# HYBRID BATTERY CHARGER FOR ELECTRIC VEHICLE

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***Abstract:*** **The scarcity of fossil fuel and the increased pollution leads the use of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) instead of conventional Internal Combustion (IC) engine vehicles. A solar PV is integrating with utility grid to supply the battery used for vehicle. In this paper, PV- grid load sharing algorithm was added to the utility grid operation control to compensate fluctuation of PV output, with its main purpose is to deliver constant power to the battery. Here dual loop control algorithm is implemented to the phase shift full bridge converter such that the sum of load current is summation of PV and grid current. In this research, the total power output from the system is limited to 3kW. For example, if PV produced 1kW, then PSFB closed loop controller drove the utility grid to produce 2kW. A MPPT algorithm is implemented to the solar PV so that maximum power is delivering the load. The objective of the project work is to design a charger that can charge the battery with the use of renewable energy adding only compensation through grid. The grid is connected with the battery through Interleaved Boost PFC converter at the first stage to obtain unity power factor with low Total Harmonic Distortion (THD) and a DC-DC phase shift full bridge converter to regulate the charging voltage and current of the battery. The battery is a Lead-acid battery with a nominal voltage of 120 V, and is charged from cut-off voltage of 80V to fully charged voltage of 124V. The function of the second stage DC-DC converter is to charge the battery in a Constant Current and Constant Voltage manner. A 3KW prototype of battery charger is designed and simulated in MATLAB/Simulink. The power factor obtained at full load is 0.999 with a THD of 2.08%.**

***Index Terms*: *Interleaved Boost power factor correction(PFC), Phase Shift Full Bridge Converter(PSFB), Power conditioning system(PCS), Total Harmonic Distortion(THD) and MATLAB SIMULINK.***

## I. Introduction

A hybrid electric vehicle battery charging, in which a battery is charged by an efficient hybrid system that can utilize both solar power and utility grid supply is a necessity when there is intermittent power supply. A hybrid battery charging system suited to Indian scenario. The design implemented paves way to effectively and efficiently coordinate the utilization of both solar power and utility grid supply to charge a battery. MPPT algorithm is utilized to extract maximum power from solar PV at different irradiance and temperature condition, and through power factor correction and phase shift full bridge, utility grid is connected to battery.

As the sunlight is not constant throughout the day and also in year so power delivered by solar PV is not sufficient accordingly the grid supplies the needed power to the battery. This paper not only present the hybrid battery charging but also makes this system inimitable in a way by eliminating the harmonics in the input grid side and adding zero voltage switching(ZVS) of mosfet and controlling the power by introducing phase shift between the switches.

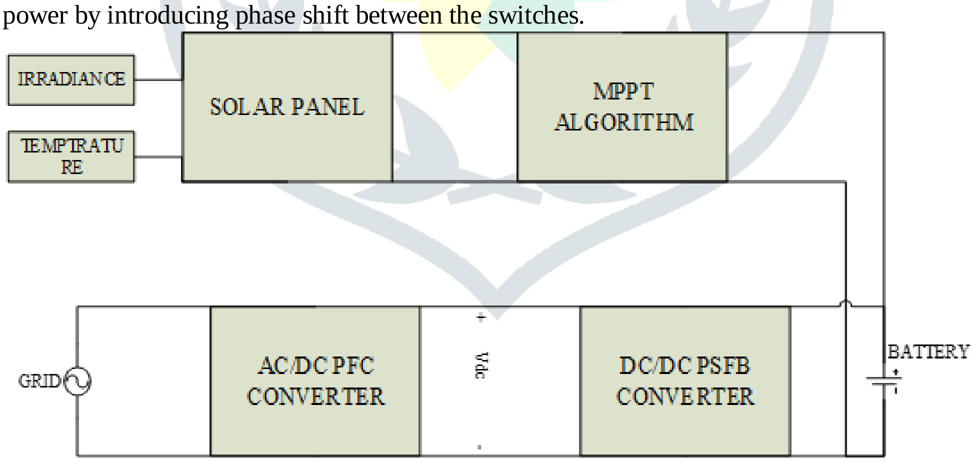


Fig. 1: Block Diagram of Current Sharing Between Grid and Solar PV

Further in this paper in 2nd part Solar PV charger is explained. In the 3rd part interleaved boost converter for power factor correction is explained, 4th part is for phase shift full bridge converter, 5th part is the run of all the above part collectively.

