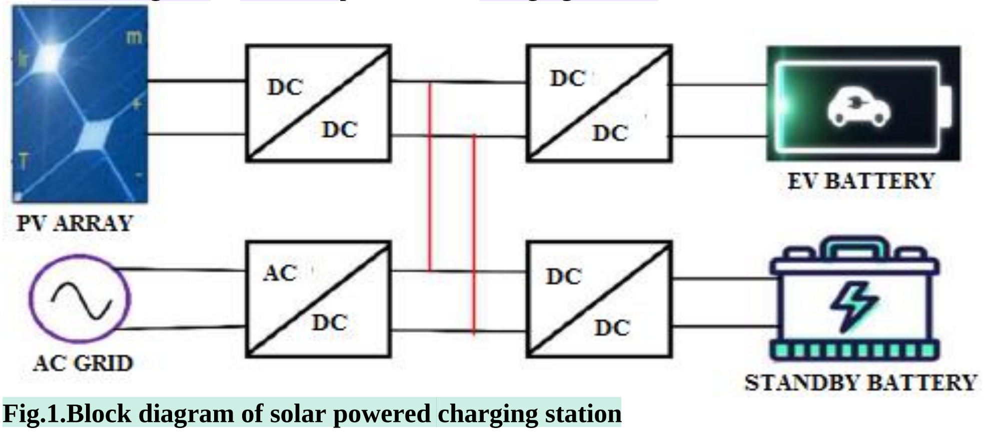
3. To minimize low distortion and High voltage gain in single-phase output by using renewable energy sources

I.INTRODUCTION

Specifically, the present study focuses on classifying EVs into a sustainable transport system. 45 In this case, solar photovoltaic (PV) systems add sustainability to the EV charging station by 29 improving the non conventional energy source share of renewable energy sources in charging the network of an EVCS. The purpose of this work is to assess such modelling in simulation/matlab ,it can be developed solar PV based EV powered charging especially on the schematic diagram of the proposed network system.

36 BLOCK DIAGRAM

The block diagram of the solar-powered EV charging station includes:



39 **Fig.1.Block diagram of solar powered charging station**

The block diagram consists of a PV array with a DC to DC converter and mppt algorithm and the standby state element is nothing but storage battery and DC to DC converter, directional 3 and DC bus voltage regulator and grid integration. and supplying the EV battery grid with a DC to DC converter. The new modes of transport development are faster developing the various forms of global warming and other negative climate changes that have an impact on our environment. ICE vehicles always release toxic emissions which impact the quality of the environmental air and trigger increased emissions of green gases. They are passenger cars with internal combustion engines which due to worsening environmental impacts can be categorized as worse. The above challenges can be met primarily through the conversion of transport via a process well known as electrification of transport.

The populace is progressively moving from the old-fashioned automobiles with internal-combustion engines owing to their high energy efficiencies and hence energy conservation, and hence non-use of oil, on the assumption that the energy used to recharge the batteries of the electric automobiles is not fossil-fuel based. But, using more electric cars on roads, the challenge of charging such cars using the existing electric network will be more challenging. The two of them are the fact that it may be hard for the grid to meet the power demand that many electric vehicles will be demanding and thus they cause operational issues.

Besides, if the electric grid employs conventional sources of energy for charging, the improvements made may be erased wholly. This development needs charging infrastructure for EVs that will enable the incorporation of renewables into the process. A rather rare option is a spinning reserve that can fully protect EVCS from the utility grid for enough time. However, since the number of EVCSs is expected to rise in the future, one can find a challenge although standby batteries alleviate the load on the utility grid to some extent. There is still a present weakness in the availability of a sustainable cheap method in the creation of outdoor solar EV chargers and microgrids, particularly for solar electric vehicle charging stations as well as integrating the statistical ecological data. Thus, the development of an economic photovoltaic-based optimal design model of structures using the independent energy resources in the electrical charging of EVs within solar energy stations would be desirable.
The key renewable energy source included in this project is solar power. During peak radiation, the PV energy is used to charge the EV, and the remaining energy is sent to the AC grid to charge the battery backup. At night when there is no electricity, PV can use batteries to charge the energy flow, up to EV. Basically electric cars require charging which is derived from power sources of solar or backup batteries. Sometimes the AC grid will be used for drawing power and charging of the EVs as well as a standby battery bank for APS-IPS system. Indeed, the Matlab/Simulink simulation of the proposed system has been conducted. This means if there is no power available in the Solar PV then there can be no power generation from PV panel during that time we will use stationery battery to supply power and charge EV battery; if there is no power in the PV and the soc of these stationery battery is very low we will look for it from the grid.

II.ELECTRICAL VEHICLE CHARGING STATION MODEL

Figure 1 shows a block diagram of a recommended solar charging station. It has an energy storage facility and an AC network in one battery. for the work presented One EV battery connected to a 380 V DC bus at the same time is considered. The technical specifications of all components are listed in the table.

A. PHOTOVOLTAIC ARRAY ALONG WITH BOOST CONVERTER

The charging station is characterized by a 2000 W photovoltaic panel with an open circuit voltage of 278.4 V

Table.1.Solar powered EV charging station ratings

PV Module data	
Number of cells	60
Open circuit voltage	37.3V
Short circuit current	8.66A

MPPT voltage	30.7V
MPPT current	8.15A
1 **PV array data**	
Parallel cells	1
Series connected module per string	8
Standby battery data	
Nominal voltage	230V
Rated capacity	40Ah
Battery type	Lithium-ion
EV battery data	
Nominal voltage	230V
Rated capacity	40Ah
The initial state of charge	70%
Battery type	Lithium-ion
Boost converter data	
Switching frequency	10kHz
Capacitance	4.0704 µF
Inductance	0.0153H

5 Especially for charging stations MATLAB/Simulink A boost converter is used to change the voltage of the solar panels to achieve a voltage level of 380V DC at the bus. ANFIS and PI
35 controllers are designed to improve the power rating of the solar panels.

B. GRID CONNECTION WITH AN INVERTER

A charging process of the present study involves utilizing the 230V, 50Hz direct alternating current grid to respond to the higher power demands of the station. This 230VAC source is utilized in most Static Frequency Converters (SFCs) and is modeled as the grid source in MATLAB/Simulink. To this machine it is connected to an AC grid system and also to 380 V
27 DC link through an inverter. In order to generate the necessary pulses for the inverter
3 switches, a neural network is developed in simulink for PV array output power and standby battery discharge current SOC as input data.

C. ELECTRICAL VEHICLE BATTERY

44 To charge the battery, the battery in the device must be a 230V, 7Ah battery. The battery of the proposed electric vehicle (EV) will be charged from a 380V DC bus via a proportional
10 control circuit (PI) for a DC-DC boost converter for local simulation of the battery of an EV. The newly arrived must have at least 10 % SOC amount. The energy requirements to charge
12 the EV battery can be estimated from the rated voltage of 400V DC bus voltage and the PI
33 controller is used for the DC- boost converter. The proposed DC system consists of photovoltaic (PV) panels. A boost converter integrated into the system is optimized for MPPT functionality by proposing a neural-fuzzy inference system. Controlled and controlled by (ANFIS), this ANFIS MPPT algorithm takes two inputs between radiation and temperature. and transfer the maximum power and voltage using ANFIS MPPT obtained by the above method. It measures the actual PV voltage and compares it for maximum power point detection. This information is then followed up with a PI controller for further control and optimization. This is followed by a PWM generator that sends pulses to the IGBT to achieve maximum amplified power. It thus combines the spatial configuration of the Solar PV system with the solar charging station. Scope- Parts are integrated.

