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# Bidirectional Charging Circuit for Electric Vehicles based on Renewable Energy using an ANN Controller

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**ABSTRACT:** In this work, an Artificial Neural network (ANN) controller full bidirectional electric vehicle (EV) charging circuit that utilizes renewable energy for power management optimization in vehicle-to-Grid (V2G) and Grid-to-vehicle (G2V) applications is proposed. The system comes with a boost converter as the main energy managing device with a solar photovoltaic (PV) array being the power source, utilizing an Incremental Conductance maximum power point tracking (MPPT) algorithm to optimize strength extraction. A bi-directional DC-DC converter provides energy transfer between grid and battery under control, thus enabling efficient discharging and charging. The ANN controller provides dynamic response and stability as a result of adaptively changing system parameters, which is better than a standard Proportional-Resonant (PR) controller in managing non linearity and dynamic grid conditions. A 100AH battery is charged by a boost converter providing 400V as output voltage from a solar PV panel. Voltage is reduced to 220V battery requirement. Voltage and current remain in the same phase at the time of charging mode but current aheads voltage at discharging mode, i.e., reverse power flow exists. SOC behavior shows the quick and proper charging. Simulation results confirm that the ANN controller works well as far as optimization of power flow, grid dependence reduction, and efficiency are concerned. The proposed system can charge EVs with zero emissions, enhance the grid robustness through V2G operation, and provide a green energy solution to next-generation smart grids. Key words— Renewable energy, bi-directional charging, artificial neural network, maximum power point tracking, vehicle-to-grid (V2G), grid-to-vehicle (G2V)

## I. INTRODUCTION

Electrically powered Vehicles (EVs) are today an integral part of the shift towards clean transport, due to the need to lower greenhouse gas emissions, fossil fuel reliance, and real air pollutants. but large-scale deployment of EVs will place additional strain on the strength grid, especially during peak charging times. To meet these stringent demands, the use of renewable energy sources and solar photovoltaic (PV) systems for electric vehicle (EV) charging stations is progressively gaining a lot of interest. Solar power is clean, abundant, and renewable power that can potentially greatly reduce the environmental footprint of EV charging.

Among the prominent issues of solar-powered fully EV charging systems is how to optimize power extraction from the pv panels under varied environmental conditions like irradiance and temperature. traditional maximum power point tracking (mppt) approaches, i.e., incremental conductance and perturb & observe, are broadly used, typically in conjunction with proportional-critical (PI) or proportional-resonant (PR) controllers. but these controllers are restricted by repetitive tuning parameters, slow dynamic response, and less good performance under nonlinear and time-varying operations. In order to overcome these drawbacks, in this paper, a renewable energy based bidirectional EV charging circuit with an Artificial neural network (ANN)-based MPPT controller is proposed.

The system consists of a solar pv array coupled with a Boost converter, energy storage battery coupled using a bidirectional DC-DC converter, and grid connection using a bidirectional AC-DC converter. the ANN controller is a

substitute for the traditional PI architecture to achieve real time learning and adaptive control to realize quicker convergence, reduced steady-state error, and improved power quality. The V2G as well as the G2V modes are aided by the system.

While in G2V mode, the system charges the EV battery with Solar or grid electricity, in V2G mode, the power stored can be fed into the grid at any given time of peak demand. this two-way flow flow stabilizes the grid, encourages load balancing, and improves the overall energy usage. The ANN-completely method also offers better reduced Total Harmonic Distortion (THD) and better dynamic as well as nonlinear system behavior regulation.

## **II. DESIGNING AND CONFIGURING AN EV CIRCUIT**

The intended charging system for the EV will be powered to the maximum possible extent by renewable energy, which is primarily supplied by the solar photovoltaic (PV) array. The DC output power of the PV array is regulated based on the following equation:

$$P_{PV} = V_{PV} \times I_{PV}$$

But voltage and current are varying because of the change of temperature and sun irradiation. The PV output is supplied to a DC-DC boost converter according to the MPPT algorithm, which increases the output voltage with the assistance of the formula as follows in order to maintain the system in efficient operation.

