An Improved Energy Management for Pv/Battery Hybrid System Using interleaved Boost Converter

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Abstract: This project proposes the integration of photo voltaic array and battery in a micro grid and management of energy happening in the grid. The regulation of battery depending on the requisite of load i.e., battery hold, charge and discharge actions using a bi-directional DC-DC converter has been proposed. The usage of a simple boost converter and interleaved boost converter with MPPT control, two-level inverter and three-level NPC inverter has been compared for various situations like PV delivering supply to the load and charging battery, only PV system delivering supply to the load, only battery delivering supply to the load and PV-battery both delivering supply to the load. Output factors like power, voltage and current are analyzed and plotted for all the situations. The proposed micro grid energy management system is simulated under MATLAB/Simulink environment.

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INTRODUCTION

With the increasing concerns about environment and rising prices of energy, more renewable energy sources are incorporated into the power grid in the form Distributed Generation (DG) or Distributed Energy Resources (DER). Instead of using fossil fuels, energy storage like battery or ultra-capacitors coupled with power electronic converter system offers fast response for frequency regulation and load changes. Recent development in battery technology offer several advantages like high power, longer overall life and high charge and discharge efficiency. For microgrids to work reliably, the system must be able to provide electrical power to the islanded loads maintaining appropriate voltage and frequency levels within in acceptable limits of harmonics. The analysis carried out in this paper targeted towards addressing the requirement of reliable operation of micro grid (MG) system involving power electronic converters. Transforming the DC power output of the PV array into DC or AC power is done by using power electronic converters [1-2]. AC power that is obtained is connected to the grid or to local loads.[3-5]. During the light load periods, batteries store the DC power. The Battery energy storage system plays a significant role in flexible control and optimal operation of Active Distributive Network (ADN), due to its fast power adjustment capability and good supply and storage competency characteristics. However using a large number of batteries is inappropriate and uneconomical as the deterioration of even one cell can completely interrupt the current flow [6]. Isolated bidirectional converters based on transformer are expensive besides incurring huge power losses owing to usage of many switches [7]. Because of extended life and low cost, the Lead-Acid battery has been considered for analysis [8-12].

In this paper the output of PV source is boosted up to required input (DC link) level of inverter and load by a simple boost converter as well as interleaved boost converter. A dc-dc bidirectional converter has been used for charging and discharging of battery storage unit. The dc-dc converter employs IGBT switches owing to its small output impedance as well as fast switching speed. Detailed analysis has been done for four different modes of operation as listed above with the combination of PV source and battery energy storage system. These modes are influenced upon the PV output and state of charge (SOC) of battery along with load dissimilarities. The block diagram of the micro grid EMS system under consideration is revealed in fig. 1.

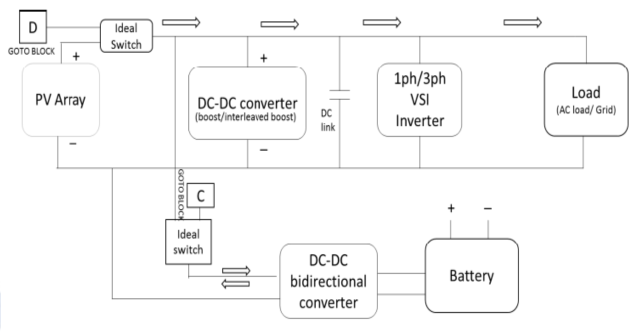


Fig. 1. Block diagram of EMS

SYSTEM CONFIGURATION

PV segment

The renewable energy source that has been considered is solar PV module for delivering the load in normal conditions and charging the battery. The PV model used for the analysis is depicted in Fig. 2 (a) and PV module parameters are listed in table 1. The PV Module works at varying irradiation level at an ambient temperature of 25^{o} C. Under ideal environmental conditions it yields an output of 23 V. The PV module output is connected to the AC load via a dc-dc boost converter and single phase inverter. It is also coupled to a lead acid battery storage unit through a dc-dc bidirectional buck-boost converter. Simulink models of the PV are shown in Fig. 2

