ISSN: 0974-5823 Vol. 7 No. 8 August, 2022

International Journal of Mechanical Engineering

Solar Powered Off-Board Smart Charging Station for Electric Vehicles based on Artificial Neural Network Technology

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Abstract: Using solar panels and artificial neural networks (ANNs), this initiative aims to enable off-board smart charging for electric automobiles. Solar panels and a complete bridge converter are combined with an ANN controller and solar panels to create an EV charging station that can be used at home. This kind of DC off-board charger relies on a power supply and full-bridge DC-DC converter. There must be an MPPT device to monitor and provide the solar panel's maximum output if the power source is a PV array. The efficiency of chargers has been improved by the use of various converter topologies. To achieve a quick reaction time, this research used a DC-DC converter with a high-frequency transformer and artificial intelligence. An implementation of the suggested system using Simulink/Matlab has been performed, and the findings have been well documented.

Keywords: Photovoltaic (PV), DC-DC boost converter, Full bridge DC/DC converter, SEPIC converter, Artificial Neural Network (ANN)

I.INTRODUCTION

As typical ICE automobiles fueled by gasoline, diesel, natural gas, and other fossil fuels have an increasingly negative influence on the environment, electric vehicles are now attracting more attention. The usage of conventional cars has resulted in an increase in harmful air pollutants including CO2 and NOX in the atmosphere. Because of their capacity to minimise fossil fuel usage and pollution, electric cars are a good alternative. In contrast, drivers of traditional automobiles are often forced to make a tradeoff between performance and efficiency. Electric cars are projected to exceed gasoline-powered vehicles in terms of power transfer and range. Electric vehicles are expected to take over as the primary mode of transportation in the majority of countries throughout the world by the year 2030. In India, electric automobiles will also be encouraged by 2030. There will be a need for both commercial and household charging stations in every state [1]. Many charging stations in remote and island settings will be reliant on renewable energy and off-grid power sources [2]. Solar power can only be utilised during the day since it is reliant on a range of environmental factors. [3] The solar array's optimal power generation necessitates the construction of efficient power trackers. Energy storage systems are required for both supplying electricity in an emergency and storing it when there is a surplus. It is being developed battery management technologies to keep the battery's charge level in the correct range and to prevent overcharging [4]. A charger is now being developed using cutting-edge machine learning and artificial intelligence technology [5]. A converter and a control circuit make up the bulk of a standard DC-to-DC charging station. Design and efficiency considerations are unique for each charger converter topology. It is a DC-DC boost converter [10]. contains the fewest components of the three variants. Compared to SEPIC, the converter's efficiency is higher [6,7]. To get the most out of this system's power point tracking, the output voltage of the PV array must be kept lower than the battery's terminal voltage. MPPT requires voltage and current sensors, hence the SEPIC topology employs more components than any other [8,9]. Due to the increased costs and decreased efficiency, the charging system becomes more and more costly. As a result, using the procedure with both sensors makes it more difficult. Battery corrosion and battery life are harmed because the voltage sensor shortens the time it takes to charge the battery when the voltage is high. As a result, in terms of power output, the SEPIC converter is significantly less efficient than a DC-DC boost converter. There is a topology to both the Cuk and Zeta converters, just as there is with SEPIC. A negative DC-DC converter output supply comes standard with Cuk converters, which offer a wide range of output voltage and an unlimited MPPT execution zone. The efficiency of the solar panel is lowered as a result. Compared to a typical full-bridge converter, the HFT full bridge converter is more difficult to build cost-effectively. The full Switched mode power supply is used to power the bridge DC-DC converter (SMPS). The galvanic isolation between the input and output is provided by the HFT technology. ' a high-power factor is achieved by having a low harmonic content [16, 17]. In order to design basic converter topologies that can be mimicked in computer programmes, these research attempt to provide a fundamental knowledge of how an electric vehicle charger works. This exercise aids in the development of a cost-effective off-board charging device for residential and commercial applications with stringent space restrictions. This approach might be beneficial as a first step in the development of future smart charging solutions. The efficiency and component requirements of as part of the design of this EV charger, a complete comparison of three converter methodologies is being conducted: Full-bridge converter using HFT, SEPIC, and DC-DC boost converters. Detailed descriptions of all topologies are provided. It is at this point that Simulink/MATLAB findings are revealed

II.EXISITNG TOPOLOGIES FOR CHARGERS

Figure 1 shows a DC-DC charger fueled by solar energy. The solar PV module, converter topology, and load are the main components (battery pack). The 30-kWh battery pack is powered by a single-phase system with a 110 W solar PV module. The converter switches at a rate of 20 kHz, which is rather fast. Following are the different converter topologies that were used in this research, as previously stated.

