

# SOLAR PANEL BASED BOOST CONVERTER WITH NEURAL NETWORK FOR HIGH VOLTAGE GAIN APPLICATIONS

<sup>1</sup>Prema.V, <sup>1</sup>Vignesh Moorthy.R, <sup>1</sup>Umashankar Ram, <sup>1</sup>Nithyanandam.C  
<sup>1</sup>GGR college of Engineering ,Vellore,Tamilnadu-632009

## ABSTARCT

Due to the more vigorous regulations on carbon gas emissions and fuel economy, Solar Cell Electric Vehicles (SCEV) are becoming more popular in the automobile industry. This paper presents a neural network based Maximum Power Point Tracking (MPPT) controller for 1.26 Kw Solar cell, supplying electric vehicle power train through a high voltage-gain DC-DC boost converter. The proposed neural network MPPT controller uses Radial Basis Function Network (RBFN) algorithm for tracking the Maximum Power Point (MPP) of the PEMFC. High switching frequency and high voltage gain DC-DC converters are essential for the propulsion of SCEV. In order to attain high voltage gain, a three-phase high voltage gain Interleaved Boost Converter (IBC) is also designed for SCEV system. The interleaving technique reduces the input current ripple and voltage stress on the power semiconductor devices. The performance analysis of the SCEV system with RBFN based MPPT controller is compared with the Fuzzy Logic Controller (FLC) in MATLAB/Simulink platform.

## 1. INTRODUCTION

Due to the environmental pollution and finite reserves of fossil fuels, automobile industries are showing more interest in Solar Cell Electric Vehicles (SCEV). The rapid advancements in power electronics and fuel cell technologies have empowered the significant development in SCEVs Solar cells have the advantages of clean power generation, high reliability, high efficiency and low noise . Depending on the type of solar cells, amorphous silicon solar cell, cadmium telluride solar cell, copper indium gallium selenide solar cell, crystalline silicon solar cell, dye sensitized solar cell. Among all of these amorphous silicon solar cell are dominating the automobile industry due to their high efficiency. The output voltage of solar cell depends on membrane water content and cell temperature. Notably, solar cells have non-linear voltage-current characteristics. Hence, there is only a single unique operating point available for solar cells with the maximum output voltage and power. The maximum power point tracking (MPPT) technique is necessary to extract the maximum power from the solar cell at different operating conditions. In the literature, various MPPT techniques are available like perturb and observe (P&O), practical swarm optimization (PSO), incremental conductance (INC), fuzzy logic control (FLC), sliding mode control, neural network (NN) to track maximum power point (MPP). Among all of these available MPPT algorithms, P&O is simple, popular and easy to implement. P&O and incremental conductance methods produce oscillations at steady state which will reduce the efficiency of the solar cell system. To overcome this problem, fuzzy logic controller and neural network algorithms are introduced to track the MPPT with increased efficiency and accuracy. In this paper, radial basis function network (RBFN) base MPPT controller is proposed to track the MPPT of the Solar cell.

## 1.1 SCOPE OF THE PROJECT

The proposed BLDC motor driven SCEV system with three-phase high voltage gain IBC. It consists of a 1.26 kW Solar cell, three-phase high voltage gain IBC, voltage source inverter (VSI) and a BLDC motor. The three-phase IBC operates as an interface between Solar cell and VSI. RBFN based MPPT algorithm is designed to extract the maximum power from the solar cell. Three-phase IBC supplies power to the BLDC motor through VSI. The switches of the VSI are controlled by using electronic commutation of BLDC motor. The motor shaft is connected to vehicle wheels for the propulsion.

## 1.2 EXISTING SYSTEM

A DC bus capacitor and a diode bridge rectifier (DBR) followed by a VSI based drive are common schemes of BLDCM drive. Three phase switching signals based on pulse width modulation (PWM) are required to drive six VSI's switches of the drive. PFC (Power Factor Correction) built converters, embedded after the DBR, achieve the power factor near to unity at AC mains, but result in rich conduction losses in DBR. The operation of PFC converter is a precarious factor as it has straight effects on the rating of inert components and overall cost requirement of the drive.