$$V_{out} = \frac{V_{in}}{1 - D}$$

where D is duty cycle. Classical Perturb and Observe (P&O) or Incremental Conductance techniques are substituted by ANN based MPPT controller which dynamically adjusts this duty cycle so as to draw the maximum power Once MPPT condition is achieved,

$$\frac{dP}{dV} = 0$$

which is calculated by the ANN by correlating environment inputs to control outputs, using the P learned by it, or to be provided by the designer

The switched EV battery pack bidirectional DC-DC converter is supplied from the boost converter. It is charging mode (G2V) and the output voltage is

$$V_o = D \cdot V_{in}$$

It is discharging mode (V2G), it is in boost mode, which is

$$V_o = \frac{V_{in}}{D}$$

Battery power exchange is calculated through

$$P_{battery} = V_{bat} \cdot I_{bat}$$

and overcharging or deep discharge protection, the state of charge is regulated by the system in batteries. The optimum energy balance equation is regulated by ANN controller and control signals are synchronized at predetermined intervals to above mentioned parameters so that maximum energy flow is ensured:

$$P_{PV} + P_{grid} = P_{battery} + P_{load} + P_{loss}$$

where the switching loss and conversion losses of converters are part of P loss.



For grid connection to be enabled, synchronization and absorbing/reactive power is achieved with a bidirectional AC-DC converter. The actual power flow equation from the grid and to the grid is given below.

$$P_{\text{grid}} = V_{\text{grid}} \cdot I_{\text{grid}} \cdot \cos(\theta)$$

Historical data of solar irradiance, temperature, grid load, and demand are used in ANN training for the identification of the control towards the goal of system efficiency and loss of power minimum. Historical variable records are used in ANN training without the need for a specific system mathematical model such that it will learn to identify its nonlinear and dynamic properties, which may not be possible with traditional PI or PR controllers.

In addition, the voltage-power characteristics of the PV module are given by the following equation:

In addition, the voltage-power characteristics of the PV module are given by the following equation

$$I_{\text{PV}} = I_{\text{ph}} - I_0 \left( e^{\frac{q(V_{\text{PV}} + I_{\text{PV}} R_s)}{nkT}} - 1 \right)$$

where  $I_{\text{ph}}$  is photocurrent,  $I_0$  is reverse saturation current,  $q$  is electron charge,  $R_s$  is series resistance,  $n$  is diode ideality factor and  $T$  is temperature in Kelvin. This non linearity interaction is one of the reasons why ANN would be preferable to be utilized in control since it can learn and react accordingly to such a pattern. The ANN is trained for many operating conditions so that the EV charging circuit becomes adaptive, robust, and reactive enough to attain the optimal energy utilization in G2V, V2G modes.

### III. PV-BASED EV CHARGING

Solar and PV power are charging the EV battery in daytime. Direct solar PV system charging of an EV utilizes a proficient and efficient MPPT algorithm for the efficient harvesting of energy. These dominant MPPT Algorithm results in the use of Perturb & Observe (P&O), in an effort to prove oscillation along the along maximum power point thus resulting in sub optimal performance. In contrast the ANN based- MPPT controller trains real time solar conditions and conditions such as PV current voltage, irradiance and temperature variation in order to dynamically optimize the duty cycle of the boost converter. The ANN keeps training from various solar conditions. The technique enhances the response time and precision of monitoring in order to achieve better solar power efficiency. Since the ANN capacity to predict the best operating factor under changing circumstances ensures that the PV system achieves optimal efficiency, energy wastage is avoided while the EV charging system as a whole is maximized.

Controller	Voltage	Current
PI	0.76%	1.52%
ANN	0.45%	1.17%

THD Comparison

### IV. GRID-CONNECTED ELECTRIC VEHICLE CHARGING

In this operating mode the grid charges the electric vehicle. This mode operates under the non-existence of solar power. The ANN control system optimizes charging rate in real time primarily on the basis of real time grid condition, battery SOC, and energy demand. In traditionally disparate conventional PR controllers, which follow pre-programmed charge rates, the ANN model learns the changes in the grid continuously and modulates the charging power in a dynamic way. The ANN prevents the overloading of the grid by the charging process through scheduling energy use off-peak time, enhancing grid stability. Besides, the ANN minimizes Total Harmonic Distortion (THD) by controlling the switching patterns of AC-DC converters, maintaining power quality. The capability of ANN to forecast grid fluctuations enables effective management of energy, minimizing peak demand stress and preventing voltage instability.