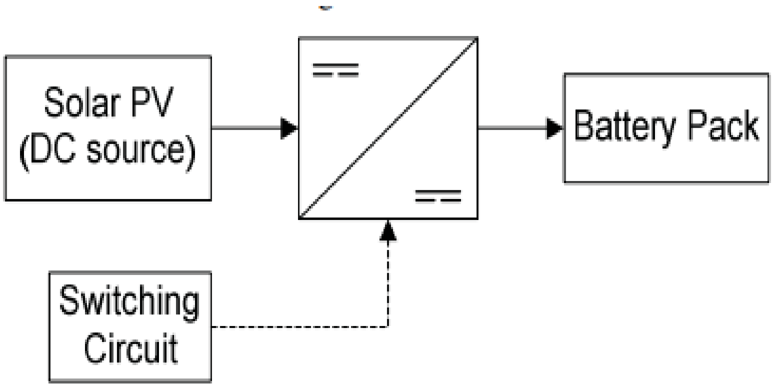

Figure.1. DC-to-DC charger based on solar PV power

a) Battery charger using a solar-powered DC-DC boost converter

Figure 2 displays a solar PV-powered EV charging station that uses a boost converter to charge the vehicle. It is important to enhance the voltage of the battery bank using a DC–DC converter.

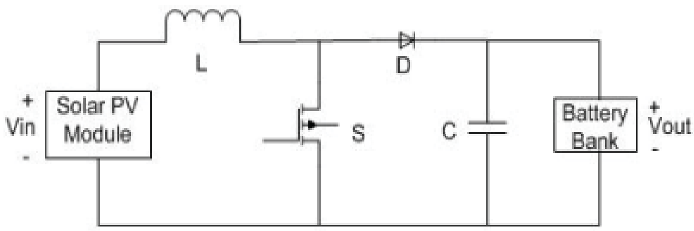

Figure. 2. Diagram of a DC-DC charger that uses a boost converter

There are 2 operating modes for a DC/DC boost converter. A blown fuse: Electricity may flow freely through the switch because of its low resistance. The switch and the DC input source produce a current-conducting loop. During the ON state, the inductor current increases continuously with a positive slope until it reaches its maximum value. In the end, the current returns to its original value, albeit with a downward slope. As a result, the nett change in the inductor current throughout the course of a whole cycle is zero. The diode is biased "forwards" since the switch is acting as an open circuit. In this situation, the inductor's polarity has been reversed. The load receives the stored energy from the inductor. The flow is still going in the same direction. The voltage at the output is raised because the inductor also functions as an input source. This equation may be used to calculate the duty cycle (D) depending on input and output characteristics.

$$D = 1 - {}^{V_{in}}/_{V_{out}} \qquad (1)$$

Where,

Vin-input voltage

Vour-output voltage

b) Battery charger using a solar-powered SEPIC converter

Figure.3 depicts a SEPIC-based EV charging setup powered by solar PV panels. It is possible to set the output voltage to be less, larger, or the same as the input voltage. Duty cycle of the switch is used to regulate output.

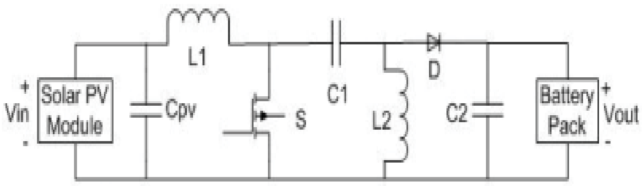

Figure 3. Diagram of a DC-DC charger that uses a SEPIC converter

The SEPIC can operate in two different ways. The IGBT is now powered up as a result of this. Voltage Vin and capacitor C1 charge inductors L1 and L2, respectively. When the diode is switched off, the output is the voltage across capacitor C2. The capacitors are charged whenever the diode's current is supplied to the load through a low-pulse IGBT. By charging the inductor over a longer length of time, more inductor voltage may be achieved, which boosts output as the duty cycle rises. This equation may be used to calculate the duty cycle (D) depending on input and output characteristics.

$$D = \frac{V_{out}}{V_{in}+V_{out}} \qquad (2)$$

Where,

Vin-input voltage

Vout-output voltage

c) Battery charger using a solar-powered full bridge converter with HFT

Fig. 4 shows the design of a complete bridge converter, which includes a transformer for galvanic isolation (Q1, Q2, Q3, and Q4).