## 1.3 EXISTING SYSTEMS TECHNIQUE:

The output voltage of solar cell depends on membrane water content and cell temperature. Notably, solar cells have non-linear voltage-current characteristics. Hence, there is only a single unique operating point available for solar cells with the maximum output voltage and power. The maximum power point tracking (MPPT) technique is necessary to extract the maximum power from the solar cell at different operating conditions. In the literature, various MPPT techniques are available like perturb and observe (P&O), parctical swarm optimization (PSO), incremental conductance (INC), fuzzy logic control (FLC), sliding mode control, neural network (NN) to track maximum power point (MPP). Among all of these available MPPT algorithms, radial basis function network (RBFN) base MPPT controller is proposed to track the MPPT of the Solar cell

## 2. CIRCUIT EXPLANATION

A **solar cell**, or **photovoltaic cell**, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels. In basic terms a single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts.

Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or an artificial light. They are used as a photodetector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

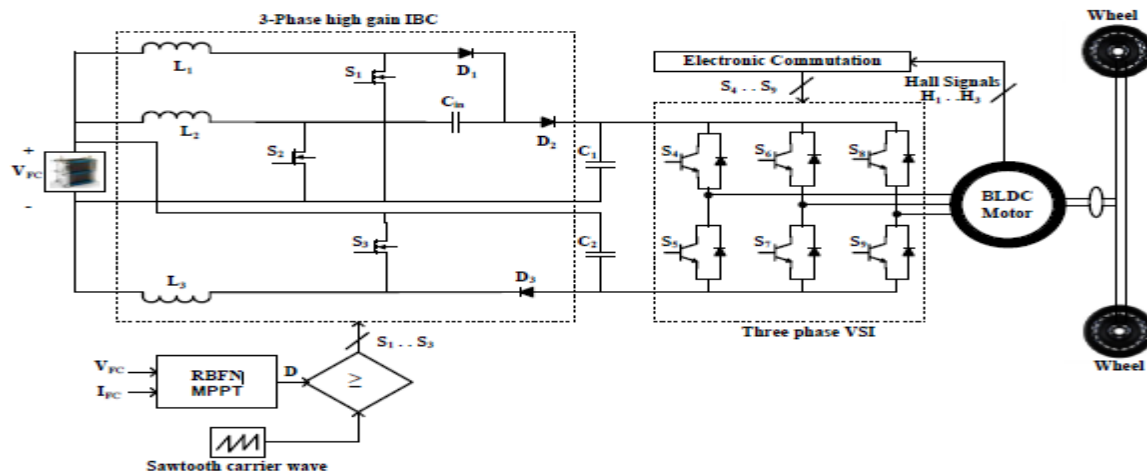


FIGURE 1.1. Proposed configuration of solar cell fed BLDC motor driven electric vehicle.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron-hole pairs or excitons.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

In contrast, a solar thermal collector supplies heat by absorbing sunlight, for the purpose of either direct heating or indirect electrical power generation from heat. A "photoelectrolytic cell" (photoelectrochemical cell), on the other hand, refers either to a Stype of photovoltaic cell (like that developed by Edmond Becquerel and modern dye-sensitized solar cells), or to a device that splits water directly into hydrogen and oxygen using only solar illumination.

### 1.5 OPERATION OF THREE-PHASE HIGH VOLTAGE GAIN IBC

The proposed converter consists of three switches ( $S_1$ ,  $S_2$  and  $S_3$ ) and three diodes ( $D_1$ ,  $D_2$  and  $D_3$ ).  $L_1$ ,  $L_2$  and  $L_3$  are the filtering inductors of phase-1, phase-2 and phase-3 respectively.  $V_{FC}$  is the input voltage,  $V_O$  is output voltage and  $R$  is the load resistor. The following assumptions are considered for the analysis of proposed high voltage gain IBC: i. Inductors of all the three phases are assumed to be ideal ( $L_1 = L_2 = L_3 = L$ ). ii. Filtering capacitors  $C_1$  and  $C_2$  are considered as same ( $C_1 = C_2 = C$ ). iii. The proposed converter always operates in Continuous Conduction Mode (CCM). iv. The voltage and current ripples across the capacitor and inductor are assumed to be very small. The switches  $S_1$ ,  $S_2$  and  $S_3$  are switched ON by using two gate pulses which are  $180^\circ$  phase shifted. One gate pulse is given to the switch  $S_2$  and another gate pulse with  $180^\circ$  phase shift is given to both the switches  $S_1$  and  $S_3$  [29]. Fig. 3 explains the operation of the proposed converter in different operating modes and the steady-state waveforms of this converter .