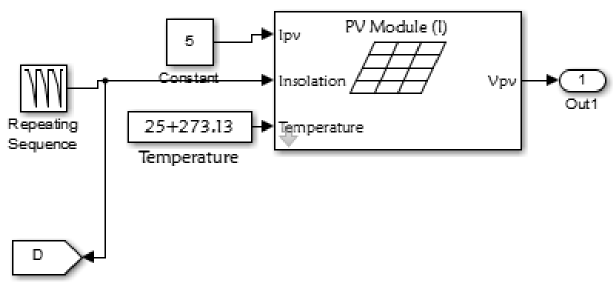


Fig. 2. Simulink model of PV segment

Maximum Power Point Tracking (MPPT) technique

The technique of holding the operating point of PV panel for corresponding irradiation at maximum power is defined as MPPT. In order to transfer the maximum power to the load, it is possible to vary the duty cycle of power electronic converters with the help of MPPT control. The most frequently used MPPT technique is the perturb and observe (P&O) technique where the terminal voltage and current of PV array are detected and processed. As shown in Fig. 4, the output of PV is premeditated and present output PV power is compared with that of the power of former perturbation cycle. After comparing , the PV voltage and current are perturbed at times and the maximum power point (MPP) is achieved.

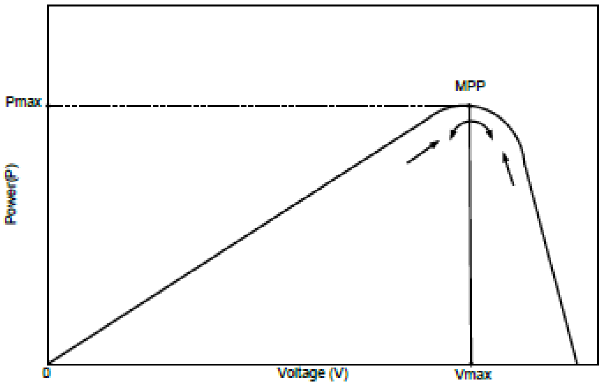


Fig. 3. Graph power Vs voltage cast-off for P&O method

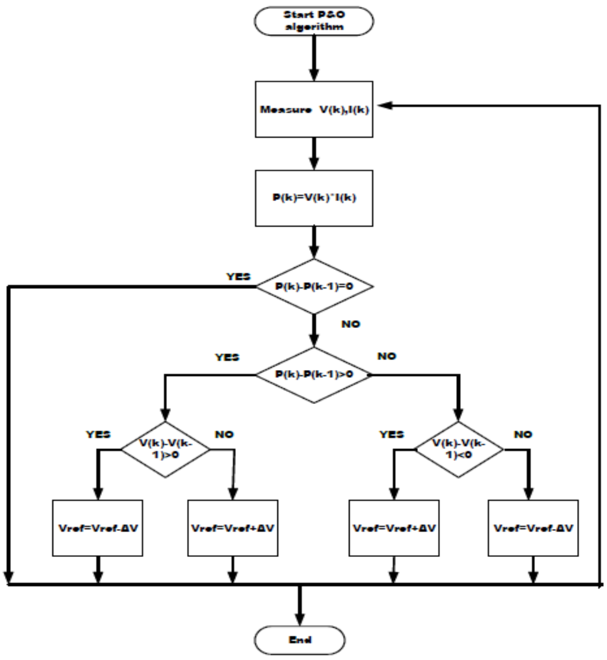


Fig. 4. Flow chart of P&O MPPT method

DC-DC boost converter

Usually, in PV arrangements, dc-dc boost converters are used to set up the DC voltage. These converters are also used to extract maximum power with the assistance of MPP techniques. The Circuit diagram of simple dc-dc boost converter is presented in Fig. 5. Two intervals of boost converter can be attained during continuous mode of operation. In both the intervals of operation, the steady state analysis is given below in terms of charge balance in capacitor and volt-second balance in inductor. Later, the required converter is premeditated with the help of a small ripple approximation.