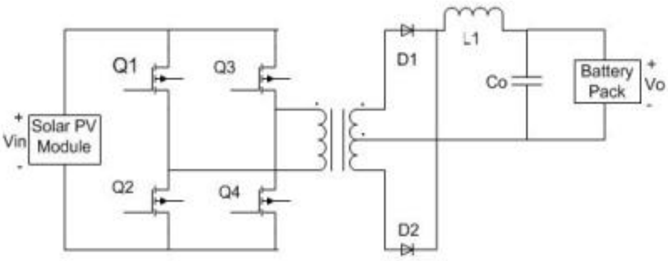

Figure. 4. Diagram of a DC-DC charger that uses a full bridge converter

In pulse width modulation, the switches are turned on and off every half cycle. The converter can be used in one of two ways. Switches Q1 and Q4 are always on during the first half of the cycle. An electric current is delivered to a load by means of an HFT and two diodes. The diodes are now being loaded with electricity, which can be seen flowing through them. Switches Q3 and Q2 are on during interval 1 of the second half cycle, while all other toggles are off.

d) MPPT Algorithm

The charging system's MPPT mechanism is built using the Perturb and Observe algorithm. Figure 5 shows the logic used to compute the converter's duty cycle based on the MPP value. With this method of voltage detection, the voltage may be increased or decreased (V). The dP is determined by a change in voltage (difference in power). We've hit maximum power when there is no change in output. 'The shift in power may not be 0 percent' if a scenario is less than perfect. In the case when V0 does not lead to P0, perturbation takes the same path as perturbation, and vice versa.

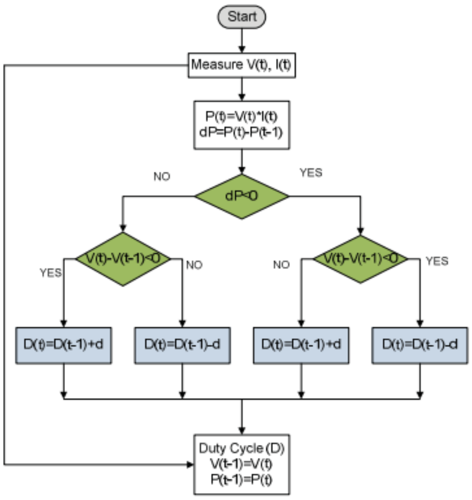

Figure.5 Flowchart for MPPT implementation

When the current and voltage readings are compared to the previous calculations, V = V(t) V(t-1) and P = P[(t) P[(t-1)] are the resultant results. An MPPT technique for duty cycle estimates in the constructed system's duty cycle estimations yields D(t) = D(t – 1) – d. Index words dmax and dmin indicate the maximum and minimum duty cycles, respectively. Selecting the best candidates for the DC-DC converter is the goal here.

III. PROPOSED SYSTEM

The DC-DC charger with a full bridge topology and ANN control shown in figure 6. This graphic shows a full bridge converter (Q1, Q2, Q3, and Q4) plus a transformer for galvanic isolation. In pulse width modulation, the switches are turned on and off every half cycle. The converter can be used in one of two ways. Switches Q1 and Q4 are always on during the first half of the cycle. An electric current is delivered to a load by means of an HFT and two diodes. The diodes are now being loaded with electricity, which can be seen flowing through them. Switches Q3 and Q2 are on during interval 1 of the second half cycle, while all other toggles are off.