## II. SOLAR PV

Fig. 2 shows the circuit configuration of the proposed Solar PV PCS with line connection. The proposed PCS is composed of a dc–dc buck converter [2]. The PV voltage *V*pv has a wide range (100–164.1 V), and the dc–dc converter is buck type to step down the PV voltage to the level of the allowable charge battery voltage. The interleaved buck converter works as to make the circuit resistance equal to the PV resistance with the help of MPPT algorithm which is written in the Matlab function block. The buck converter simply controls the PV voltage *V*pv to a voltage which is maximum at the particular irradiance and temperature. MPPT algorithms are necessary because PV arrays have a non-linear voltage-current characteristic with a unique point where the power produced is maximum [4]. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year.

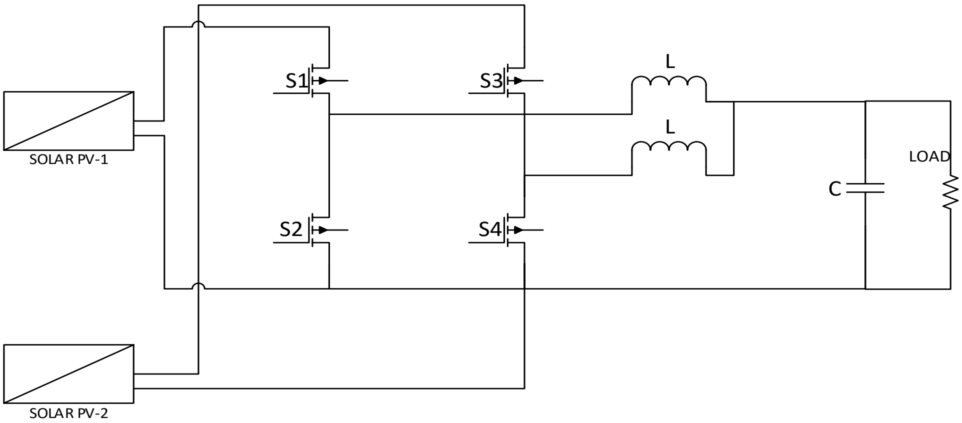


Fig.2: Block Diagram of Interleaved Solar PV with Buck Converter.

The P&O algorithm is a relatively simple yet powerful method for MPPT [3], [5]. The algorithm is an iteration based approach to MPPT.

Table 1: PARAMETERS VALUES OF SOLAR PV

| Parameters | Values |
|---|---|
| PV panel | SUN POWER SPR-300-WHT-D |
| Per unit MPP voltage and current | Vmp= 54.7V Imp = 5.49A |
| Power rating | 3.3 KW |
| Input frequency | F=50 Hz |
| Output Voltage | Vdc= 120 V |
| Switching frequency | F=50 KHz |
| Inductance | L= 108.5 uH |
| Output Capacitance | C= 100 uF |
| Resistance | R= 4 ohm |

**SIMULATION WORK**

Simulation of solar PV with the maximum PV voltage of 164.1V at 1000 irradiance is presented to charge a lead-acid battery. The battery charging voltage is 120V.