41 ***DC-DC Converter:*** This is the voltage increase over the PV array. Maximum Power Point Tracking (MPPT) algorithm: Increases the functionality of the PV array to generate power. Stationary backup battery: stores excess energy.
9 This battery will work as a stationary battery by connecting it through a directional DC to DC converter and in this voltage regulation method we will maintain a DC bus voltage of around 500 volts.We will measure this DC bus voltage and when the regulator PI then a PWM
8 generator and this bidirectional DC to DC converter processes the pulses for and this IGBT control and the way we maintain this voltage is 380V.
21 Bi-directional DC-DC converter with DC bus voltage regulator: Controls the power flow between storage batteries, EV batteries and the DC bus.

Grid Integration: The role of getting extra electricity supply or the excess electricity generated to the grid.
In the present work, therefore, we limit our discussion to a single-phase grid interfacing
43 system that is connected to a single-phase inverter and an LCL filter. Based on these measurements power will be swapped between the gird and the inverter. Angular frequency ωt will be derived out of the grid voltage Vg through the Phase Locked Loop (PLL). Finally
19 on grid control 'there is the plan to utilize the neural network view with regards to SOC of the stationary storage battery'. The neural network will process two inputs: communication between the SOC of the battery and the photovoltaic (PV) power. Therefore there arises an elicitation of a reference current from the neural network based on the preceding input signals as outlined above. This reference current is now converted to dq0 format and the actual inverter current is also converted to its dq0 form for further analysis. The comparison of the two will be controlled by a nonlinear proportional-integral-derivative controller.
EV Battery: The battery of the electric vehicle being charged.
The EV battery is connected via the bi-directional converter with the voltage control for here also have to measure the Bus voltage, and then this bus voltage is compared with 500 volts reference after processing the PI controller.PWM generator will generate pulses for this IGBT based on this voltage across this DC bus will be maintained as well as it will take power from the DC bus hence these are the components of the measurement unit.

Solar Power Generation: It absorbs sunlight to produce power, charges the stationary battery, and, if available and connected, the EV battery.
3 Battery Management: Thus, during periods when PV generation is low, the stationary battery provides electricity to the EV battery.

III.CONTROL METHODOLOGY

16 *A. AN ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM*

ANFIS is short for Adaptive Neural Fuzzy inference system which is an neural and fuzzy inference-like behavior on multi-input signals. systems. The synaptic connection is absent in the versatile neural network There is always scope to refine. There are non adaptive and adaptive nodes — but not weights. Hence it is simply transformed into a classical feed forward neural network. There, we could say that network of network sounds a lot like any structure as such. This section deals with ANFIS neural networks architecture and presents an application of a concept is similar to an adaptive Takagi-Sugino fuzzy controller. It operates in a manner similar to how fuzzy inference systems are executed. The approaches used, are back- propagation as gradation decline and least-squares methodology in context of tuning of enter − output relationship of ANFIS network wrt a set o f enter − output data. The ANFIS network is a neuro-fuzzy model consist of two parts (1) defined as Antecedent and 2) Availability. Fuzzy systems are the first one is inference system constructed from nodes

1 associate with rule based system which e and Δe are the inputs for the layer 1 node i. The Ai and Bi represent the membership values that each node possess. In general input, membership function of each node is assigned, include Membership functions implementation Gaussian distribution for variables function. Gaussian membership function is modeled

Due to Eq. (3).

$$f(x;\sigma,c) = e^{\frac{-(x-c)^2}{2\sigma^2}}$$

In the case of the Gaussian MFs for the options' width and centre, respectively denoted by σ and c. The width and center are the non linear parameters these are the modified parameters during the learning process.

Layaer2: Π is a representing and fixed node with an output node from the product of layer 1
26 Whenever an output node from each of layer 2 node is then fixed the firing strength of the rule base is determined.

for i= 1, 2….j2(4)

$$L_{2,k} = W_i = \mu A_i(e)\mu B_i(\Delta e)$$

Layer 3: Fixed nodes are defined and symbolically designated by "N" for this layer. The node function is described in the following Equation 5.

$$L_{5,i} = \sum_{i=1}^{j2} \overline{W_l} f_i = \frac{\sum_{i=1}^{j2} W_l f_i}{\sum_{i=1}^{j2} W_i}$$

Level 4: This node is flexible. Equation (6) indicates from the current function of this node that

In this regard, we have p, q and for the standardized level 3 firing force and α , β and γ are called linear parameters of the ANFIS network or network output parameters. These parameters get learned and the more learning is adjusted by the certain least-squares technique. The 5th layer is called Σ or output layer though it is a fixed node. This was achieved by arriving at an output of this layer using a weighted average formula represented by Equation (7).

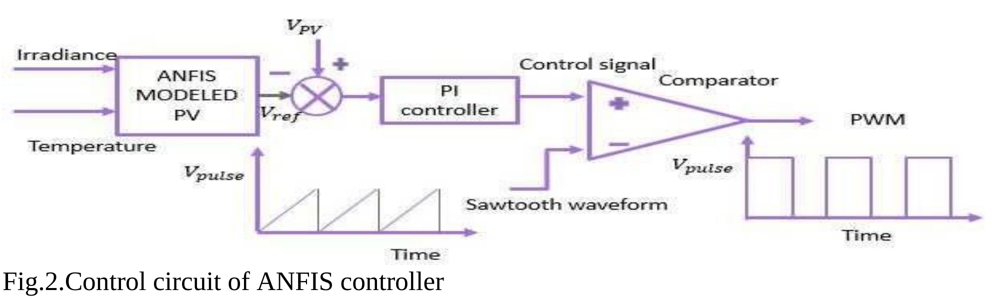


Fig.2.Control circuit of ANFIS controller

This hybrid approach significantly reduces the dimensions of the search space during training, resulting in much faster convergence compared to traditional back-propagation algorithms. The effectiveness of the hybrid algorithm lies in its capacity to simultaneously optimize both linear and nonlinear parameters, leading to quicker convergence and enhanced overall performance. This method enables more precise modeling of complex systems by capitalizing on the advantages of both the steepest descent and least-square techniques. Additionally, the adaptability of the ANFIS structure makes it particularly valuable in diverse applications, including pattern recognition, control systems, and time series prediction.

1. Significance of MPPT in Solar PV Systems

23 The available output power of solar PV systems is a function of the environmental conditions (e.g., irradiance, temperature) and varies as these conditions change. The MPPT controller assists the unit function at its optimum power point despite varying conditions.

14 Traditional maximum point tracking (MPPT) techniques such as Perturb and Observe (P&O), Incremental Conductance, etc. has disadvantages especially under rapidly changing environmental conditions. ANFIS can be a more flexible alternative between the two.

2. Implementation of ANFIS for MPPT

Adaptive Nature: ANFIS is adaptive as rules can adapt over time with the help of random inputs and outputs which make them effective in varying environmental conditions.

Ability to Learn: The strong learning potential of neural networks (for change detection) aids
31 in fast and reliable maximum power point (MPP) tracking by using fuzzy logic (for uncertainty management).