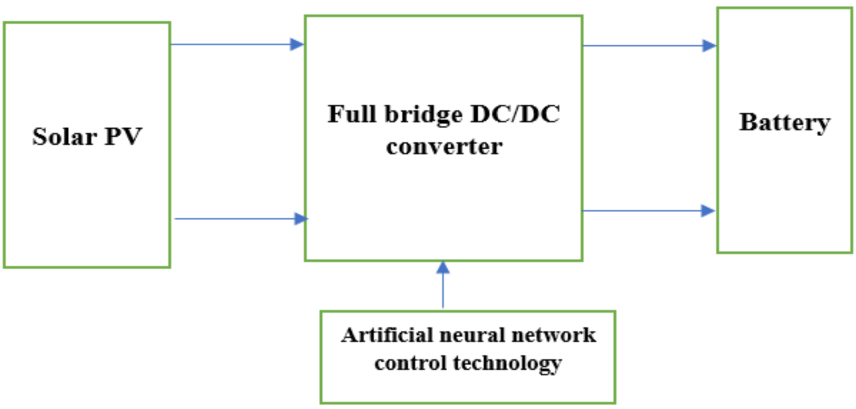

Fig 6 Proposed circuit diagram of DC-DC charger with ANN control technique employing a full bridge topology.

It is possible to calculate an HFT's nominal voltage and current values by applying the following formulae: VinD, voutD

$$V_{in-D} = V_{in} * D_{max} \quad (3)$$

$$V_{out-D} = V_0 + 1.6 \quad (4)$$

$$I_{out-D} = I_O * D_{max} \quad (5)$$

$$I_{in-D} = {I_{out-D}}/{\eta} \quad (6)$$

$$\eta = \frac{V_{in-D}}{V_{out-D}} \quad (7)$$

Where,

V_{in} denotes as i/p voltage

V_O denotes as o/p voltage

I_O denotes as o/p current

D_{max} denotes as maximum duty cycle

T_S denotes as PWM period

n denoted as turn ratio of HFT

IV.AERTIFICIAL NEURAL NETWORK CONTROLLER

The offline trained Neural Network (NN) controller as shown in fig (7).

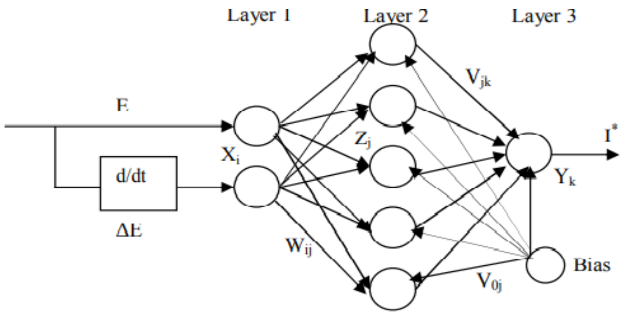

Figure.7 Neural network control system

They're well-suited to industrial processes because of their versatility and nonlinearity, as well as their ability to reject noise effectively. Error (E) and rate of change of error (E*) should be minimised while training connective weights for NN-based control systems. There are five neurones in the deep layer of the neural network, each with two inputs (Xi) and one output (Yk) (Zj). While purelin activates the output layer, tansigmoide is used to activate the hidden layer. There are linkages between the neurones in each layer, and each link has a certain weight that determines the strength of the connection (Wij, Vjk). A neural network has been trained using data from a traditional controller.

V.SIMULATION RESULTS

A) EXISTING RESULTS

a) Modelling of a DC-DC boost converter used to charge a battery powered by solar PV

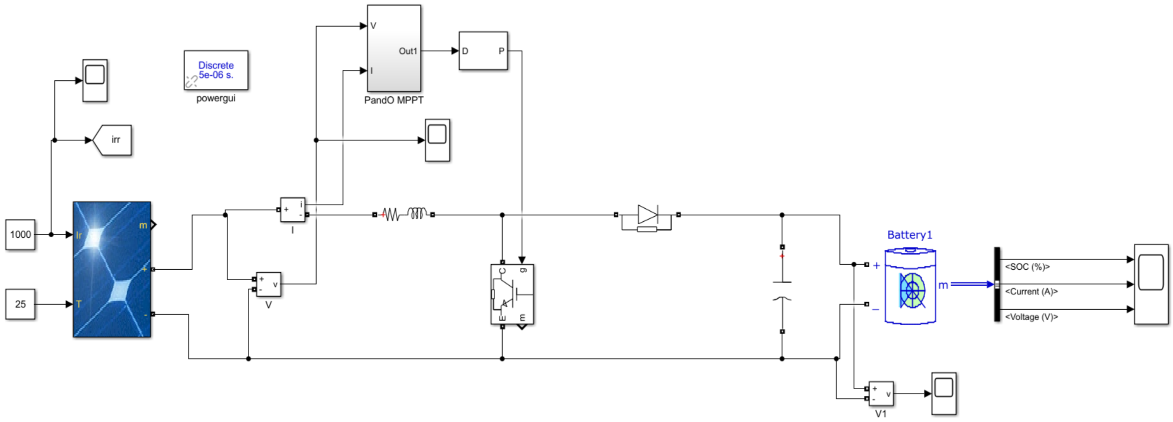

Figure. 8 MATLAB/SIMULINK circuit diagram of DC-DC boost converter used to charge a battery powered by solar PV

