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Simulation Study of Hysteresis Current Controlled Single Phase Inverters for PhotoVoltaic Systems with Reduced Harmonics level

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Abstract

This paper presents model and simulate hysteresis current controlled single phase inverter for a photovoltaic system application and to maintain low THD level and constant switching frequency output from the single phase inverter using Hysteresis current controlling method. Photovoltaic inverters are used to convert the D.C power produced by the solar photovoltaic cell into AC. The proposed hysteresis controller is capable of reducing the total harmonic distortion and to provide constant switching frequency. The mathematical model of Photovoltaic array is developed using the Newton's method. The modeled Photovoltaic array is interfaced with DC-DC boost converter, inverter and load. The performance of the proposed hysteresis current controller of inverter is evaluated through MATLAB-Simulation. A comparative study will be done between the conventional fixed hysteresis current controller for single-phase photovoltaic inverter and proposed adaptive hysteresis current controller for single-phase photovoltaic inverter. The results obtained with the proposed algorithm are compared with those obtained when using conventional fixed hysteresis current controller for single-phase photovoltaic inverter in terms of THD and switching frequency.

Keywords: Photo Voltaic (PV), Hysteresis Current Controller (HCC), Total Harmonic Distortion (THD).

INTRODUCTION

Renewable energy technologies today are harness for electrical power generation which are reliable and cost competitive with the conventional fuel generators. Among various renewable energy technologies, the solar energy has several advantages like clean, power, unlimited, and provides sustainable electricity. However, the solar energy produces the dc power, and hence power electronics and control equipment are required to convert DC to AC power. The performance of the power inverter depends on the control strategy adopted to generate the gate pulses. To control the inverters, current control methods are normally used. There are several current control strategies proposed, namely, PI control, Average Current Mode Control (ACMC), Sliding Mode Control (SMC) and hysteresis control.

Among the various current control techniques, hysteresis control is the most popular one for voltage source inverter. As the photovoltaic arrays are good approximation to a current source, most of photovoltaic inverters are voltage source inverters. The conventional fixed hysteresis band very simple has robust current control performance with good stability very fast response, an inherent ability to control peak current and easy to implement. An hysteresis band controller changes the hysteresis bandwidth as a function of reference compensator current variation to optimize switching frequency and THD of supply current.

MATLAB simulations are carried out for modeling solar photovoltaic array based on its mathematical equation and that model is used to interconnect DC to DC converter, proposed hysteresis current controlled DC to AC converter and load. The performance of the proposed controller are evaluated by comparing with the results obtained when using conventional fixed hysteresis current controller at the point of THD (Total harmonic reduction) and switching frequency.

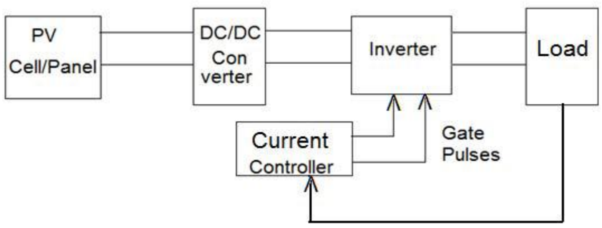

Figure 1. Block Diagram of Photovoltaic System

Figure 1 shows the block diagram of a photovoltaic system, which includes solar photovoltaic panel with DC to DC converter, single phase inverter and load. The solar photovoltaic panel produces electricity when the photons of the sun light strike on the photovoltaic cell array. The output of the photovoltaic panel is directly connected to the DC to DC boost converter to step up the DC output of photovoltaic panel. Then it is fed to an inverter which converts DC into AC power at the desired voltage and frequency.

A current controller is normally preferred due to its advantages like flexibility-modify easily through of software, simplicity- possible implementation in fixed point computation etc. The main task of the control systems in current controlled inverters is to force the current of single phase load according to a reference signal. There are many current control techniques in the literature as mentioned in the Introduction.

The simplest current control technique is hysteresis current control technique. The actual value of the output current is controlled in order to remain in a defined area. This method is fast, simple and provides good results. The only problem is the variable switching frequency of the semiconductor switches that is a direct consequence of this control strategy. An hysteresis current controller is proposed in this paper for the control of inverter to obtain the better result in terms of less total harmonic distortion and constant switching frequency.