B. MPPT WITH ANFIS-PI CONTROLLER

MATLAB/Simulink The current reference at the instantaneous time is obtained from the Simulink neural network model. and compare it with the current input of the AC network to establish the current error. The integral proportional control calculates the error current. and develop the duties of Inverter

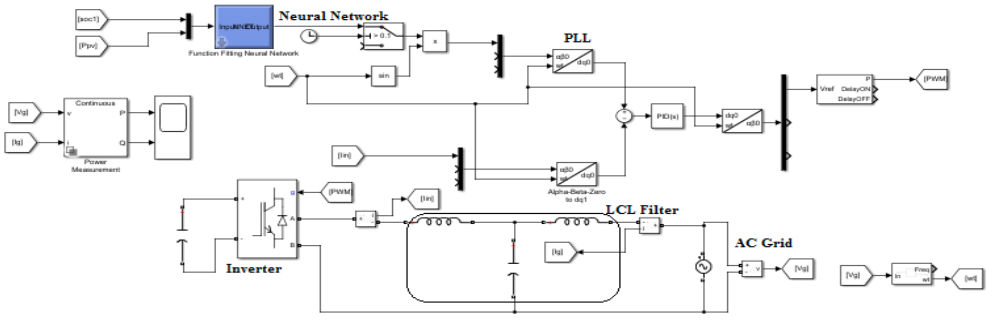


Fig.3.Simulation model diagram for Neural network based AC grid

IV.SIMULATION MODEL IMPLEMENTATION

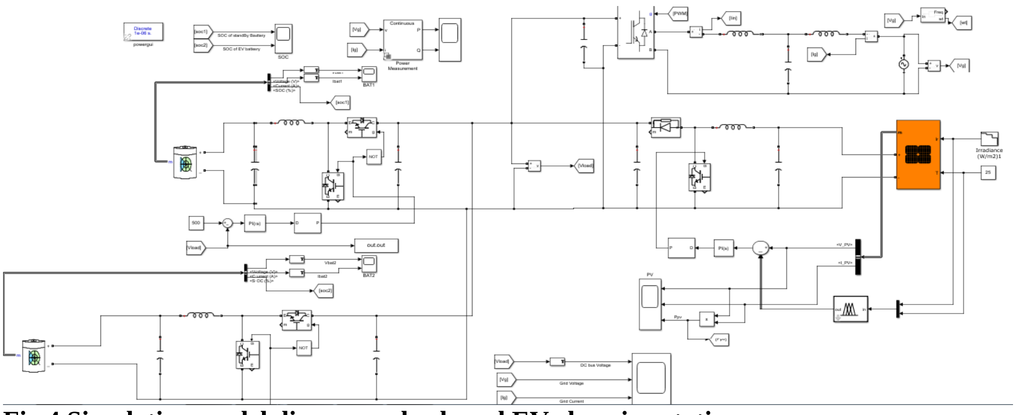


Fig.4.Simulation model diagram solar based EV charging station

Our MATLAB simulation includes several key components:
Solar PV Array and Boost Converter: The PV array is interfaced with to boost converter through an MPPT; the ANFIS is used in this research based on its ability to control the boost converter and maximize the power output.
Stationary Battery with Bi-directional Converter: Ensures charging and discharging of the energy storage to keep the DC bus voltage within operationally acceptable 380V range.

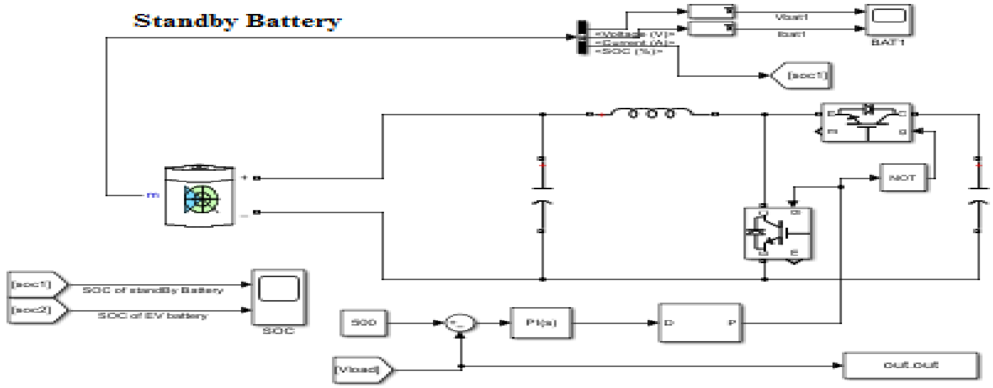


Fig.5.Simulation circuit of standby battery

EV Battery with Bi-directional Converter: Like the case of stationary battery deployment, it guarantees the EV battery is recharged effectively.

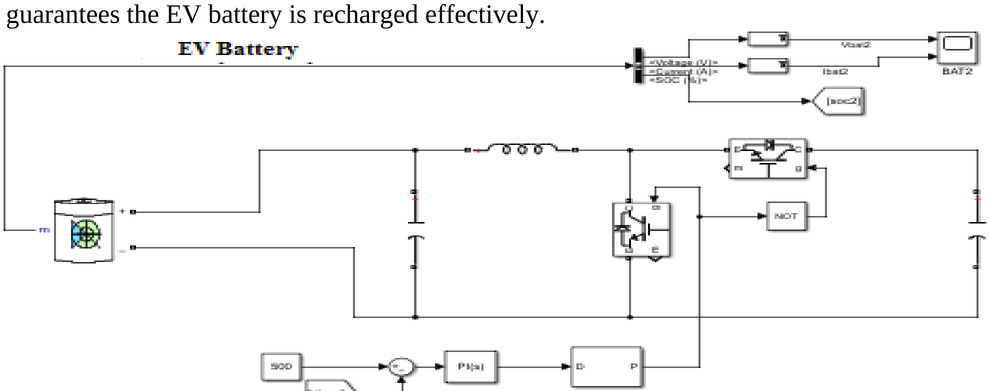


Fig.6.Simulation circuit of EV battery with Bi-directional converter

Grid Integration with Single-Phase Inverter: Uses a Phase-Locked Loop (PLL) for synchronization and neural networks for grid control.