**Mode-1 (to  $\leq t \leq t_1$ ):** During this mode, all the three switches  $S_1$ ,  $S_2$  and  $S_3$  are switched

ON and all the three diodes D1, D2, and D3 are reverse biased as shown in Fig. 3(a). The input voltage source VFC charges the inductors L1, L2 and L3. The current through these inductors I1, I2 and I3 increased linearly with a slope of (VFC/L). The input capacitor Cin is disconnected from the load as well as from the supply. The output capacitors C1 and C2 supplies energy to the load resistor and the voltage of output capacitors VC1 and VC2 decreases with a slope of (- VO/RC).

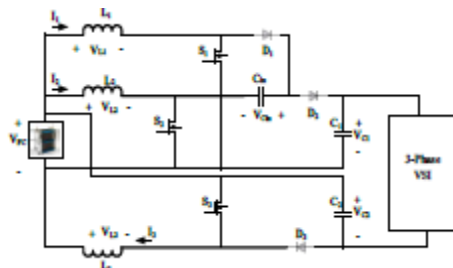


FIGURE 1.2. Modes of operation of 3-phase high voltage gain IBC.

**Mode-2 ( $t_1 \leq t \leq t_2$ ):** In this mode, the switch S2 is switched ON and the switches S1 and S3 are switched OFF. The diodes D1 and D3 are forward biased and the diode D2 is reverse biased as shown in Fig. 3(b). The current through the inductors L1 and L3 decreased with a slope of (VFC - VCin)/L and (VFC - VC2)/L respectively. The current through the inductor L2 increases with a slope of (VFC/L). The capacitor C1 supplies the energy to the load and the capacitors C2 and Cin are charged by the input voltage VFC.

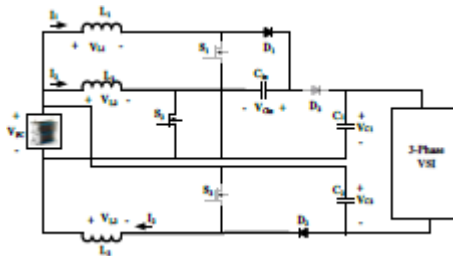


FIGURE 1.3 Modes of operation of 3-phase high voltage gain IBC.

**Mode-3 ( $t_3 \leq t \leq t_4$ ):** This mode is similar to mode-1. All the three switches S1, S2 and S3 are switched ON and all the three diodes D1, D2 and D3 are switched OFF.

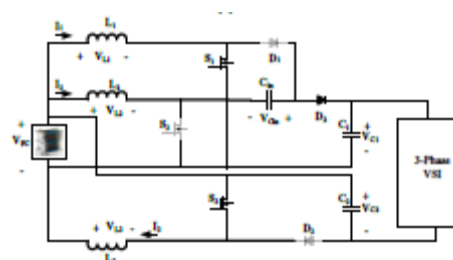


FIGURE 1.4 Modes of operation of 3-phase high voltage gain IBC.

**Mode-4 ( $t_4 \leq t \leq t_5$ ):** In this mode, the switch S2 is switched OFF and the switches S1 and S3 are switched ON. The diodes D1 and D3 are reverse biased and the diode D2 is conducting as shown in Fig. 3(c). The input voltage source VFC charges the inductors L1 and L3 and the current through these inductors increases with a slope of  $(VFC/L)$ . The current through the inductor L2 decreases with a slope of  $(VFC+VC_{in}-VC_1)/L$ . The capacitors C2 and C<sub>in</sub> supplies energy to the load. Capacitor C1 gets charged by the input voltage VFC.