A. SINGLE-PHASE VOLTAGE SOURCE INVERTERS

Single-phase VSI can be found as half-bridge and full-bridge topologies. Although, the power range they cover is the low one, they are widely used in power supplies, single-phase UPSs, and currently to form high-power static power topologies, such as the multicell configurations that are reviewed. The main features of both approaches are reviewed and presented in the following undefined ac output-voltage condition; the modulating technique should always ensure that at any instant either the top or the bottom switch of the inverter leg is on.

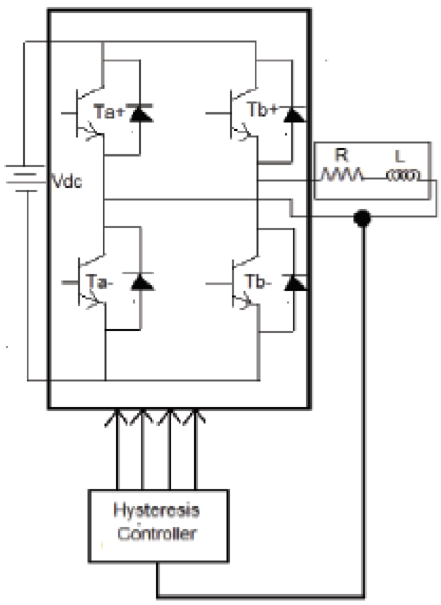

Figure 2. Single Phase Inverter

HYSTERESIS CURRENT CONTROLLER

The basic hysteresis current control is based on an on-line PWM control that fixes the output voltage of the inverter instantaneously. The main task of the PWM current controller in an inverter is to adjust the output current, i, in order to track the current reference provided by i*. Comparing the instantaneous current in the load with the reference signal the controller should adjust the duty cycle of the PWM signal in the inverter. As a consequence, the error signal (δ) should be reduced. A basic scheme of the PWM current controller is shown in Figure 3

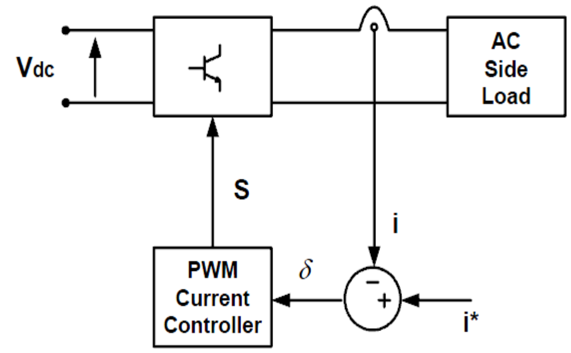

Figure 3. Basic Current Control Scheme in a single phase inverter.

In this kind of controller, the output voltage level depends on the error between the current set point and the real currents injected by the converter. In this way when the load current is lower than the current reference, the inverter connects the positive side of the DC bus to the load, reducing thus the currents. On the contrary when the load current is higher than the current reference, the inverter connects the negative side of the DC bus to the load. Taking into account the previous description, the error signal can be maintained within a certain fixed band.

However, and in spite of its good dynamic response, this fixed error band makes the switching frequency vary according to the slope of the reference signal. This variable switching frequency may cause several problems in the system such as: overheating of the converter, difficulty in the filter design, resonances and appearance of non optimum current ripple in the load. In order to overcome the aforementioned problems the basic hysteresis current control system can be modified in order to get an almost constant switching frequency. In the following section it will be shown how, it is possible to design an adaptive hysteresis band algorithm for a single phase PV inverter able to keep a constant switching frequency.

In unipolar modulation, as shown in Fig.4, two hysteresis band controllers are used to generate proper switching signals to turn on and off the switches (Ta+ ,Ta-) and (Tb+ ,Tb-) in order to control the load current. In this method, the switches are turned on and off in such a way resulting the output voltage to be either Vdc or zero (-Vdc or zero) over half a cycle.

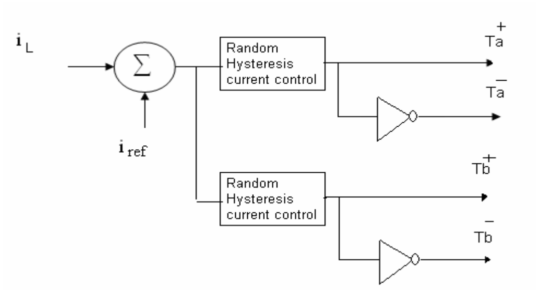

Figure 4: A hysteresis current control

IMPLEMENTATION

The implementation of the Conventional hysteresis current controller carried out in step by step as follows.

Modelling of Sinusoidal Pulse Width Modulated inverters with sinusoidal reference .