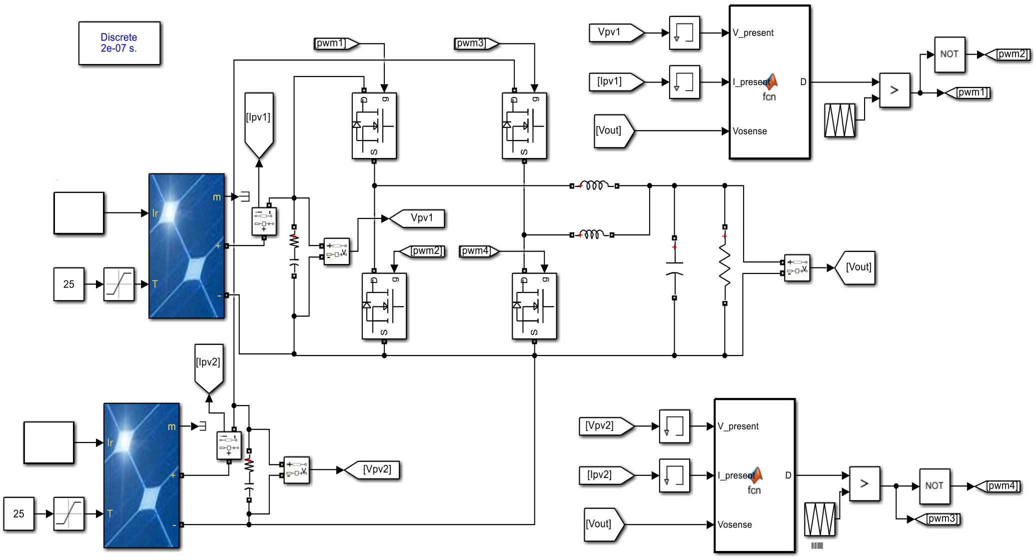


Fig.3: Matlab diagram Interleaved buck converter with MPPT

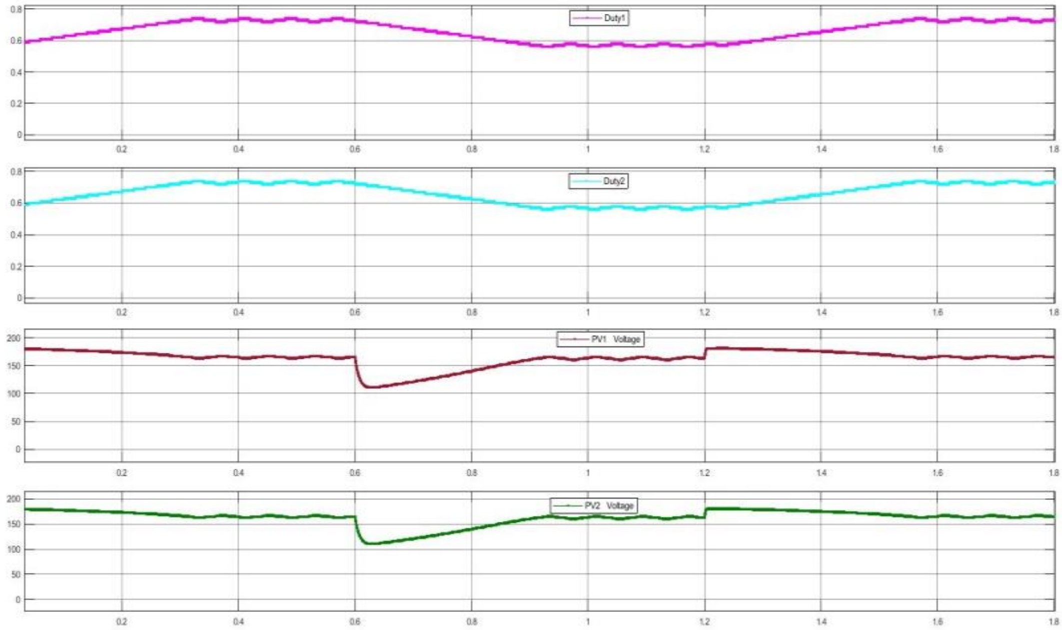


Fig. 4: Waveform of Simulation of MPPT at different irradiance

Here in figure 4 it is shown that irrespective of change in irradiance after a transient period the solar PV voltage attains the maximum PV voltage.

## III. INTERLEAVED BOOST POWER FACTOR CORRECTION CONVERTER

One most serious issue with the conventional rectifiers is the harmonics components of the line current which are responsible for distorting the voltage at the point of common coupling due to source inductance and produce some undesirable effects [6], [7]. Due to the presence of harmonics, the power factor becomes worst.

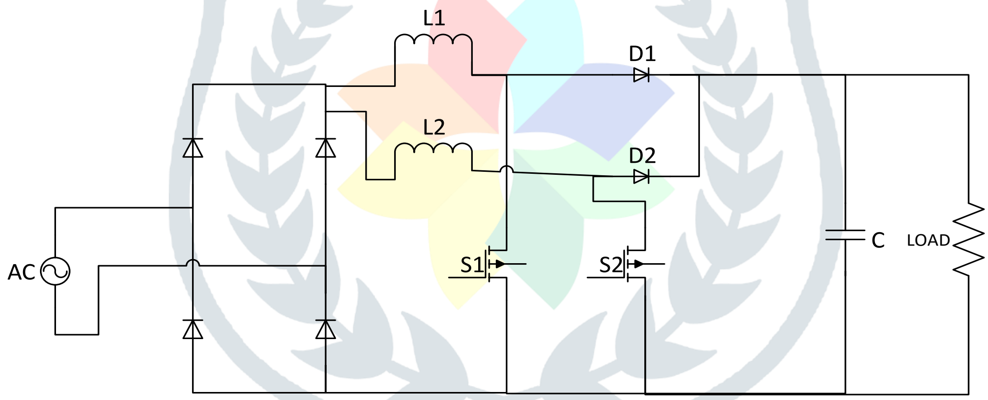


Fig.5: Interleaved Boost PFC converter

Fig 5 shows a power stage circuit diagram of an Interleaved Boost PFC converter. The input supply voltage is first rectified by a diode bridge rectifier and a Boost converter added at the later stage to make copy current sinusoidal [9].