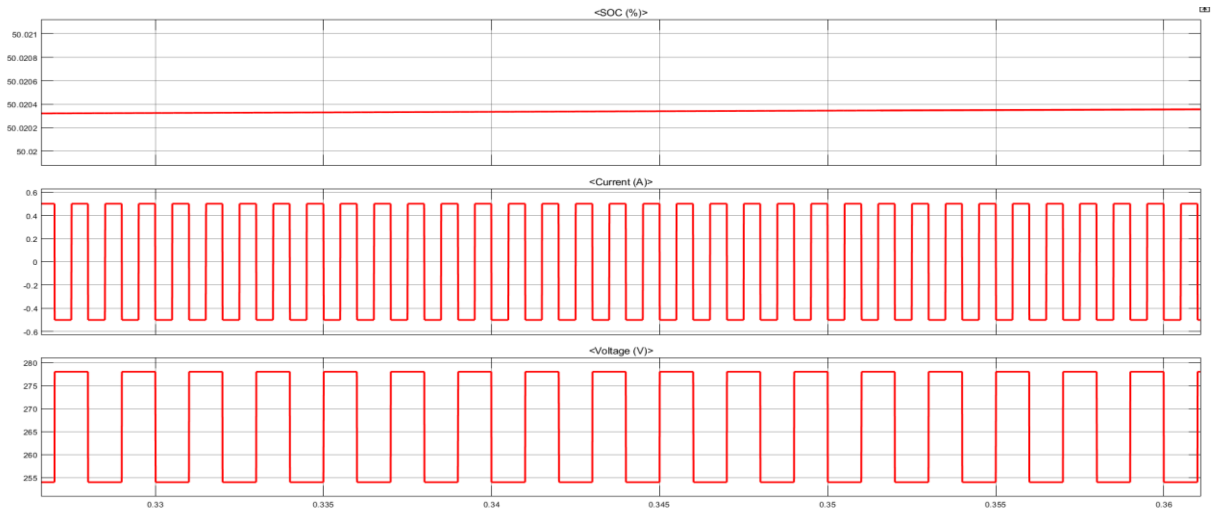

Figure. 9 (a) state of charge of Battery (SOC) (b) Battery current (c) Battery voltage using boost topology

b) Modelling of a SEPIC converter used to charge a battery powered by solar PV

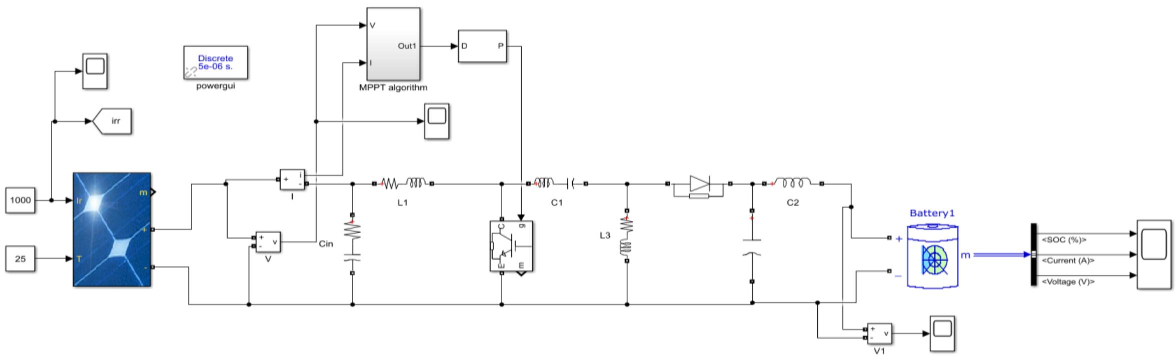

Figure. 10 MATLAB/SIMULINK circuit diagram of SEPIC converter used to charge a battery powered by solar PV