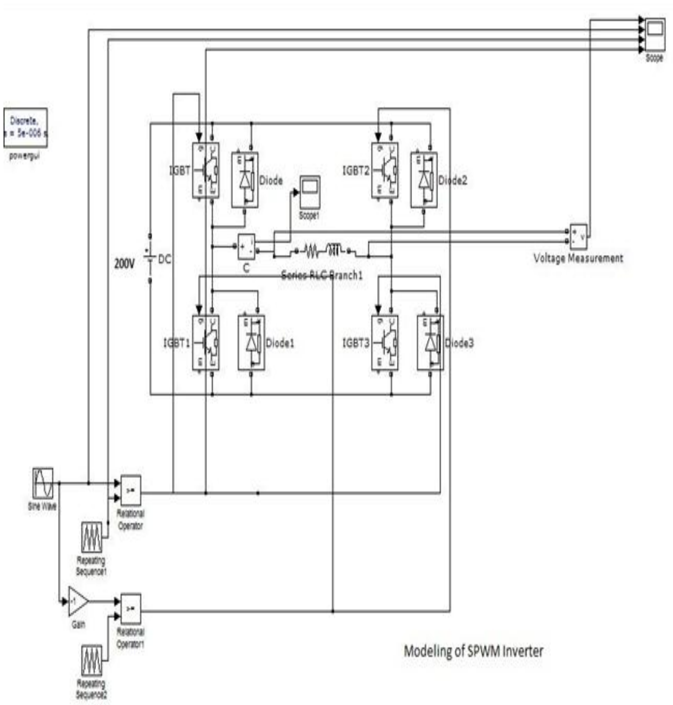

Figure 5: Modelling of SPWM Inverter

Modelling of Conventional hysteresis current controller circuit have two methodologies based on the current injection to the gate drive circuits. The two methodologies named as Unipolar and Bipolar methods.

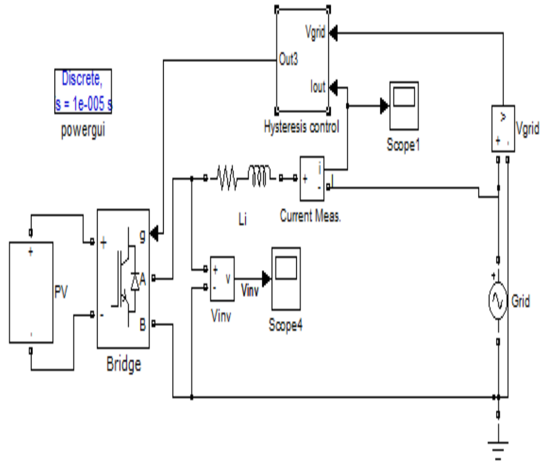

Figure 6: Modelling of Conventional Hysteresis Inverter

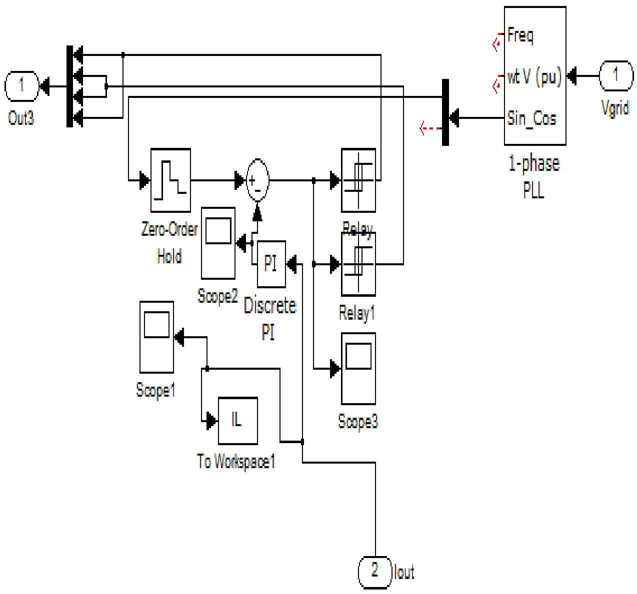

Figure 7: Modelling of Conventional Hysteresis Current Controller Block

Modelling of Proposed hysteresis current controller circuit has two methodologies based on the current injection to the gate drive circuits. Considering one of the method bipolar pulse width modulation method.