## RESULT AND DISCUSSION

### 2.1 simulink circuit

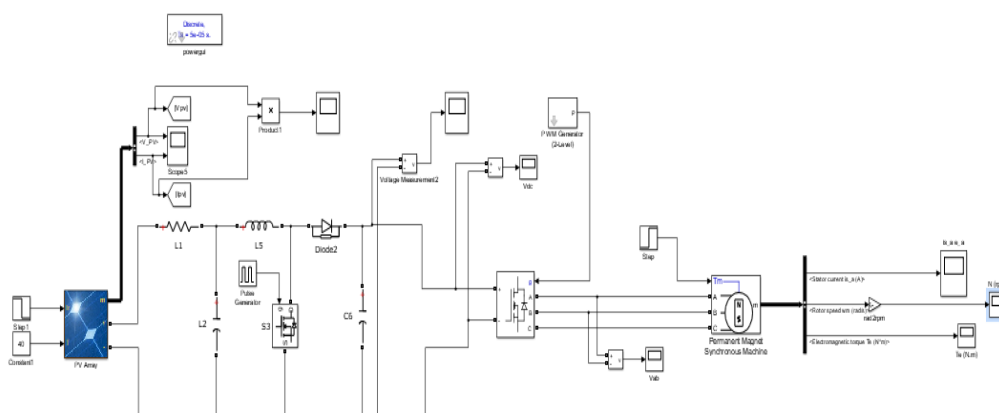


Fig 2.1 Simulink without MPPT Controller Circuit

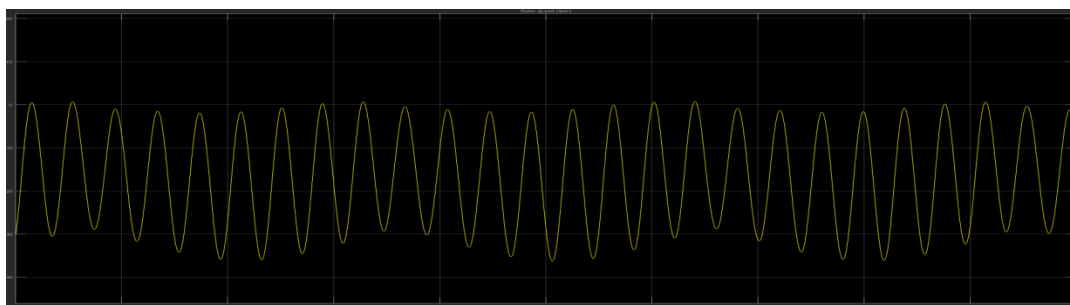
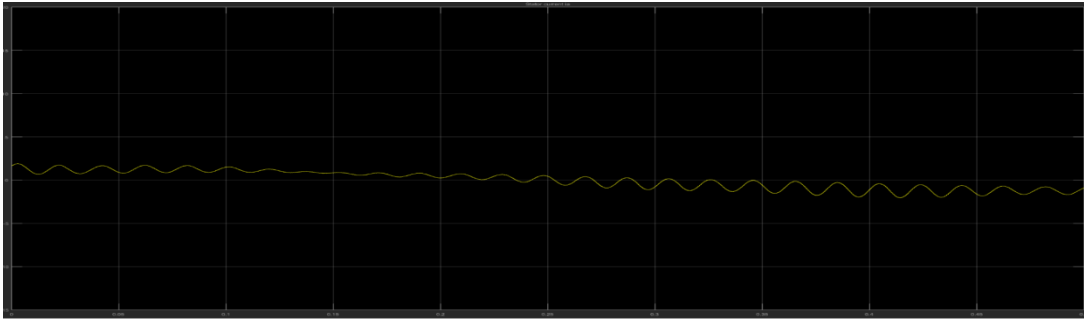
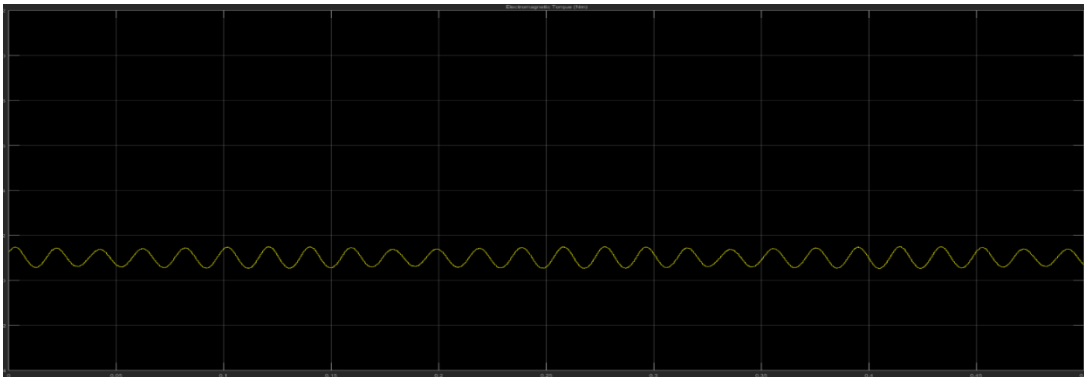