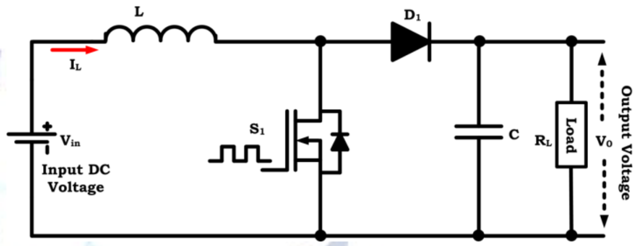


Fig.5 Conventional DC-DC Boost Converter

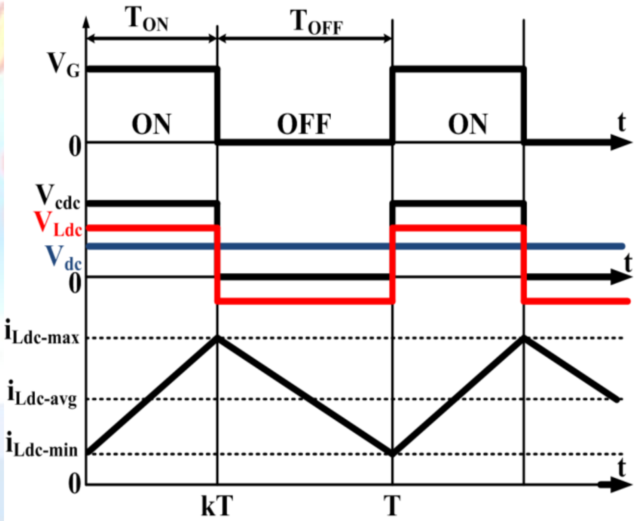
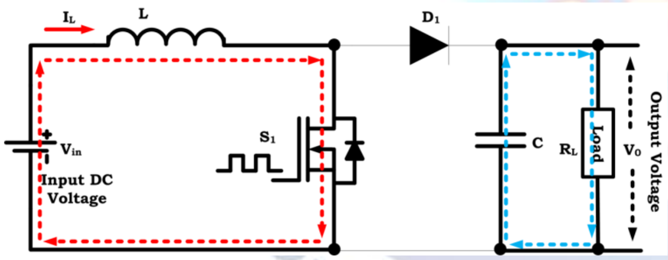


Fig.6 Typical Waveforms of Conventional DC-DC Boost Converter

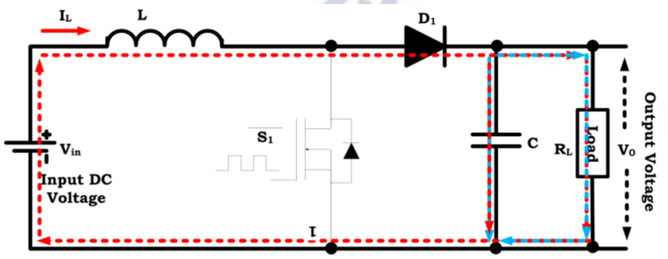
The working principle of boost DC-DC converter is more tendency of inductor to withstand current changes by energizing and de-energizing the magnetic field path. The output DC voltage of boost converter is always greater than input DC voltage, the schematic diagram and working modes of conventional DC-DC boost converter is depicted in Fig.6 and Fig.7

In mode-A, the switch S_1 is switched-ON by giving gate-pulse signals, the current flows toward the inductor in a clock-wise manner. The energy coming from input DC source which energizes the inductor and creates magnetic field stores the available energy in inductor. At this condition, the diode D_1 acts as reverse-bias and doesn't support input DC energy to output load. Then the DC-link capacitor acts as the source to maintain load voltage as constant because it doesn't allow the sudden changes and achieve the load constantly until switch S_1 is in non-conduction mode. The working mode-A of conventional DC-DC converter is depicted in Fig.7(A)