Controller	Voltage	Current
PI	1.10%	1.90%
ANN	0.56%	1.00%

THD Comparison

## V. GRID SUPPORT WITH ELECTRIC VEHICLES

In this operating mode bidirectional AC-DC converter acts as inverter and regulates grid output current. Power is transferred from grid to battery according to power grid demand as well as owner comfort of EV. ANN controller provides effective synchronizing of battery discharge cycle with frequency frequency and voltage phase of grid for the grid stabilization. Unlike traditional control systems that are engaged in dynamic grid balancing, ANN continuously monitors prevailing grid demand, SOC, and peak energy consumption patterns to ensure that it can regulate the best discharge rate so that battery degradation is avoided and power not needed is dispatched to the grid. ANN also allows EV owners to become part of demand response programs, peak sales generation in addition to sharing grid reliability.

Controller	Voltage	Current
PI	1.59%	2.47%
ANN	0.81%	1.19%

THD Comparison

## VI. RESULTS AND DISCUSSION

Figure 1 ,shows the simulation circuit diagram

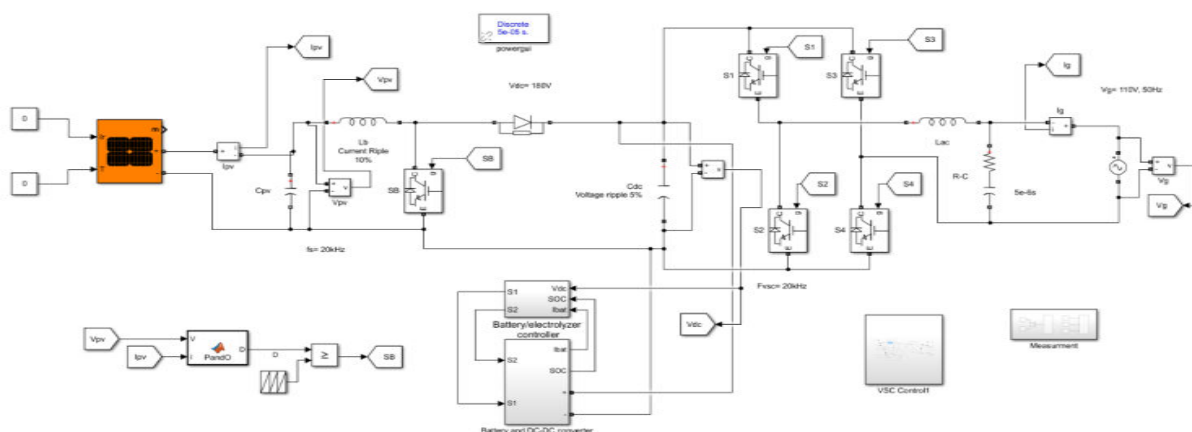
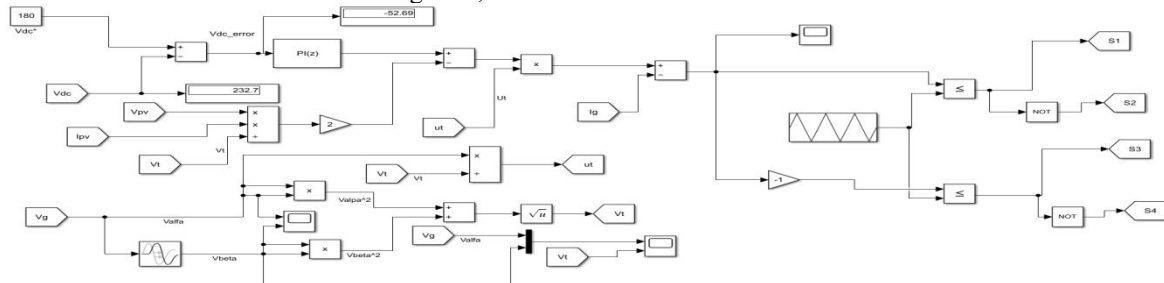