Table 2: parameter of PFC:-

| ***Parameters*** | ***Values*** |
|---|---|
| Power rating | 3 KW |
| Input Voltage Range | Vacmin= 210 V, Vacmax= 250 V, Vnom= 230V |
| Input frequency | F=50 Hz |
| Output Voltage | Vdc= 400 V |
| Switching frequency | F=100 KHz |
| Inductance | L= 43.8 uH |
| Output Capacitance | C= 19.33 uF |
| Resistance | R= 53.33 ohm |

## SIMULATION WORK

The power stage diagram of the Boost PFC converter is shown in Fig 2.3. The circuit consists of a diode bridge rectifier followed by a Boost converter for power factor correction. Switch can be controlled in a close loop manner to maintain a desired voltage across the DC link capacitor and a sinusoidal input current. One common control method of PFC converters is Average Current Mode (ACM) Control.

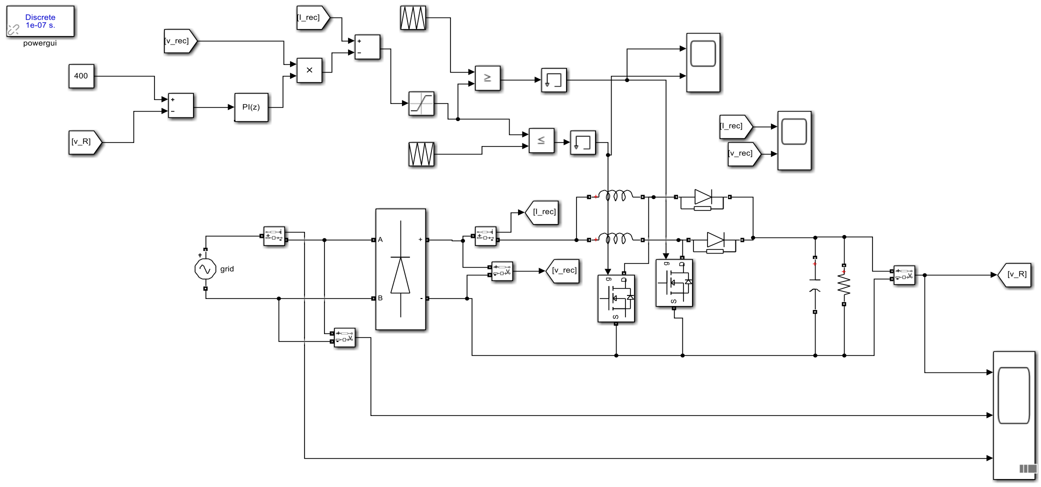


Fig.6: Boost Interleaved PFC converter model implementation in Matlab/Simulink

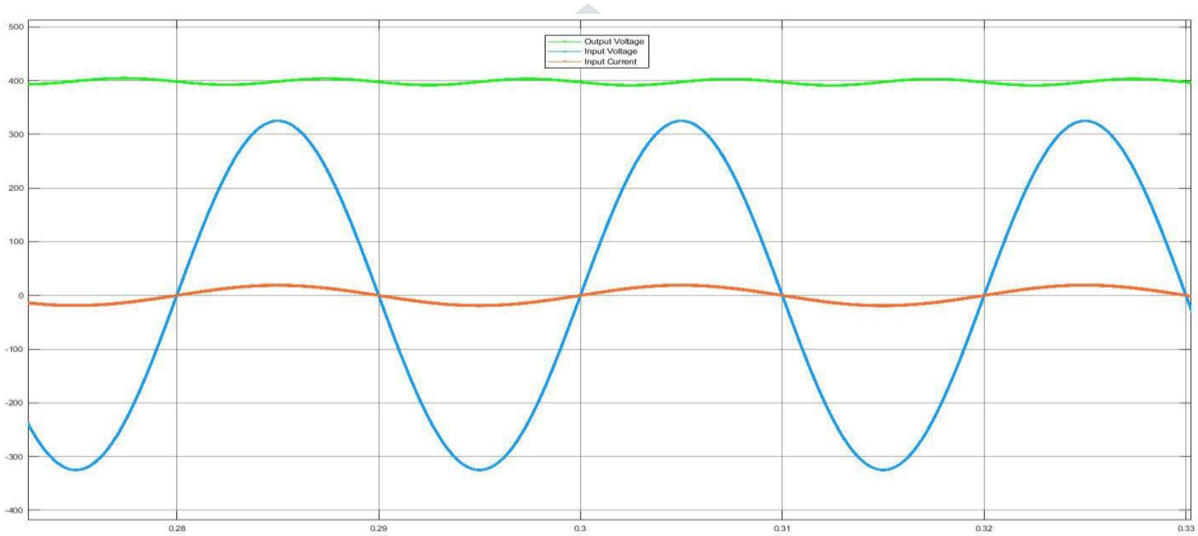


Fig.7: Output voltage, input voltage and input current waveform

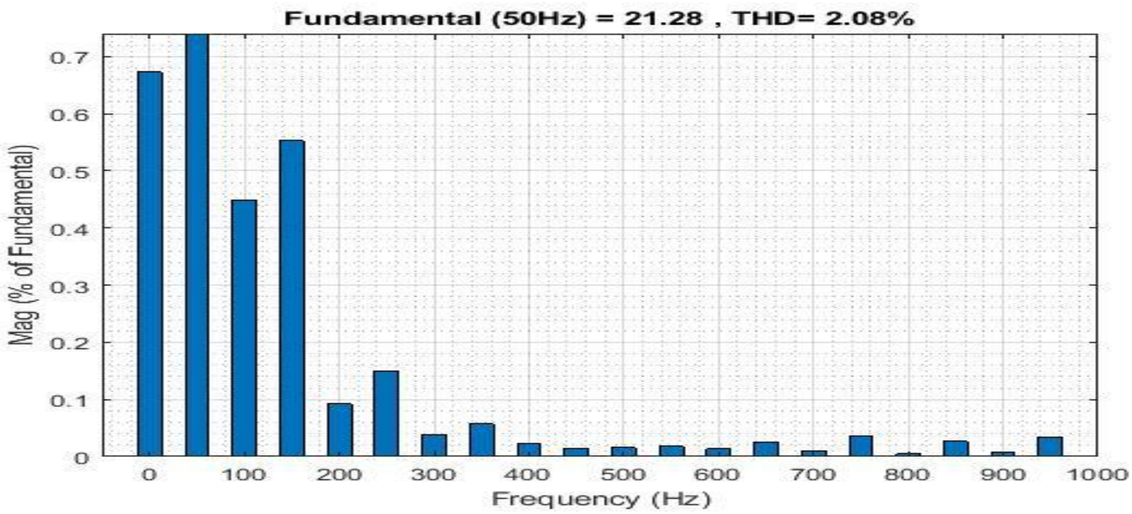


Fig.8: Total Harmonic Distortion of Grid Current

The boost interleaved PFC converter topology is presented in Fig. 2.2. It uses a dedicated diode bridge to rectify the AC input voltage to DC, which is then followed by interleaved boost PFC converters in parallel, operating 180 degree out of phase. The boost interleaved PFC converter has the advantage of paralleled semiconductors. The input current is the sum of two inductor currents, therefore it reduces output capacitor high frequency ripple, but it still has the problem of heat management for the input diode bridge rectifiers. The hardware implementation for the boost interleaved PFC converter topology as well as its controller implementation is done in Matlab/Simulink environment as depicted in Fig. 6.