Fig 2.2 Output Speed Waveform without MPPT Controller



**Fig 2.3 Output Current Waveform without MPPT Controller**



**Fig 2.4 Output Torque Waveform without MPPT Controller**

Simulink, developed by MathWorks, is a commercial tool for modeling, simulating and analyzing multi-domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in control theory and digital signal processing for multi-domain simulation and Model-Based Design

Simulink is a block diagram environment for multi-domain simulation and Model-Based Design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis.

## 2.2 Building the Model

Simulink provides a set of predefined blocks that you can combine to create a detailed block diagram of your system. Tools for hierarchical modeling, data management, and subsystem customization enable you to represent even the most complex system concisely and accurately.

### 2.2.1 Selecting Blocks

The Simulink Library Browser contains a library of blocks commonly used to model a system. These include:

- Continuous and discrete dynamics blocks, such as Integration and Unit Delay
- Algorithmic blocks, such as Sum, Product, and Lookup Table
- Structural blocks, such as Mux, Switch, and Bus Selector

We can build customized functions by using these blocks or by incorporating hand-written MATLAB, C, Fortran, or Ada code into the model. The custom blocks can be stored in their own libraries within the Simulink Library Browser. Simulink add-on products let you incorporate specialized components for aerospace, communications, PID control, control logic, signal processing, video and image processing, and other applications. Add-on products are also available for modeling physical systems with mechanical, electrical, and hydraulic components.

To build a model, by dragging blocks from the Simulink Library Browser into the Simulink Editor, we then connect these blocks with signal lines to establish mathematical relationships between system components. Graphical formatting tools, such as smart guides and smart signal routing, help we control the appearance of the model as we build it. We can add hierarchy by encapsulating a group of blocks and signals as a subsystem in a single block.

The Simulink Editor gives a complete control over what we see and use within the model. For example, we can add commands and submenus to the editor and context menus. We can also add a custom interface to a subsystem or model by using a mask that hides the subsystem's contents and provides the subsystem with its own icon and parameter dialog box.

### 2.2.2 Navigating Through the Model Hierarchy

The Explorer bar and Model Browser in Simulink helps to navigate the model. The Explorer bar indicates the level of hierarchy that we are currently viewing and lets we can move up and down the hierarchy. The Model Browser provides a complete hierarchical tree view of your model, and like the Explorer bar, can be used to move through the levels of hierarchy.