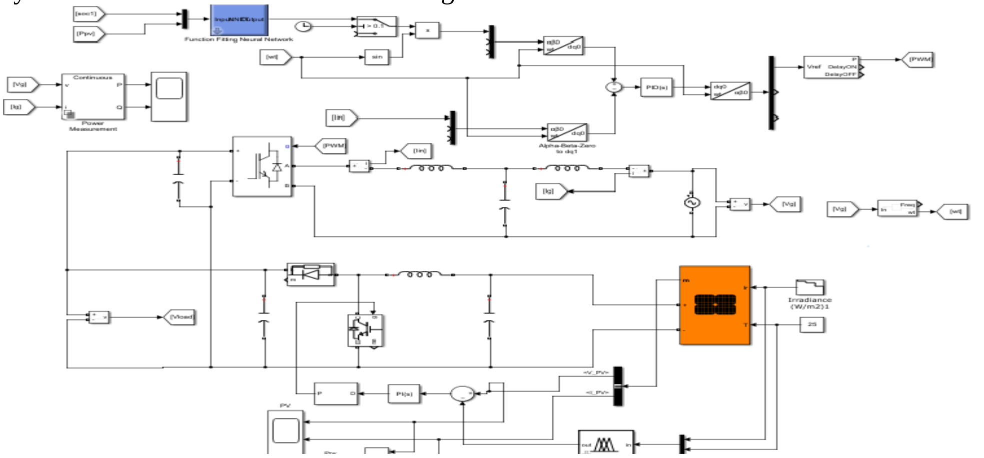


Fig.7. Grid Integration with Single-Phase Inverter

Specific Simulation Elements Solar PV System

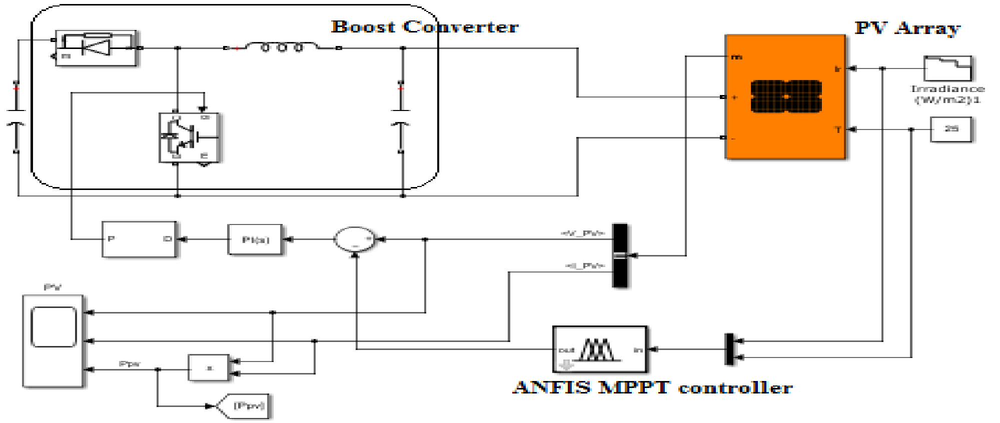
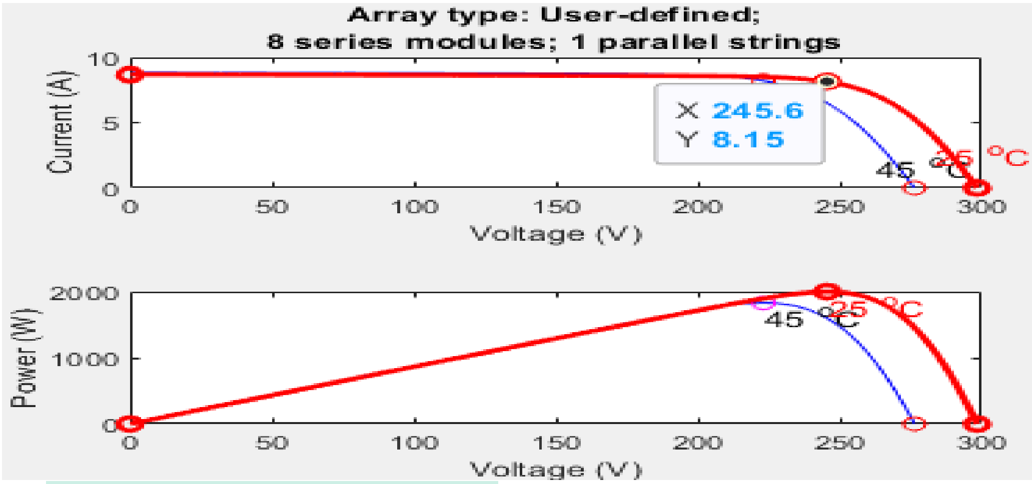


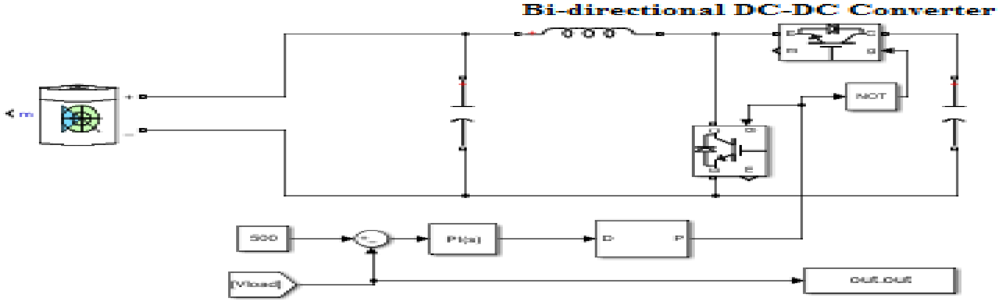
Fig.8.PV array with ANFIS MPPT controller



7 **Fig.9.I-V & P-V characteristics of PV array**

5 **Boost Converter:** An interface that increases the voltage from the PV array; regulated by a PI controller and PWM generator.

17 **Bi-directional DC-DC Converter**: Regulates the DC bus voltage by charging and
25 discharging the batteries so as to control the power flow in and out of the batteries.



Voltage Control: Maintains the voltage across the DC bus at 380V using a Proportional Integral controller along with a Pulse Width Modulation generator.

Single-Phase Inverter: Controls power flow to and from the grid.

24 **Neural Network-Based Control:** Generates reference currents based on PV power and battery state of charge (SOC) to control the inverter.

V.OPERATION OF EV CHARGING STATION

CASE 1: HIGH SOC IS 70 % FOR STATIONARY BATTERY WHILE LOW IS SOC 9 % FOR
30 *EV BATTERY.*

When the battery is charged The current flowing through the battery in an EV will be -30A.
7 Finally, the charging radiation depends on the charging state of the EV battery as the radiation increases. The grid power is around -200, which is a pretty clear indication that the grid draws power from solar panels and batteries. Because charging radiation has an effect The output power of a solar PV can therefore be between 200 and 2000 watts, so it is observed that the
38 battery current is low. The power supplied to the grid is about 400 watts, and the grid receives
15 from the system about -400 watts. The EV battery is set to the standby battery SOC charging
15 mode and the EV battery is lower than the battery capacity.

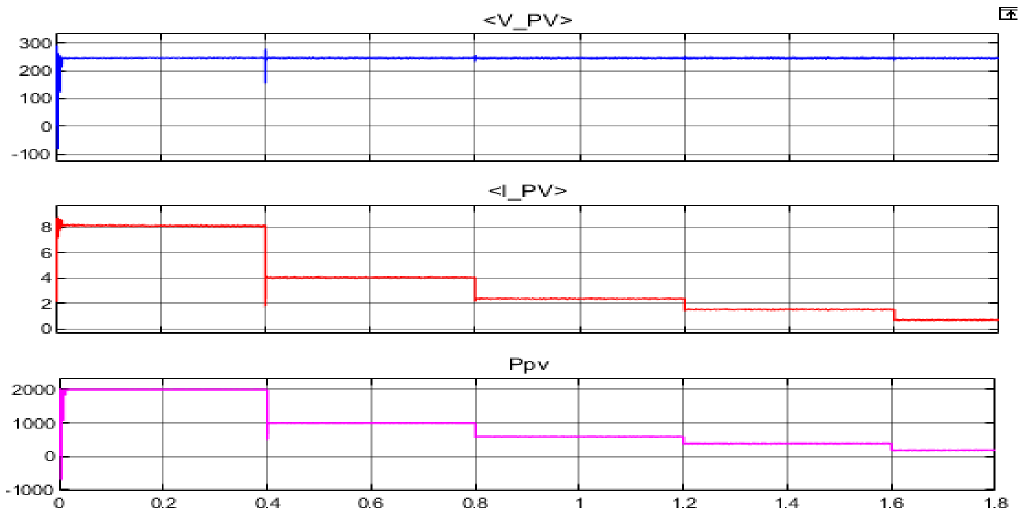


Fig.10.PV array voltage,current and power characteristics at standby battery SOC 70% and EV battery SOC 9%.