In mode-B, the switch S_1 is switched-OFF by removing gate-pulse signals, the current doesn't flows towards the high impedance path. Then the inductor slowly comes to de-energized state and the created magnetic field will slowly decrease. The energy coming from input DC source available energy in inductor supports the output load. At this condition, the diode D_1 acts as forward-bias and charges the DC-link capacitor and output DC load. Then the DC-link capacitor maintains load voltage as constant and achieving the load constantly until switch S_1 in conduction mode. The working mode-B of conventional DC-DC converter is depicted in Fig.7(B).Typical wave-forms of conventional DC-DC converter during steady state operation is depicted in Fig.5



(a) Mode-A



(b) Mode-B

Fig.7 Working Modes of Conventional DC-DC Boost Converter

The steady state analysis of conventional DC-DC converter is represented based on switched-ON and OFF states of switch S_1, generally the converter is operated in Continuous-Conduction Mode (CCM) operation. During switch S_1 is switched-ON, which makes the input DC voltage (V_{in}) comes at inductor which affects the change in current as (I_L) flowing towards the inductor during the time-period (kT) describes the,

$$\frac{\Delta I_L}{\Delta kT} = \frac{V_{in}}{L} \qquad (3.1)$$

At the end of the mode-A, the inductor current slowly increases,

$$\Delta I_{L-ON} = \frac{1}{L}\int_0^{kT} V_{in}\,dt = \frac{kT}{L}V_{in} \qquad (3.2)$$

Where, k represents the duty ratio of switch, it describes the commutation time T during switch S_1 is switched-ON, it varies 0 to 1.

During mode-B, the switch S1 is switched-OFF, so the current in the inductor slowly flows towards the load and. If the capacitor and diode have zero voltage drops consisted of large values for maintaining voltage as constant is described as,

$$V_o - V_{in} = L\frac{dI_L}{dt} \qquad (3.3)$$

Although, the variations of I_L during switched-OFF condition is,

$$\Delta I_{L-OFF} = \int_{kT}^{T} \frac{(V_{in} - V_o)dt}{L} = \frac{(V_{in} - V_o)(1-k)T}{L} \qquad (3.4)$$

As we describes that the converter works in steady-state states, the energy stored in every component has equal at starting and end of a commutation period. It specifies the over-all changes in current should be zero;

$$\Delta I_{L-ON} + \Delta I_{L-OFF} = 0 \qquad (3.5)$$

Substituting the ΔI_{L-ON} and ΔI_{L-OFF} by their sequences attains;

$$\Delta I_{L-ON} + \Delta I_{L-OFF} = \frac{kT}{L}V_{in} + \frac{(V_{in} - V_o)(1-k)T}{L} = 0$$

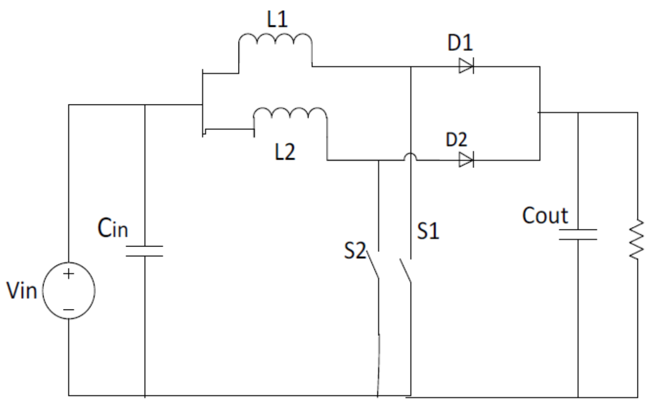
(3.6)

The above Eqn. (3.6) can be written as;