### 2.2.3 Managing Signals and Parameters

Simulink models contain both signals and parameters. Signals are time-varying data represented by the lines connecting blocks. Parameters are coefficients that define system dynamics and behavior. Simulink helps to determine the following signal and parameter attributes as shown :

- Data type—single, double, signed, or unsigned 8-, 16- or 32-bit integers; Boolean; enumeration; or fixed point

- Dimensions—scalar, vector, matrix, N-D, or variable-sized arrays
- Complexity—real or complex values
- Minimum and maximum range, initial value, and engineering units

If we choose not to specify data attributes, Simulink determines them automatically via propagation algorithms, and conducts consistency checking to ensure data integrity. These signal and parameter attributes can be specified either within the model or in a separate data dictionary. We can then use the Model Explorer to organize, view, modify, and add data without navigating through the entire model

#### **2.2.4 Simulating the Mode**

We can simulate the dynamic behavior of the system and view the results as the simulation runs. To ensure simulation speed and accuracy, Simulink provides fixed-step and variable-step ODE solvers, a graphical debugger, and a model profiler.

#### **2.2.5 Choosing a Solver**

Solvers are numerical integration algorithms that compute the system dynamics over time using information contained in the model. Simulink provides solvers to support the simulation of a broad range of systems, including continuous-time (analog), discrete-time (digital), hybrid (mixed-signal), and multirate systems of any size. These solvers can simulate stiff systems and systems with discontinuities. We can specify simulation options, including the type and properties of the solver, simulation start and stop times, and whether to load or save simulation data. We can also set optimization and diagnostic information. Different combinations of options can be saved with the model.

#### **2.2.6 Running the Simulation**

We can run your simulation interactively from the Simulink Editor or systematically from the MATLAB command line. The following simulation modes are available:

- Normal (the default), which interpretively simulates the model
- Accelerator, which increases simulation performance by creating and executing compiled target code but still provides the flexibility to change model parameters during simulation
- Rapid Accelerator, which can simulate models faster than Accelerator mode by creating an executable that can run outside Simulink on a second processing core

To reduce the time required to run multiple simulations, we can run those simulations in parallel on a multi-core computer or computer cluster.



### 2.2.7 Analyzing Simulation Results

After running a simulation, we can analyze the simulation results in MATLAB and Simulink. Simulink includes debugging tools to help to understand the simulation behavior.

### 2.2.8 Viewing Simulation Results

We can visualize the simulation behavior by viewing signals with the displays and scopes provided in Simulink. We can also view simulation data within the Simulation Data Inspector, where we can compare multiple signals from different simulation runs. Scope is the block in Simulink by which we can measure and view the voltage, current, and power in electrical domain. The output of a multilevel converter through scope. Alternatively, we can build custom HMI displays using MATLAB, or log signals to the MATLAB workspace to view and analyze the data using MATLAB algorithms and visualization tools.