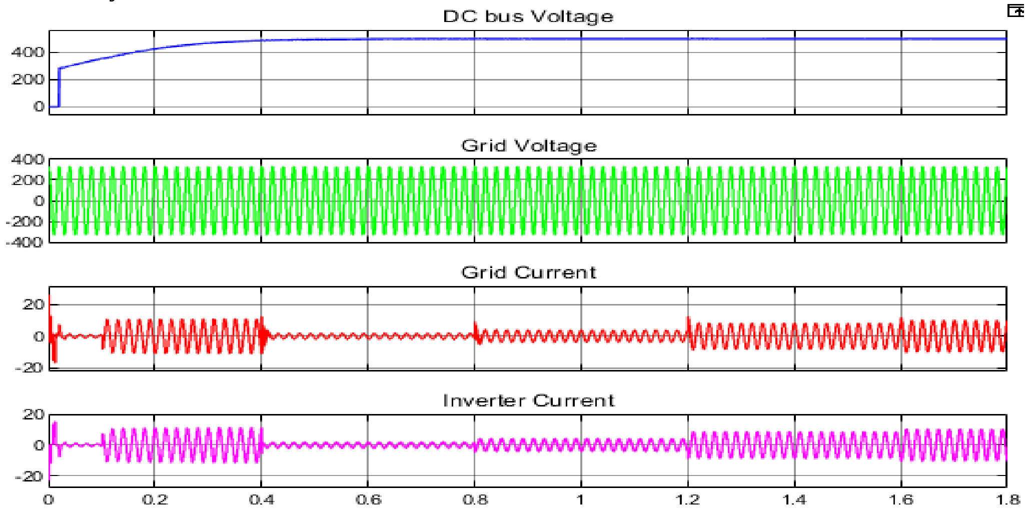


Fig.11.Single phase grid parameters current,voltage and Inverter current waveforms.

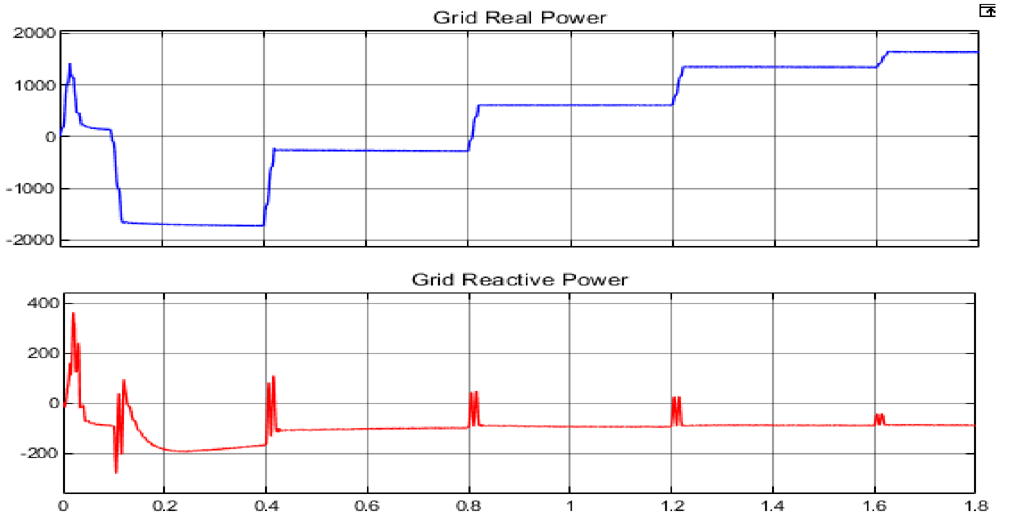


Fig.12.Real and Reactive power characteristics

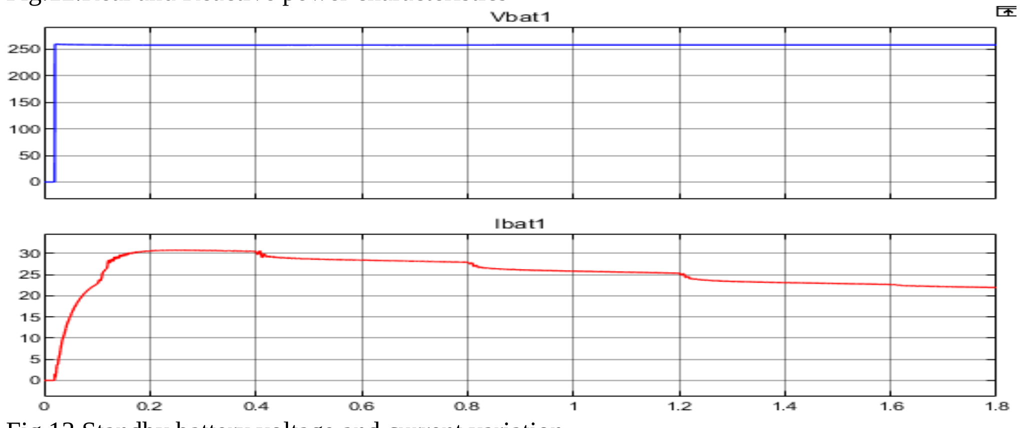


Fig.13.Standby battery voltage and current variation

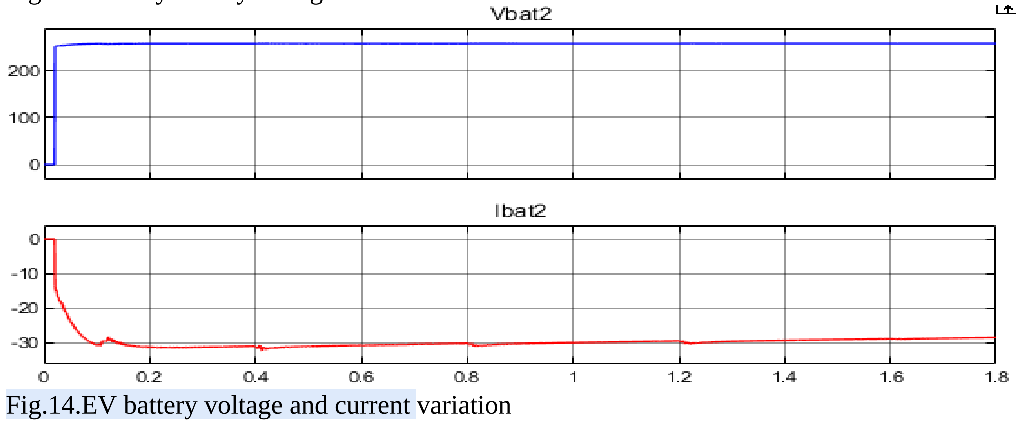


Fig.14.EV battery voltage and current variation

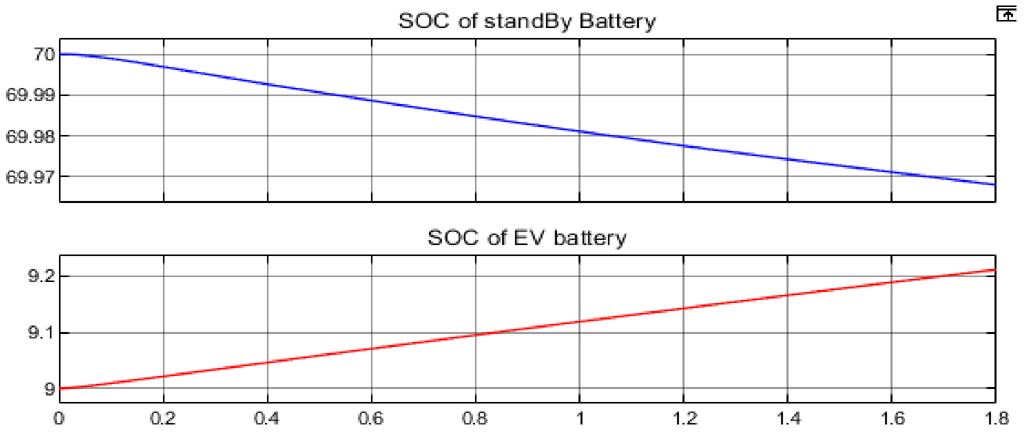


Fig.15.SOC variation of standby battery and EV battery.