## IV. PHASE SHIFT FULL BRIDGE CONVERTER

A PSFB converter consists of four power electronic switches (like MOSFETs or IGBTs) that form a full bridge on the primary side of the isolation transformer and diode rectifiers or MOSFET switches for synchronous rectification (SR) on the secondary side. This topology allows all the switching devices to switch with zero voltage switching (ZVS) resulting in lower switching losses and an efficient converter [11], [13]. In this work, ZVS for switches in the one leg of the full bridge and zero or low voltage or Low Voltage Switching for switches in the other leg is achieved across the complete load range, by changing dead times for primary side switches based on load conditions.

Rather than driving both of the diagonal full bridge switches together, a deliberate delay will be introduced between their turn-on commands with the Phase Shifted approach. This delay will be adjusted by the voltage loop of the control circuitry, and essentially results as a phase shift between the two drive signals [12]. The effective duty cycle is controlled by varying the phase shift between the switch drive commands as shown in figure 3.2. Unique to this Phase Shifted technique, two of the switches in series with the transformer can be ON, yet the applied voltage to the transformer is zero.

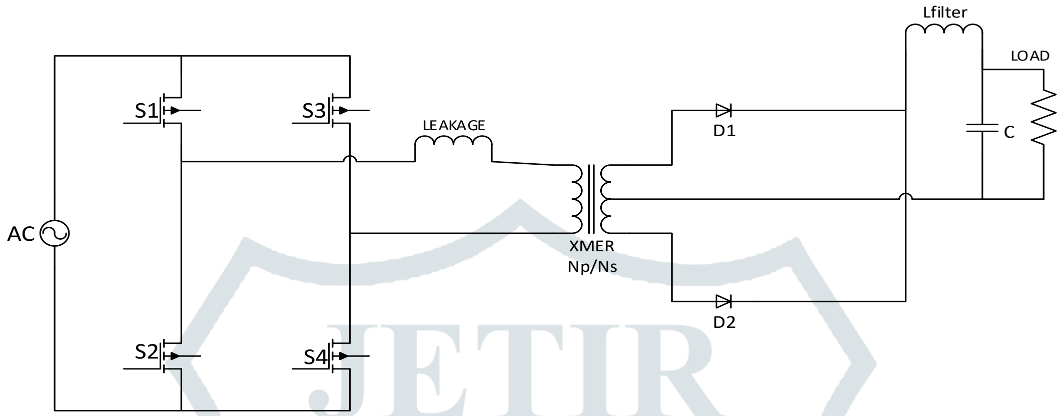


Fig.9: Circuit Model of Phase Shift Full Bridge Converter

Switches within the Phase Shifted full bridge converter will be utilized differently than those of its non-resonant counterpart. Instrumental to this technique is the use of the parasitic elements of the MOSFET switch's construction. The internal body diode and output capacitance (*Coss*) of each device [13] (in conjunction with the primary current) become the principal components used to accomplish and commutate the resonant transitions.