### 2.3 simulation with MPPT controller

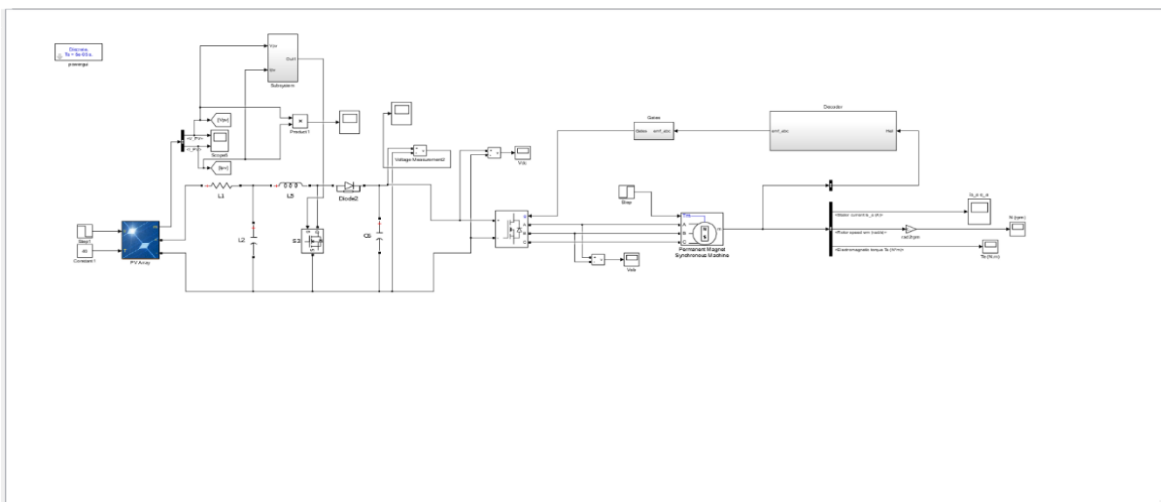
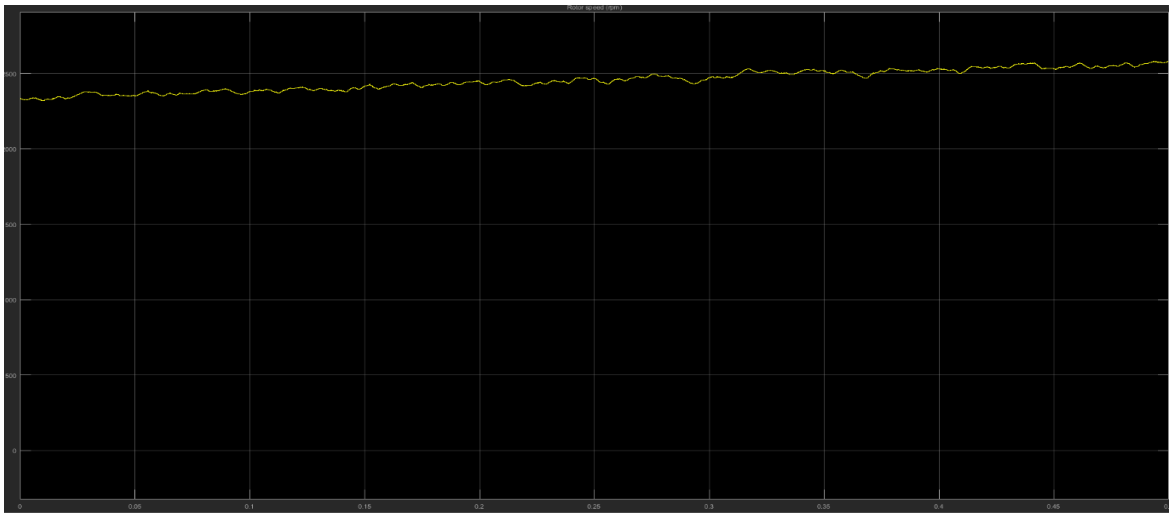
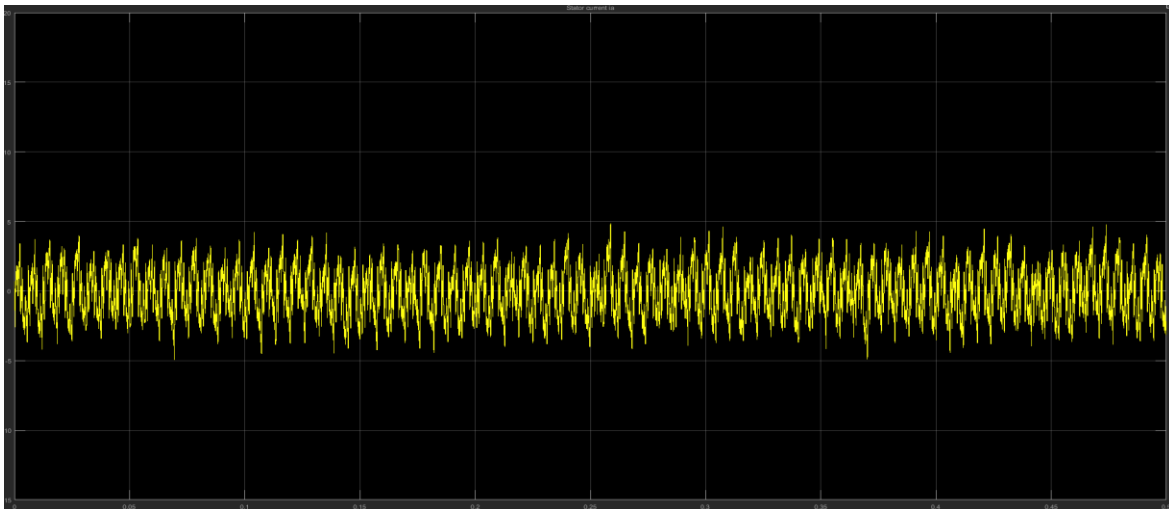