CASE 2: FOR STATIONARY BATTERY, THE SOC ESTIMATE IS AT 40% WHILE FOR THE CASE OF EV BATTERY SOC IS BELOW 10%.

Currently, the SOC of the storage system is 40%, while the SOC level of the EV battery is less than 10%. Therefore, under such circumstances The stationary battery is simulated under the same conditions to adjust the SOC to 40%, but the PV power is 2000 watts. Obviously, the SOC will vary according to the radiation adjustment. In this step, the flow flows through the stationary battery. in discharge mode While EV batteries are initially undesirable This means that the battery is in charging mode. which produces -900 watts of electricity. In other words, the solar PV system feeds power back to the grid. As a result, a charging mode that matches the PV power results in a power management plan that reduces the SOC of the backup battery at Stationary and increasing SOC of EV battery. Initial conditions: 2000 Watt rated PV array. Variation due to change in radiation level. So he surrendered.
Operation: In this SOC control scenario, both the stationary battery and the grid contribute to charging the vehicle battery. As a result, the SOC of the stationary battery declines, indicating discharge activity. The grid provides supplemental power as needed, based on the generation from the PV system.

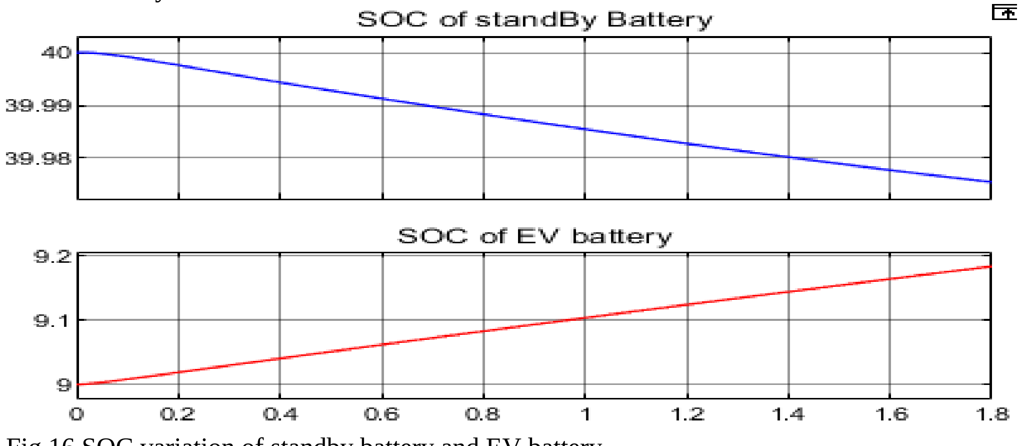


Fig.16.SOC variation of standby battery and EV battery.

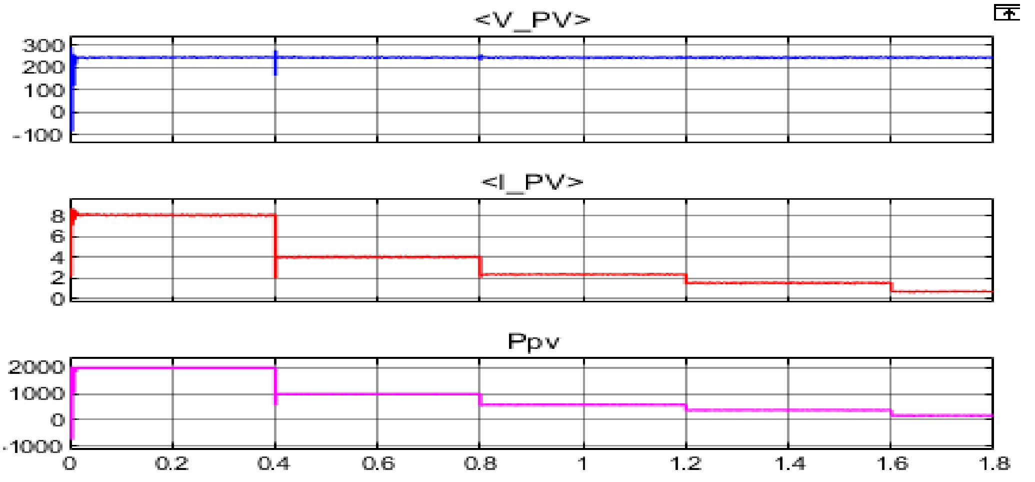


Fig.17.PV array voltage,current and power characteristics at standby battery SOC 40% and EV battery SOC 10%.

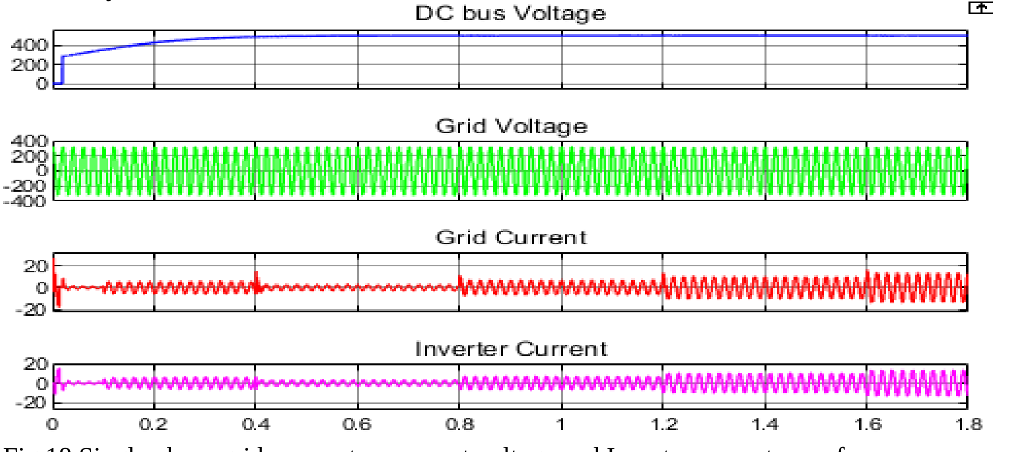


Fig.18.Single phase grid parameters current,voltage and Inverter current waveforms.