Table 3: Parameters Values of Phase Shift Full Bridge Converter

| ***Parameters*** | ***Values*** |
|---|---|
| Power rating | 3 KW |
| Input Voltage | Vdc= 400V |
| Output Voltage | Vdc= 120 V |
| Switching frequency | F=100 KHz |
| Inductance | L= 54.07 uH |
| Output Capacitance | C= 1354.16 uF |
| Resistance | R= 4.8 ohm |

## SIMULATION WORK

Dual loop PI controller is simulated, the inner loop is current loop and the outer loop is voltage loop. Inner loop is faster than the inner loop.

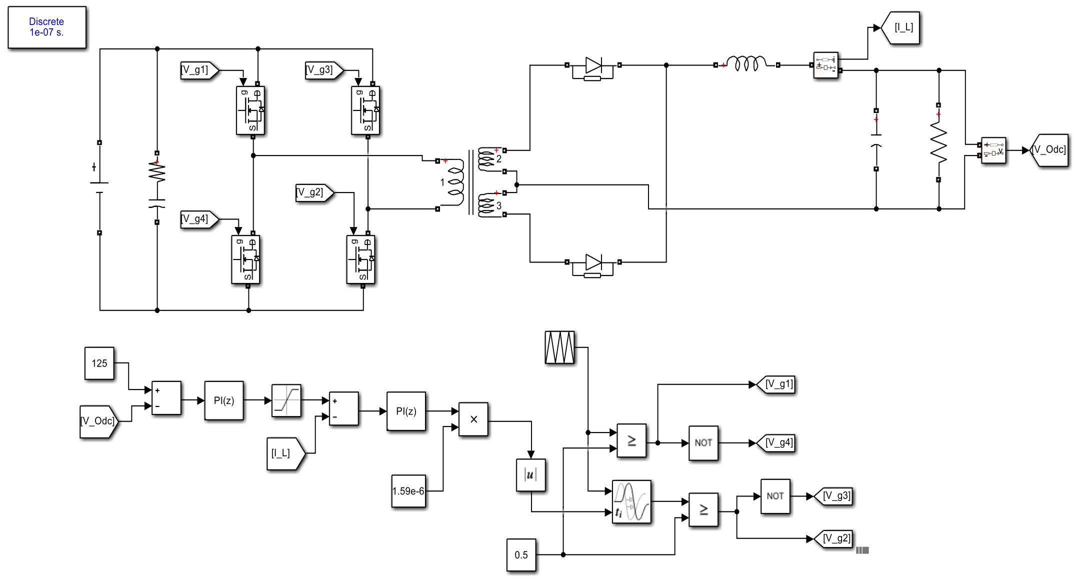


Fig.10: MATLAB Circuit Diagram of PSFB with Closed Loop Control

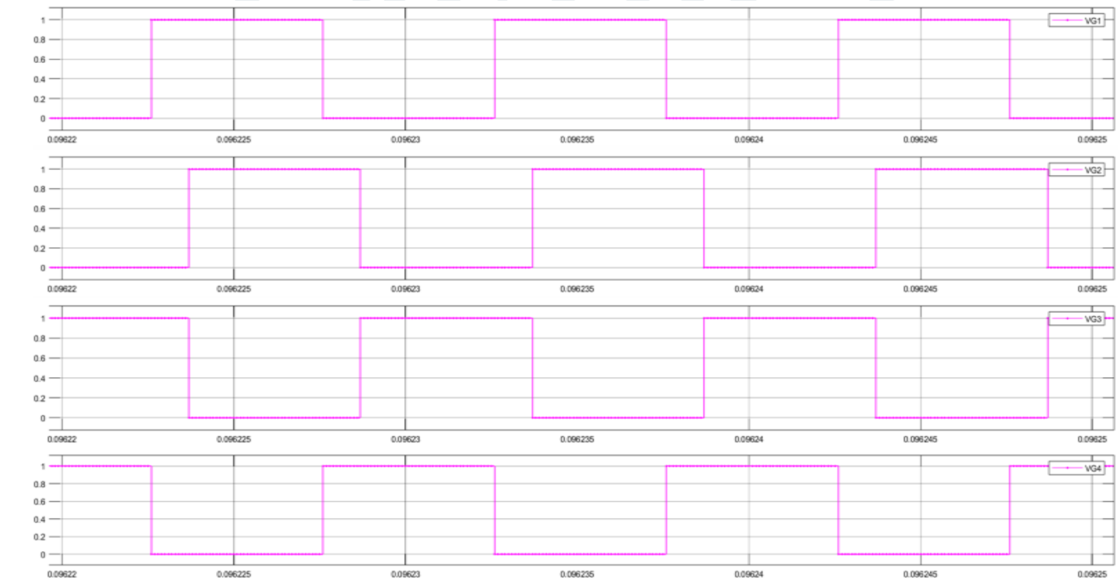


Fig.11: Phase Shifted Pulse for the MOSFET Switch

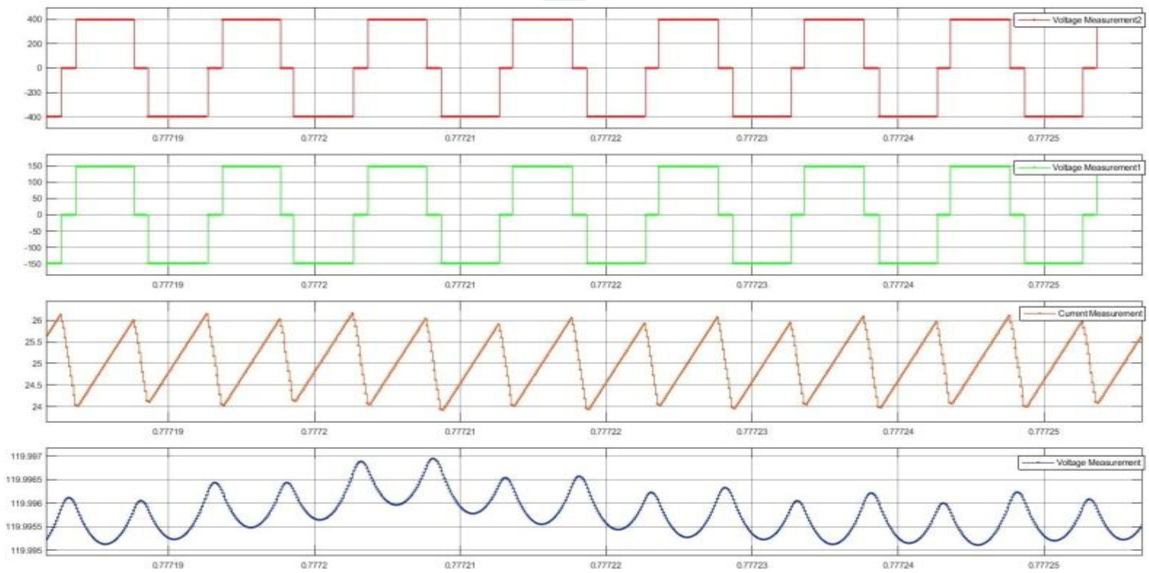


Fig.12: Primary Voltage, Secondary Voltage, Leakage Current, and Output Voltage Waveform

## V. CURRENT SHARING BETWEEN SOLAR PV AND TWO STAGE GRID CONNECTED CIRCUIT

The solar battery charging systems that are currently in use consist of a charge controller whose design is customized to regulate the voltage and current according to the rating of the battery. Other designs involve an online backup UPS system that rectify and regulate the utility grid supply to charge the battery. This paper describes a hybrid design that incorporates both the above mentioned methods of battery charging. An algorithm has been developed to efficiently charge a battery by switching between the two available power supplies. Figure 1 represents the block diagram of the proposed system.

In rural areas where transporting electricity from the centralized generating station, because it far from the station so it is more suitable to deploy distributed generation system than centralized ones. The term distributed generator is not only for conventional power plant but also refers to renewable energy generation. And also we have to increase the percentage power generation by renewable sources due to greenhouse reason. Grid-tied, on-grid, utility-interactive, grid-intertie and grid back-feeding are all terms used to describe the same concept- a solar system and utility power grid are parallel connected for supplying power to the need.

A grid-connection will allow you to save more money with solar panels through better efficiency rates, net metering, plus lower equipment and installation cost. The PV fluctuation is compensated by the utility power grid so that we use grid occasionally. Therefore, net metering got decrease and also dependency on fossil fuel energy decreases [1]. Sometimes when battery is fully charge then we send the power to the power utility grid, thus we are not only consumer but we are also a supplier. Thus here we are setting up a renewable energy base plant with less dependence on environment. As solar power is dependent on sunlight, climate, and environment temperature.