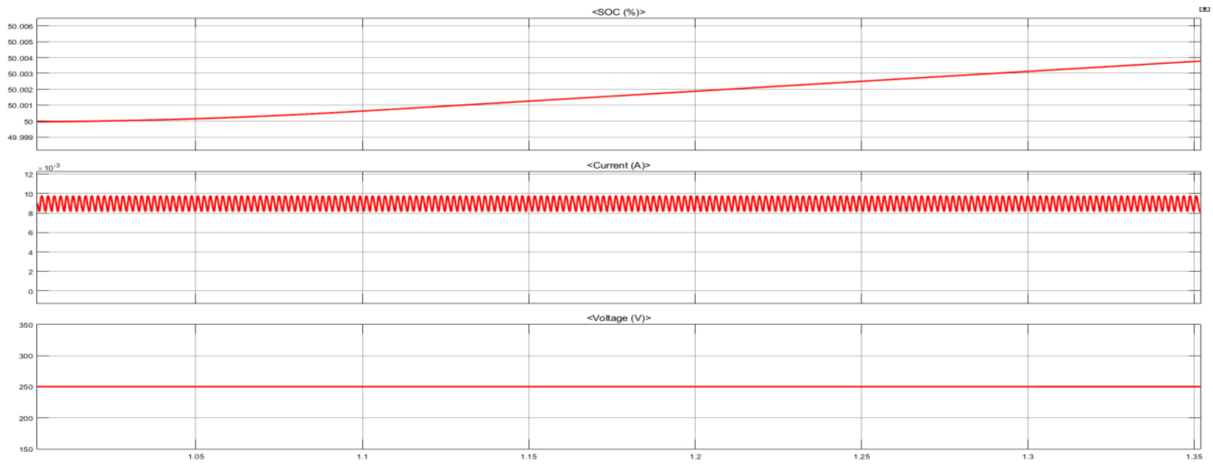

Figure.11 (a) state of charge of Battery (SOC) (b) Battery current (c) Battery voltage using SEPIC topology

c) Modelling of a full bridge converter with HFT used to charge a battery powered by solar PV