Figure 2, shows VSC Control scheme



### Case 1 ELECTRIC VEHICLE CHARGING WITH PV

Figure 3 ,shows the PV DC voltage and current

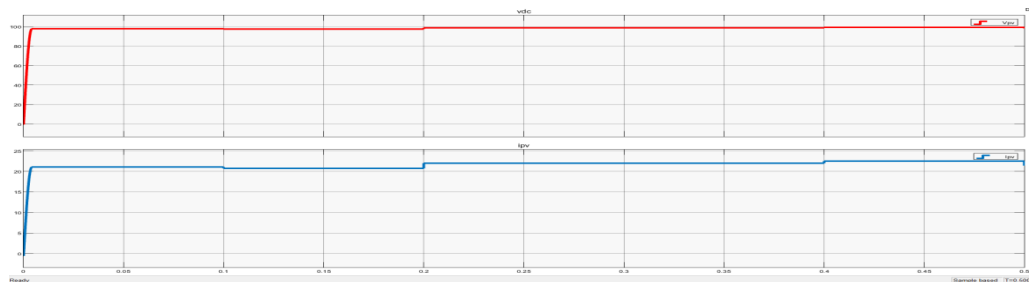


Figure 4, shows the grid voltage and current

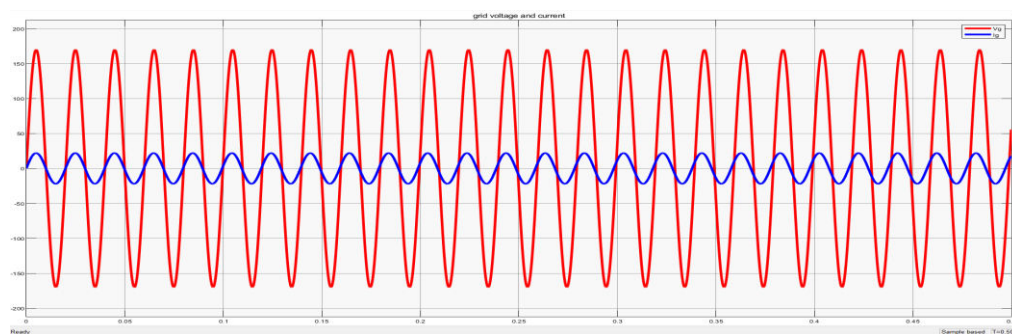


Figure 5, shows Battery voltage and current

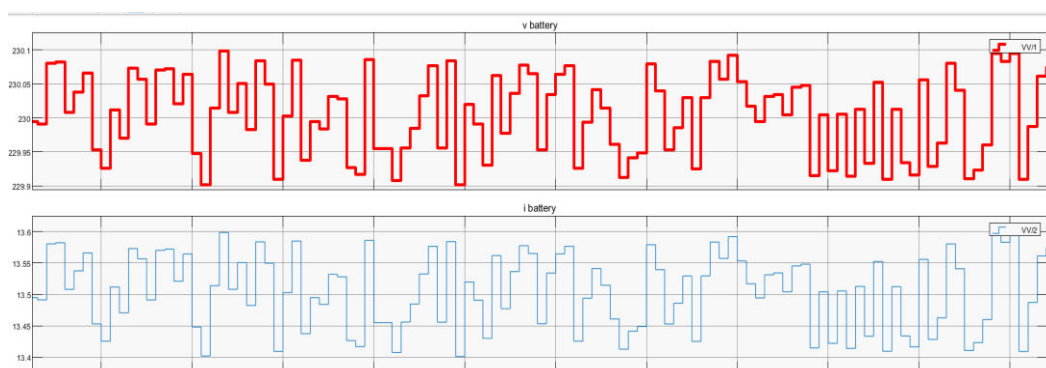
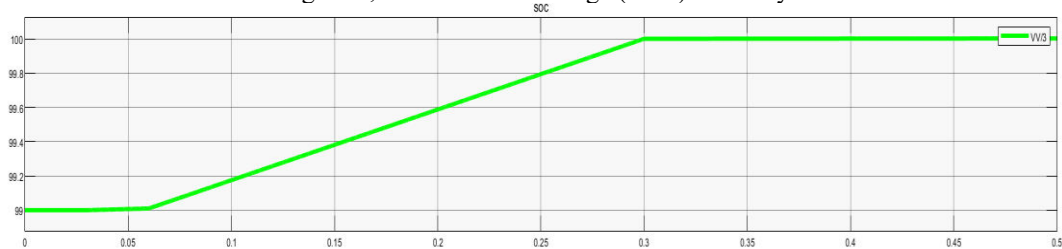