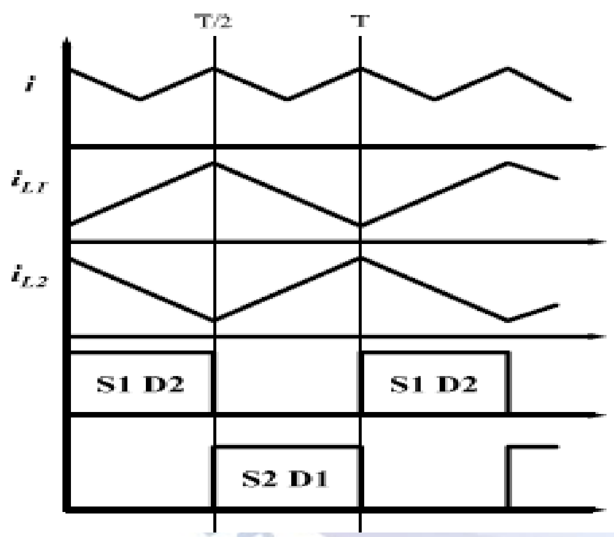
$$V_o = V_{in}\frac{1}{1-k} \qquad (3.7)$$

DC-DC Interleaved boost converter

Interleaving is a significant practice in area of power electronics. Voltage stress and current stress capability can go beyond the usage capability with high power applications. So numerous power devices should be allied in parallel or in series, but current distribution or voltage distribution will be problematic. Instead of paralleling the power devices, paralleling the power converters is an easy practice. A two-phase interleaved boost converter (IBC) comprises of two parallel coupled boost converter units. With a phase shift of 360^0/n, each unit is controlled, where n symbolizes the number of parallel connected units. As there are two parallel units, 180^0 phase shift is given.



(a)



(b)

Fig. 8.(a) Circuit of 2-phase IBC (b) Waveforms

NPC multi-level inverter

Multi-level inverters are getting interminable attention in engineering and industries. The main objectives of increasing the levels of the inverter are to lessen the current harmonic distortion and improve the efficiency of the inverter. A large number of topologies of inverters have come into existence due to the extensive study exploration on the usage of inverters and applications of specific in diverse sectors. Multilevel NPC inverter is one of them.

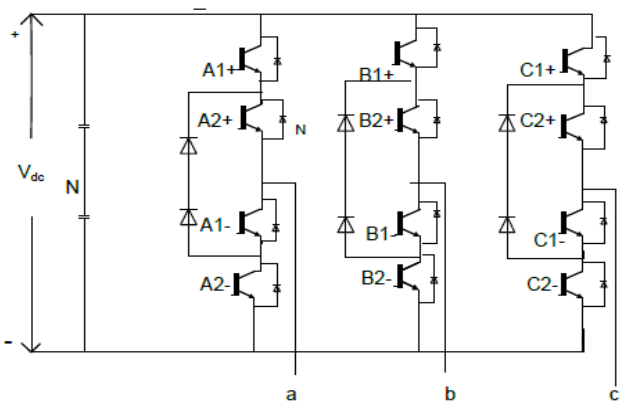


Fig. 9. Circuit of Multi-level NPC inverter

SIMULATION RESULTS

With boost converter:

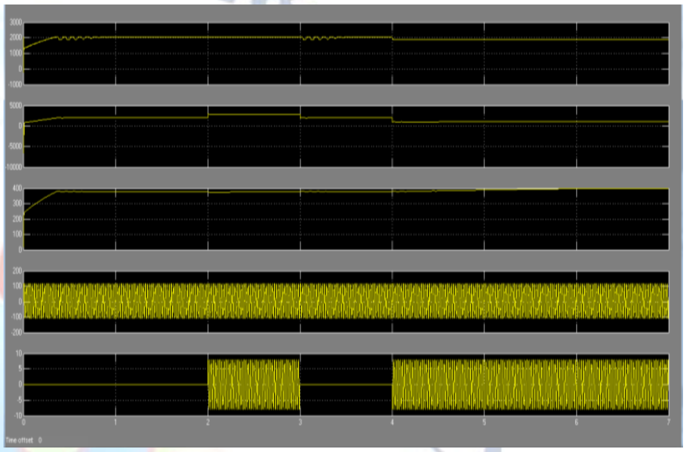


Fig. 15. PV power , Load power, DC voltage, Grid voltage, Grid current

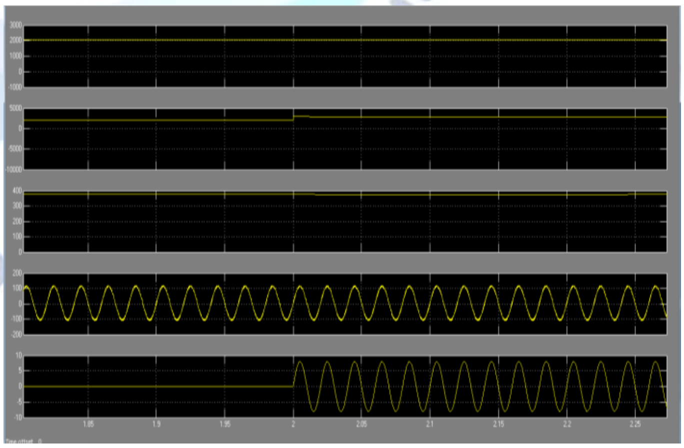


Fig. 16. PV power , Load power, DC voltage, Grid voltage, Grid current from 1.8 to 2.25 sec

With Interleaved boost converter:

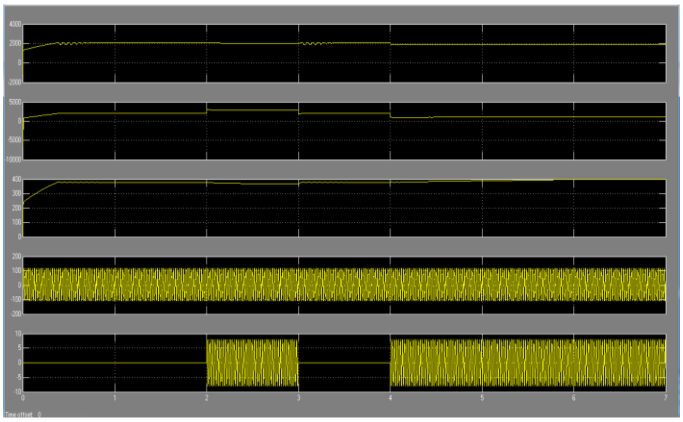


Fig. 17. PV power , Load power, DC voltage, Grid voltage, Grid current

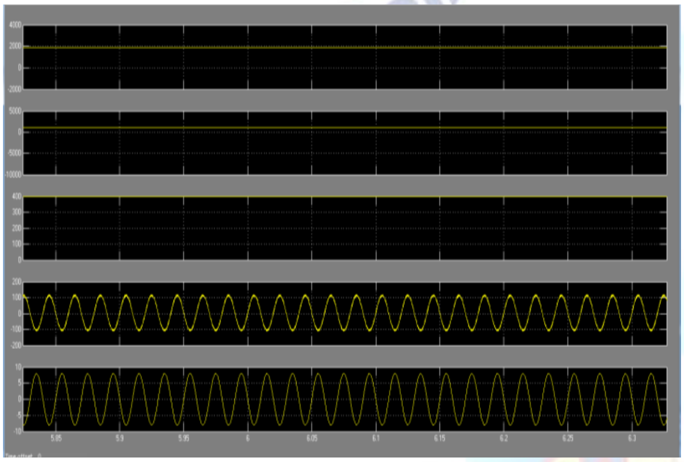


Fig. 18.PV power , Load power, DC voltage, Grid voltage, Grid current from 5.85 to 6.3 sec

With three level NPC Inverter:

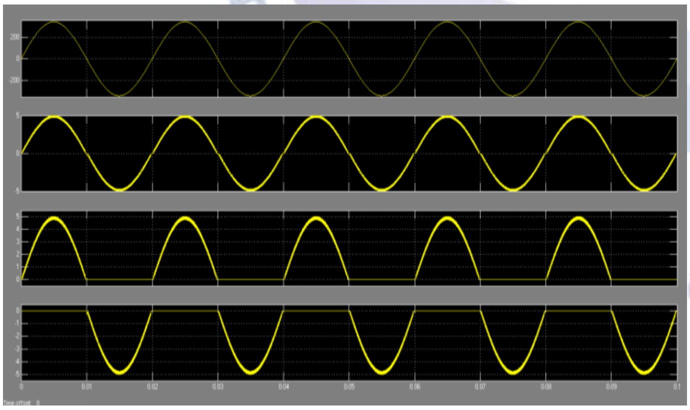


Fig. 19. Output voltage, output current, +ve leg A current, -ve leg A current

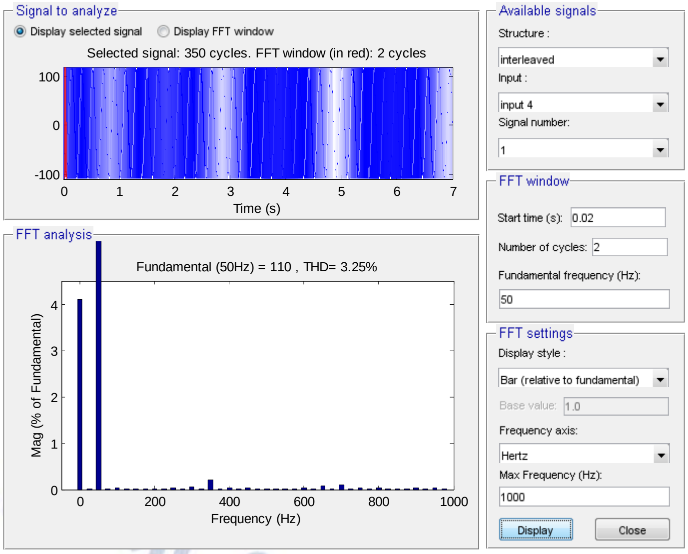


Fig: 20 THD value of the grid voltage for interleaved boost converter

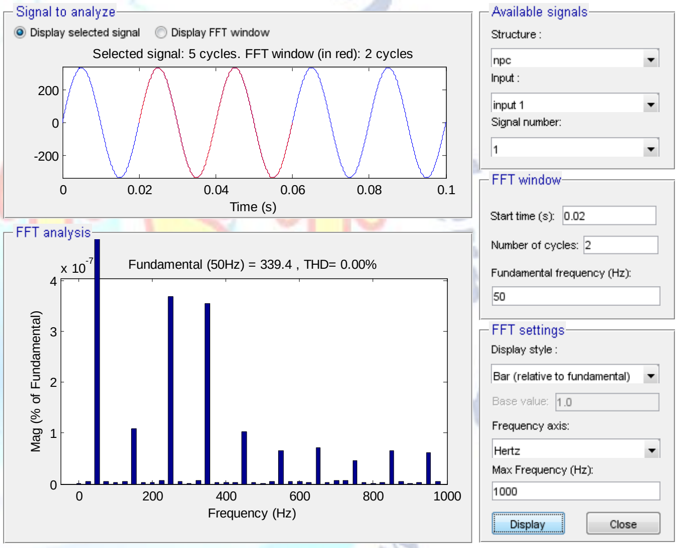


Fig: 21 THD value of the grid voltage for NPC converter

CONCLUSION:

The proposed interleaved boot converters are able to give maximum output voltage at boost level to above 400V as against 200 V without MPPT control. The combination of interleaved boost with three level NPC inverter results better performance than normal two level single phase inverter , in terms of lesser ripple in output voltage and current with no change in SOC. The ripple content in output voltage with MPPT using interleaved boost converter is 3.10% and 3 level NPC inverter is got better than NPC, which is well within the limits recommended by most of the international standards. Finally the system reveals that from the whole arrangement, how a non-conventional energy source like PV employed with MPPT can be utilized together with battery in smart micro grid to deliver power to the local loads.

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