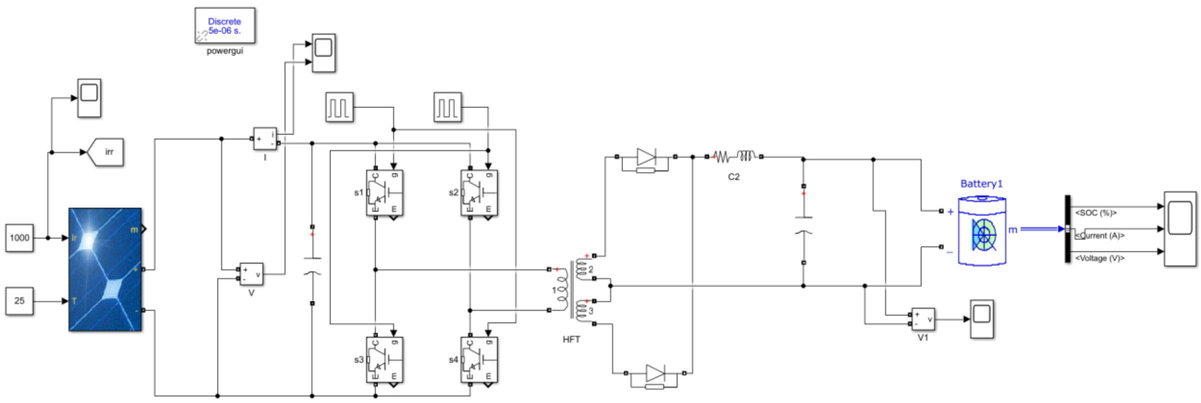

Figure.12 MATLAB/SIMULINK circuit diagram of full bridge converter with HFT

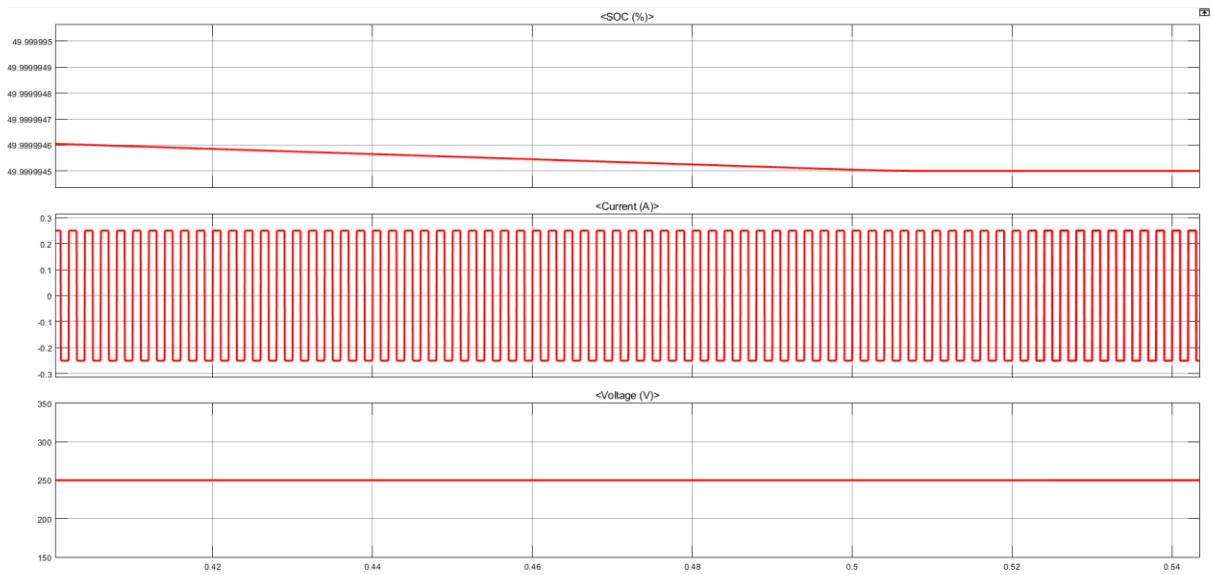

Figure.13 (a) state of charge of Battery (SOC) (b) Battery current (c) Battery voltage using HFT topology

B) EXTENSION RESULTS

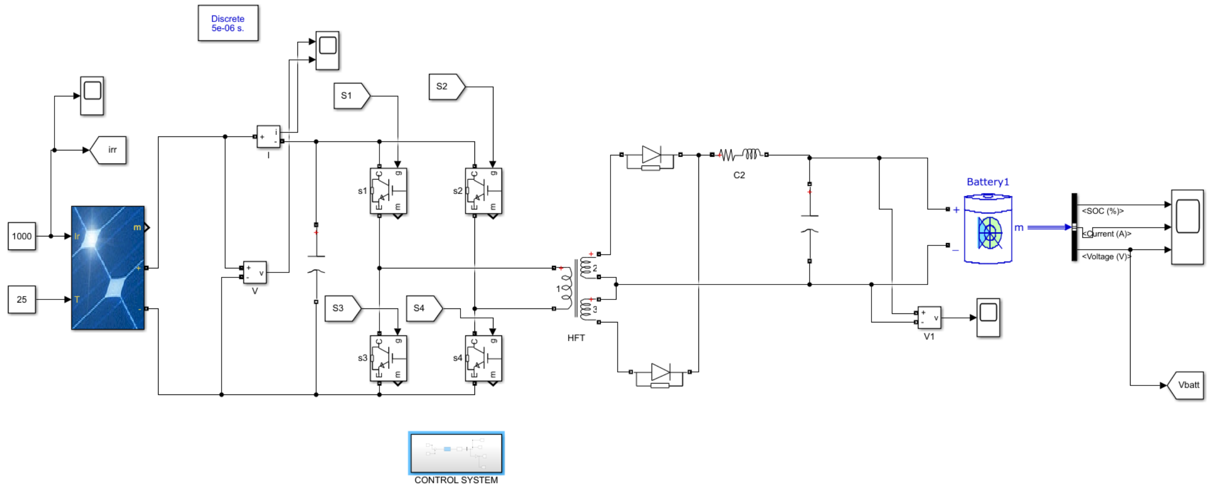

Figure.14 MATLAB/SIMULINK circuit diagram of full bridge converter with HFT based ANN controller