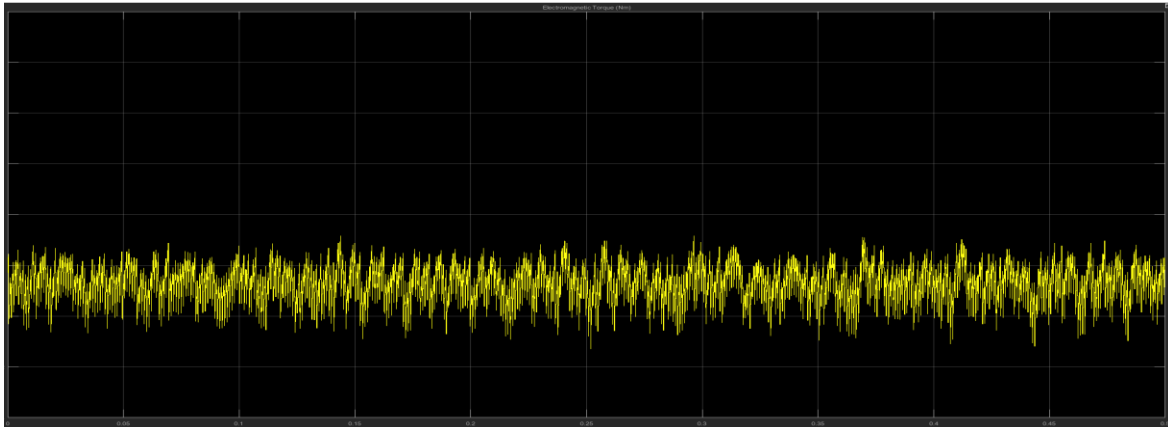
Fig 2.5 simulink circuit with MPPT controller



**Fig 2.6 Output Speed Waveform With MPPT Controller**



**Fig 2.7 Output Stator Current Waveform with MPPT Controller**



**Fig 2.8 Output Torque Waveform with MPPT Controller**



## 2.9 Hardware setup

**2.3.1** Solar output is given to the BLDC motor to driven the vehicle through boost convertor and three phase inverter. The three phase output is given to BLDC motor through Resistive load. The Solar output is given to the boost converter. The Solar output is non linear, so the low voltage from solar output is step up by the boost converter. Diode used in the boost converter is to block the reverse current. Switch used in the converter is to generate the pulse. Capacitor is used to reduce the ripple in the voltage. Inductor is used in the circuit for handling peak switching current and thus gives a constant current power supply. The output of boost converter is given to the three phase inverter which will convert DC supply into three phase AC supply. Three phase inverter is used as a driver circuit which give three phase AC supply to the load. For energy gate pulse, the MOSFET is get trigger according to gate pulse. The output is linear by using the PWM modulation the PWM will reduce the ripple in the waveform. Solar output is given to drive the BLDC motor using the MPPT controller through boost convertor and three phase inverter. The snubber circuit is to isolate the switches to avoid the voltage fluctuation MPPT circuit is used to track

the maximum power to the load under the all weather condition. Hall effect signal is converted into gate signal by Decoder through EMF and finally the gate signal is given to three phase inverter. So the maximum power is tracked by this loop in all weather condition.

## CONCLUSION

In this project, a three-phase high voltage gain DC-DC converter is proposed for SCEV applications. The proposed converter has reduced the solar cell input current ripples and the voltage stress on the power semiconductor switches. The RBFN based MPPT technique is designed for 1.26 kW solar cell for extracting the maximum power from the solar cell at different temperatures. The proposed MPPT technique is compared with the FLC MPPT controller. The simulation results reveal that the RBFN based MPPT controller has tracked the maximum power point faster when compared to the fuzzy logic controller. Also, different performance characteristics of the BLDC motor such as electromagnetic torque, speed and back EMF are analysed at different temperatures of the solar cell system.

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