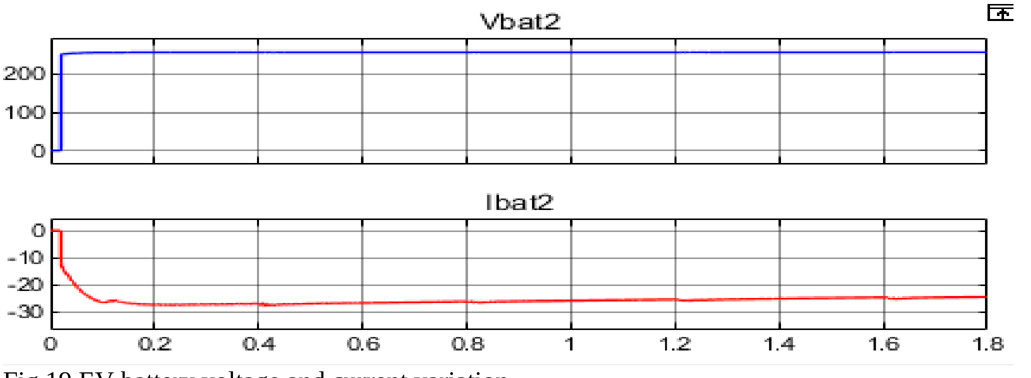


Fig.19.EV battery voltage and current variation

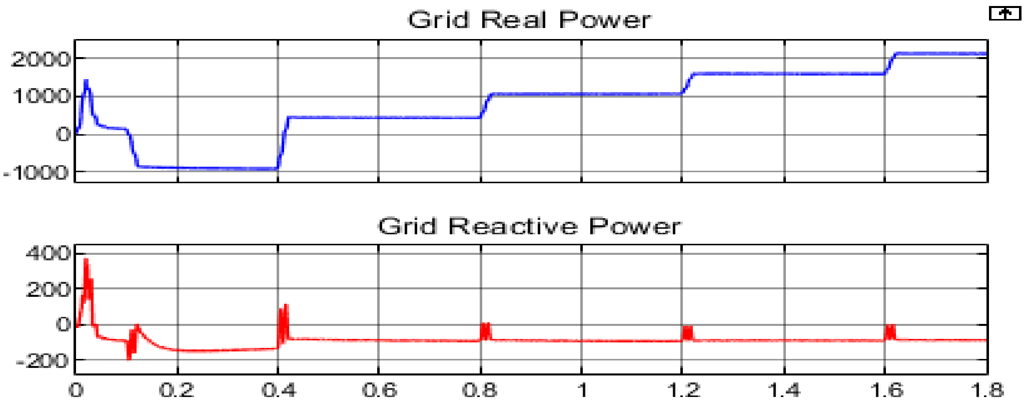


Fig.20.Real and Reactive power characteristics

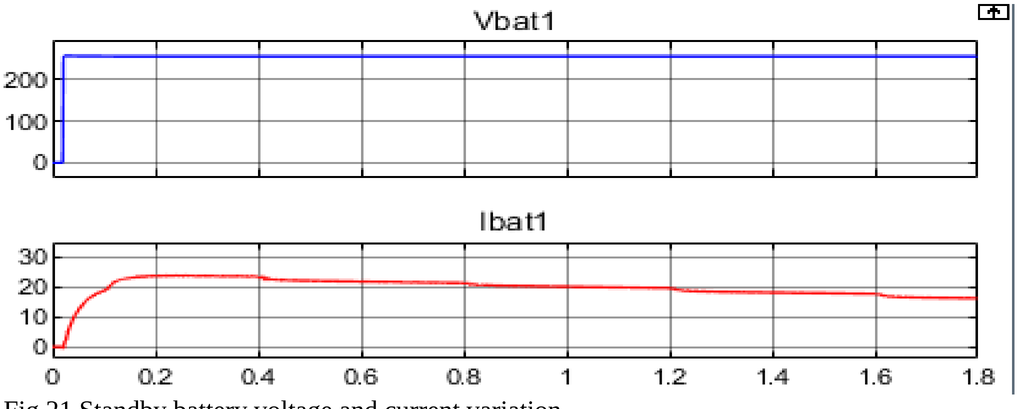


Fig.21.Standby battery voltage and current variation

CASE 3: LOW SOC (10%) FOR BOTH BATTERIES

The next adjustment involves charging the SOC of the storage battery and setting it to 10%. The next step is to calibrate this model to evaluate the feasibility of the solar electric vehicle (PV) (EV) charging station concept.) As shown in the charging mode, the SOC of the backup battery and the SOC of the EV battery were both charged at approximately the specified SOC of 10 percent. The grid is used for the availability of energy for charging both the standby and the EV batteries however, the solar PV system is influenced by degrading irrigation conditions.

The storage battery's current is negative, however, the standby battery SOC is rising as it remains in charging state, Grid is still powering. As such the current flowing between the inverter and the grid is measured and found to be reducing the PV power output. Decreases in PV power due to reduced irrigation lead to an increase in the grid power supply as shown below. However, both the storage battery and standby battery have a negative current negatively and hence they are still in the charging mode though the current in the battery increases as power is supplied from both PV systems and the utility grid.

Electrical power supply infrastructure is increasing while PV energy is decreasing, which means increased supplementation from the grid. according to the dynamics described above. We have determined how a solar-powered EV charging station will work. The model uses ANFI and EMS that researchers designed from a neural network. Supervision detected Charging the battery and the PV power input is the input to the neural network.

Operation: Two batteries are charged. By receiving power from the PV array and the grid, the capacity of both batteries increases. So we can conclude that it was charged successfully. The continuously low output of a PV system requires the grid to increase power.

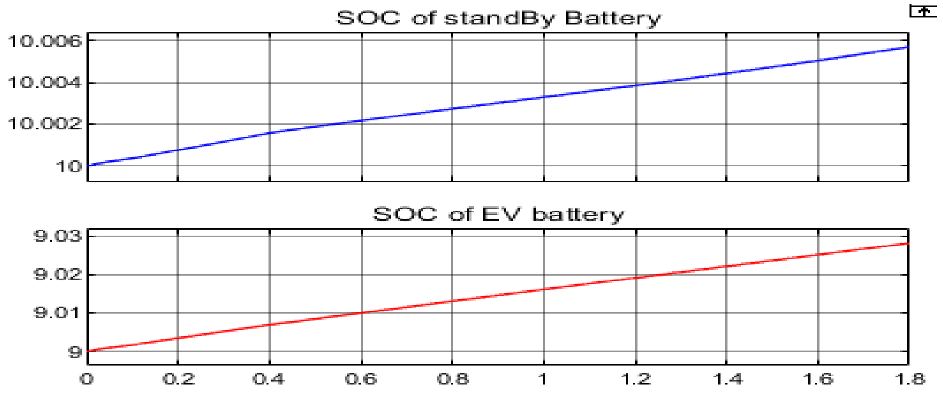


Fig.22.SOC variation of standby battery and EV battery.