Figure 6, shows state of charge (SOC) of battery



### Case 2 ELECTRIC VEHICLE CHARGING FROM GRID

Figure 7, shows grid voltage and current

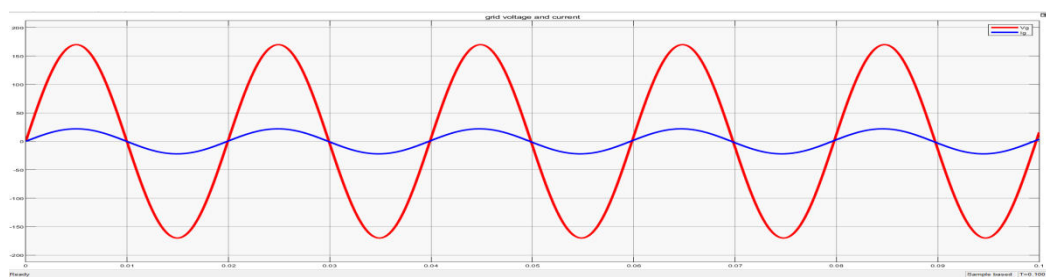


Figure 8, shows Battery voltage and current

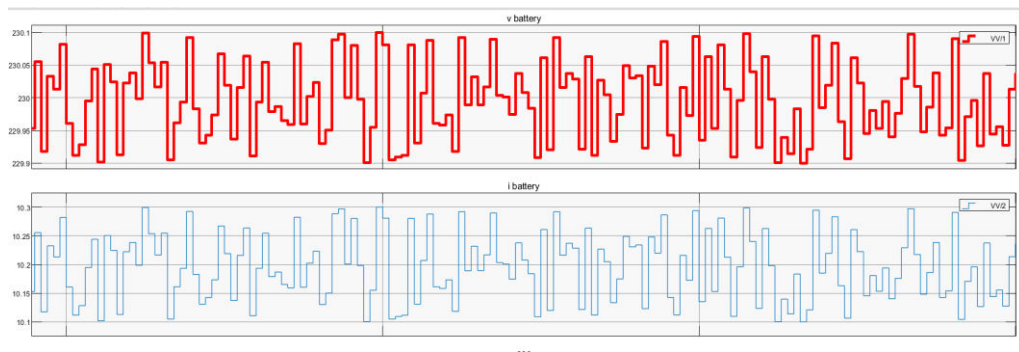
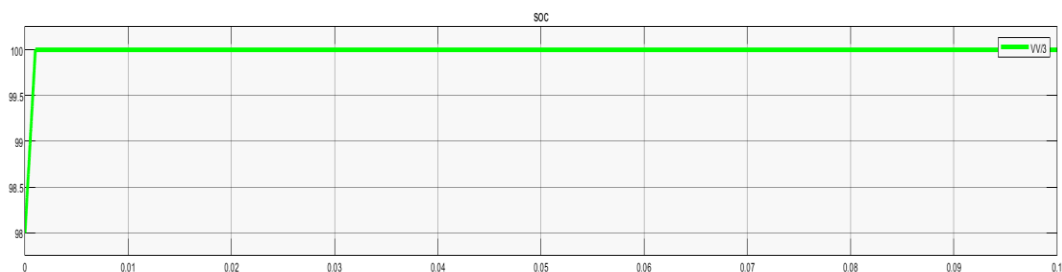