**Simulation Result**

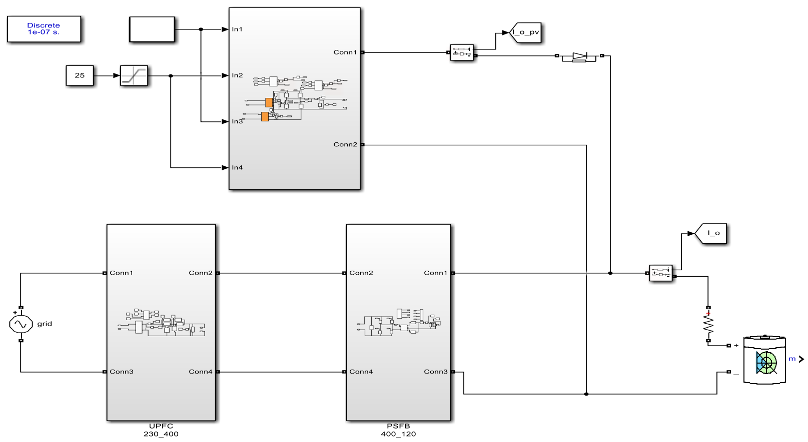


Fig.13: Parallel Connection of Solar PV and two Stage of PFC and PSFB

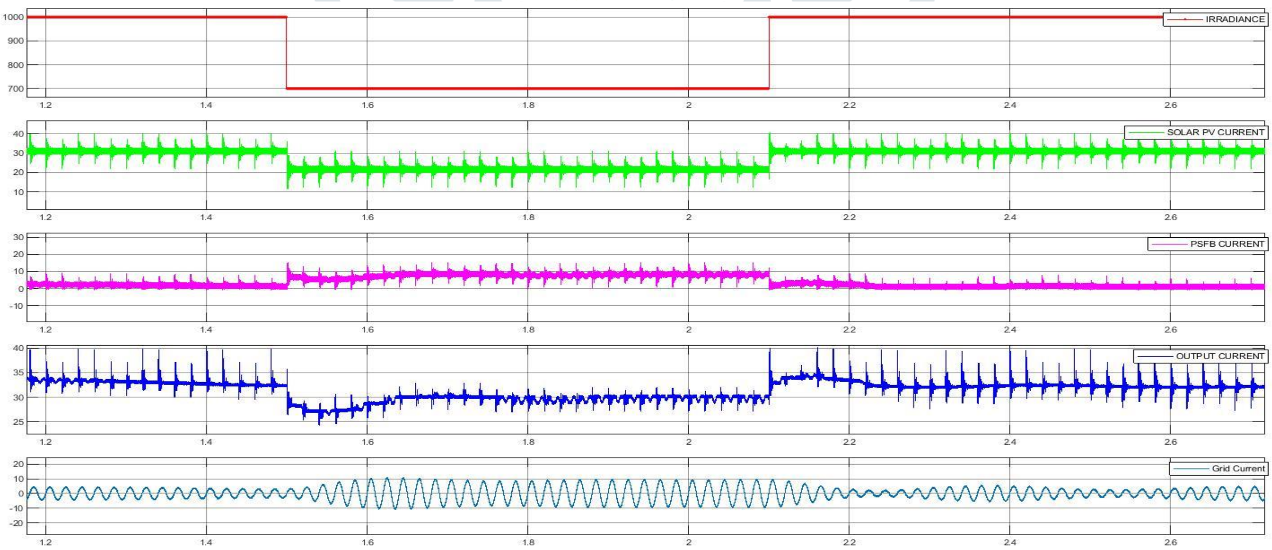


Fig.14: Graph of Current sharing between grid and solar pv

From the above graph it is clear that when the solar current decreases due to decrease in isolation the load current remains constant as the grid compensate the necessary current.

## VI. CONCLUSION

An On-Board Electric Vehicle charger is designed for level 1 charging with a 230 V input supply. Different stages of an OBC are stated and the challenges are listed. The developments have been implemented to overcome key issues. A two stage charger topology with active PFC converter at the front end followed by a Bi-directional DC-DC converter is designed. The active PFC which is a Boost converter type produces less than 5 % THD at full load. Moreover, the PFC converter is applicable to wide variation in loads. The detailed design of the power stage, as well as the controller, is discussed with the simulated results. A second stage DC-DC converter is designed and simulated for the charging current and voltage regulation. The converter performs very precisely by charging the propulsion battery in CC/CV mode over a wide range of voltage. A V2G controller has been developed for the DC-DC converter in order to supply power to the grid from the propulsion battery. A new Low-Voltage DC-DC converter is proposed to charge the Auxiliary battery via the propulsion battery utilizing the same OBC. The battery voltage and current waveforms are presented and the performance of the designed converter is verified.

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