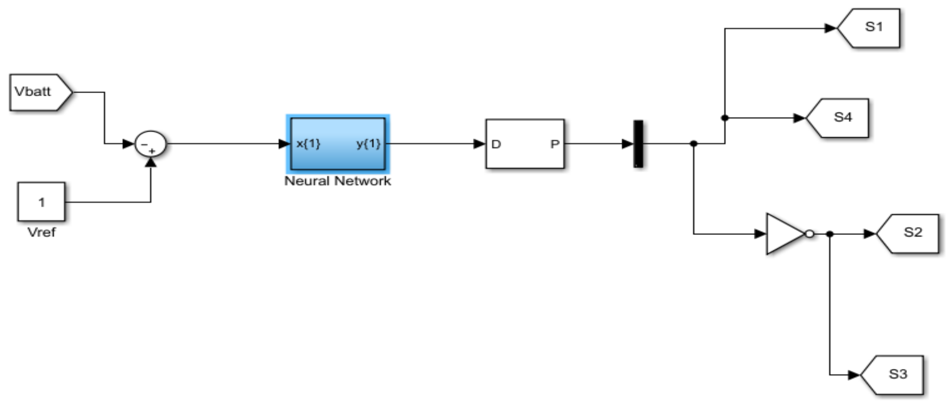

Figure .15 Subsystem of closed loop control system-based ANN controller

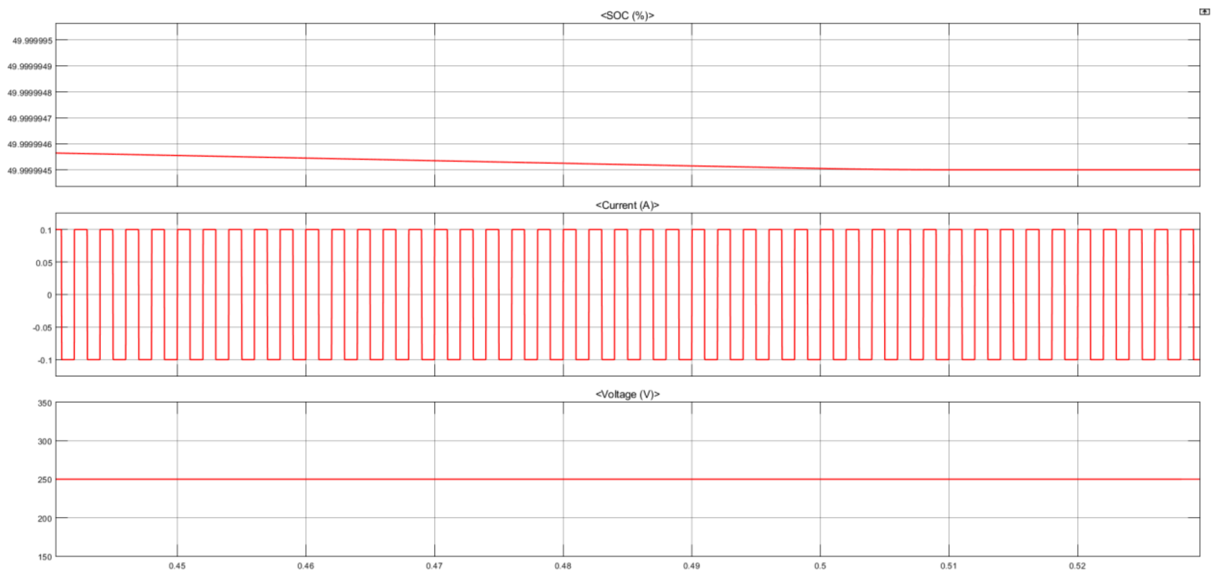

Figure.16 (a) state of charge of Battery (SOC) (b) Battery current (c) Battery voltage using HFT topology

COMPARISON TABLE

	Boost converter	SEPIC	Full bridge converter with open loop system	Full bridge converter with closed based ANN controller
Efficiency	83.2%	66.7%	98.6%	99%

CONCLUSION

An effective and reliable solar battery charging technique has been presented in this study. The most efficient topology findings have been examined and compared. An off-board electric vehicle (EV) charging station for home usage, powered by solar panels and an ANN controller, is shown in this paper. Regardless of the amount of irradiation, solar PV can be fully used using MPPT. A full bridge converter has more components than a SEPIC topology. The boost converter has the fewest components. Use of high frequency transformers and artificial intelligence is used in this work to ensure rapid response times. From here on, smart charging systems may be built using machine learning and artificial intelligence

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