Figure 9, shows State of Charge (SOC) of the battery



### Case 3 ELECTRIC VEHICLE SUPPORT TO GRID

Figure 10,shows the grid voltage and current

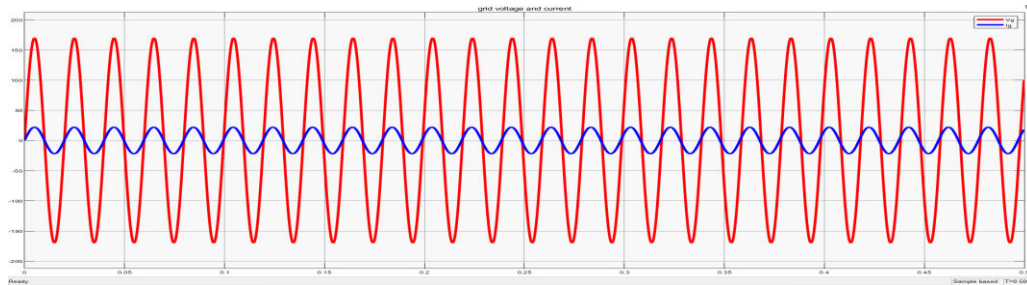


Figure 11,shows Battery voltage and current

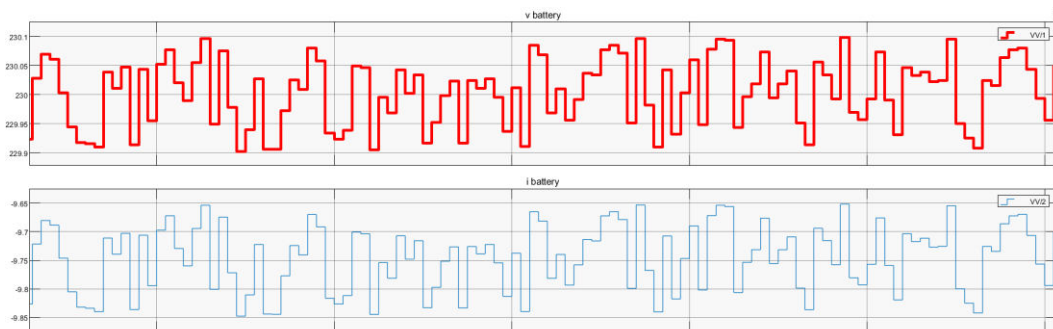
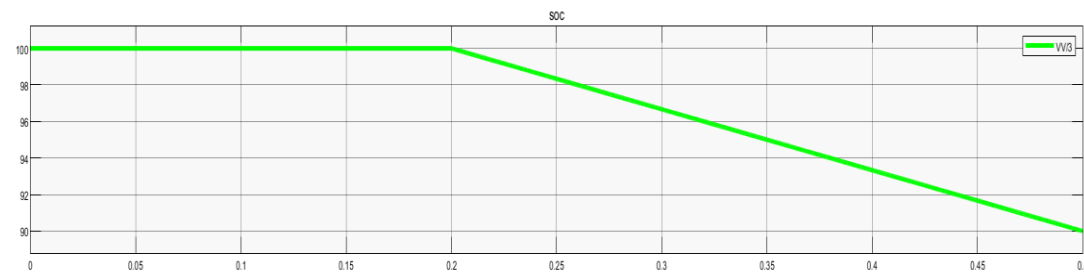


Figure 12,shows the State of Charge Soc of battery



## VII. CONCLUSION

The paper shows a fully bidirectional electric vehicle (EV) charging circuit based on renewable energy with an artificial Neural network (ANN) controller to enhance the overall performance of the vehicle-to-Grid (V2G) and Grid-to-vehicle (G2V) operation mode. The system proposed has a solar PV array since the initial source of power, in addition to a buck converter for regulation of charging voltage and a buck converter to offer some level of compatibility with EV battery demands. A passive filter is added in order to enhance power quality, minimizing harmonics and aligning with IEEE 519 standards. The ANN controller possesses adaptive learning capabilities, efficiently following reference current and voltage with minimal steady-state error. In contrast to conventional controllers, the ANN controller improves system efficiency, State-Of-Charge (SOC) control, as well as smooth switching between charging and discharging modes. Simulation implications validate that the system ensures grid stability, reduces overall Total Harmonic Distortion (THD). Moreover, use of renewable power sources reduces voltage fluctuations and overloading issues in the power distribution network. The proposed system is a sustainable, smart, and efficient means of EV charging infrastructure, offering a greener energy environment while encouraging improved EV uptake.



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