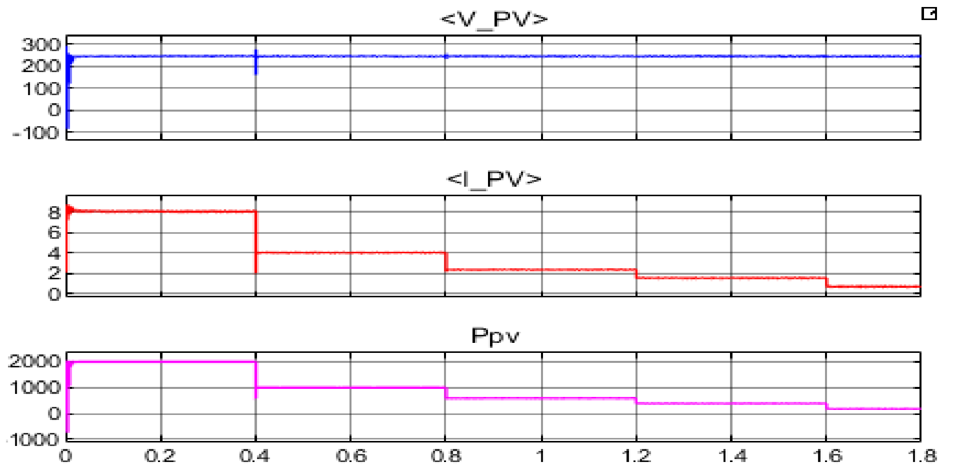


Fig.23.PV array voltage,current and power characteristics at standby battery SOC 10% and EV battery SOC 10%.

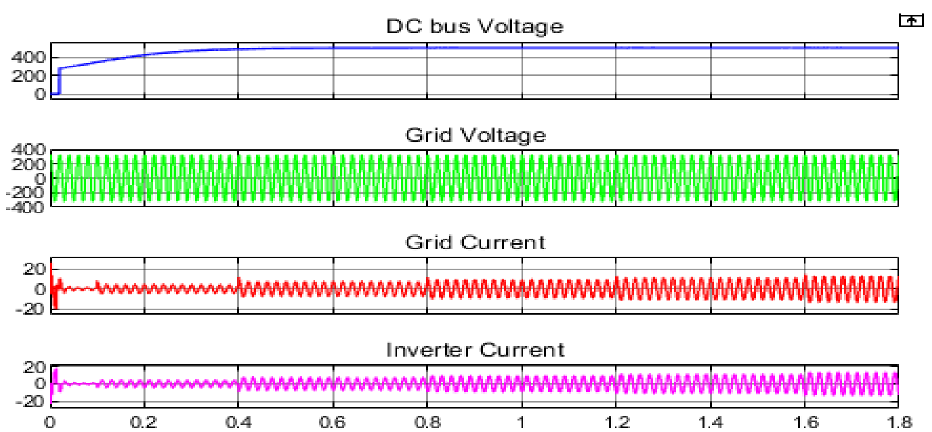


Fig.24.Single phase grid parameters current,voltage and Inverter current waveforms.

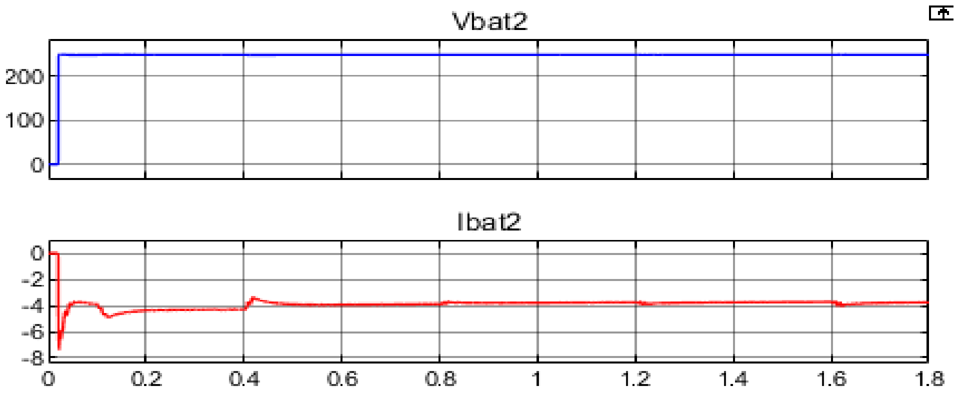


Fig.25.EV battery voltage and current variation

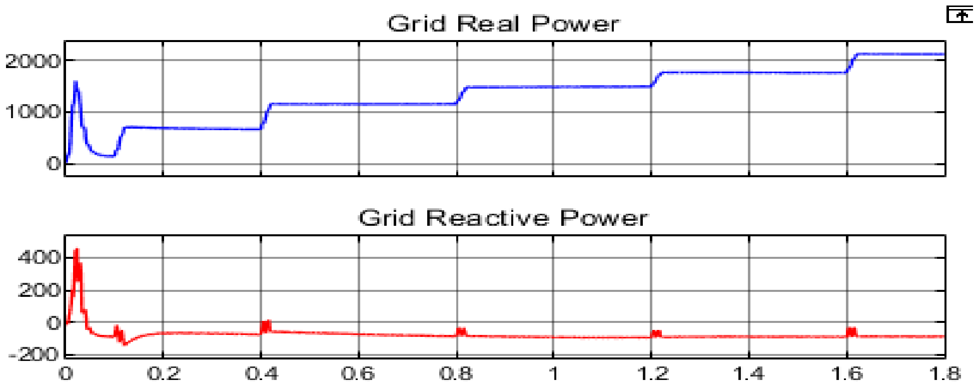


Fig.26.Real and Reactive power characteristics

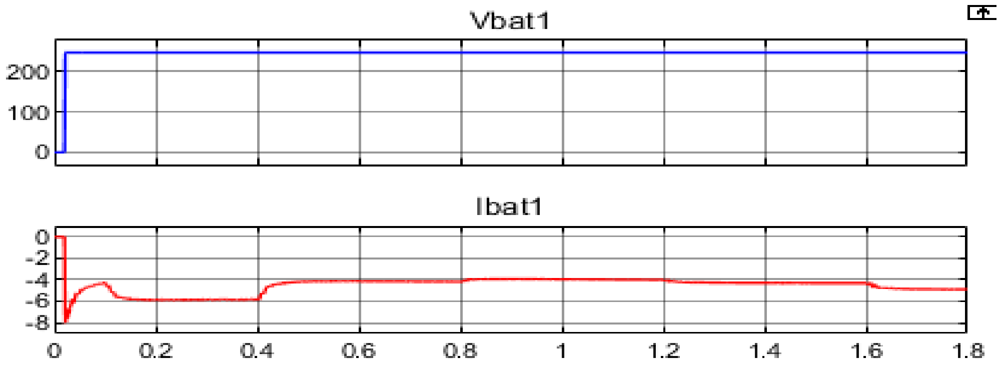


Fig.27.Standby battery voltage and current variation

VI.CONCLUSION

Analyzing the efficiency of the proposed solar photovoltaic (PV) system for charging a station that is capable of charging electric vehicles (EVs) MATLAB simulation has been done. By expanding the Peripheral ANFIS MPPT and Neural Network Energy Management it offers a satisfactory increase of power control and power consumption. As a kind of real reflection of practical cases, this kind of simulation gives a similar view and demonstrates that renewable power resources are essential to EV charging stations. A charging station employing the use of a solar PV array together with a BESS and in combination with the support of a grid results

2 in a much more feasible picture. It is essential to develop infrastructure that meets the charging demands of all connected electric vehicles. This paper emphasizes the use of ANFIS as a controller within a Proportional-Integral (PI) based system to optimize voltage output. By maintaining a constant DC bus voltage, the system ensures access to the required power. The station's bus voltage is stabilized, and its power management capabilities are proposed for three distinct scenarios. Consequently, further exploration of the proposed model is warranted to accommodate a greater number of electric vehicles, particularly in contexts such as home charging or EV charging stations located at workplaces or parking facilities.

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