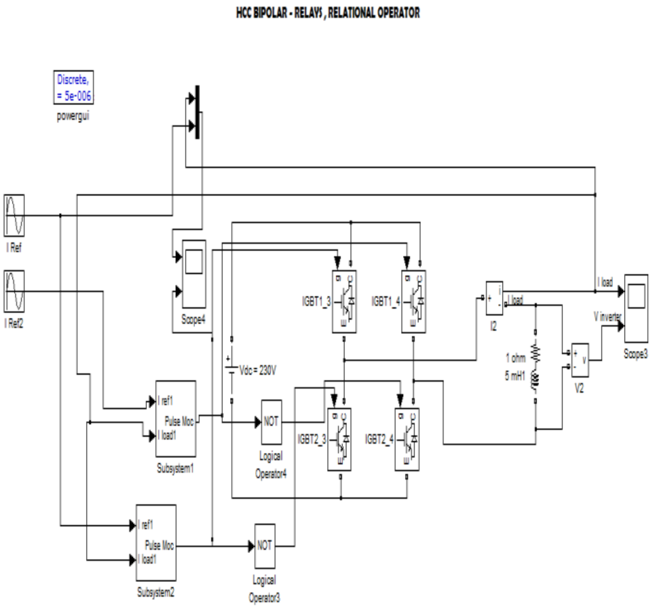

Figure 8: Modelling Of Proposed Hysteresis Current Controlled Inverter

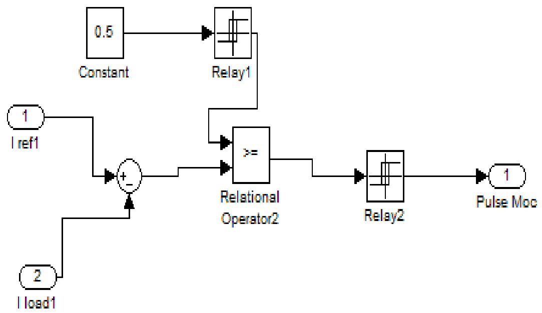

Figure 9: Modelling Of Proposed Hysteresis Current Controller - (A) Block-I

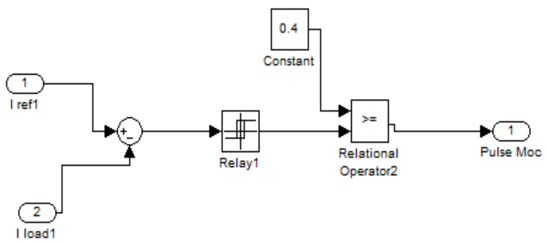

Figure 10: Modelling Of Proposed Hysteresis Current Controller - (A) Block-I

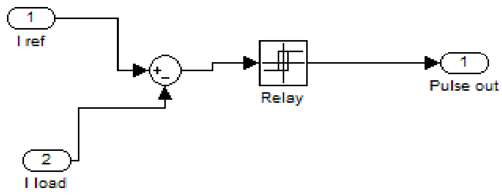

Figure 11: Modelling Of Proposed Hysteresis Current Controller - (A) Block-I (B) Block-II (C) Block-III

SIMULATION RESULTS

A. SIMULATION OF PRPOSED HCC INVERTER - BLOCK-I

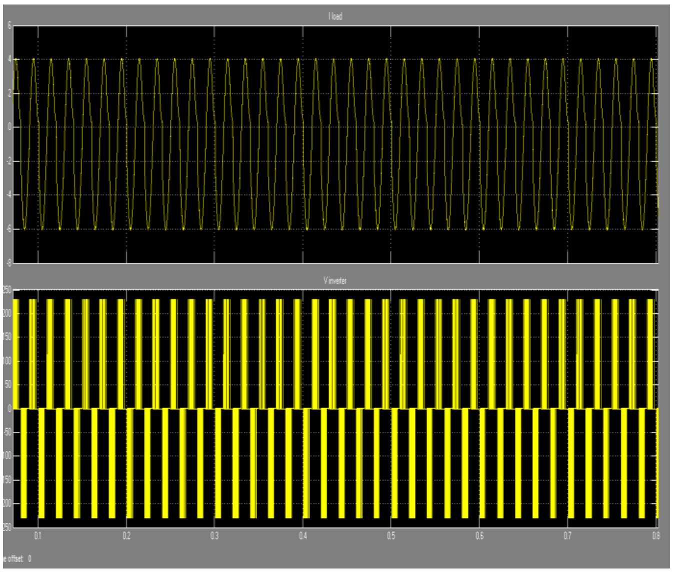

Figure 12: Voltage and Current Curve of Proposed HCC Inverter - Block-I

B. SIMULATION OF PRPOSED HCC INVERTER - BLOCK-II

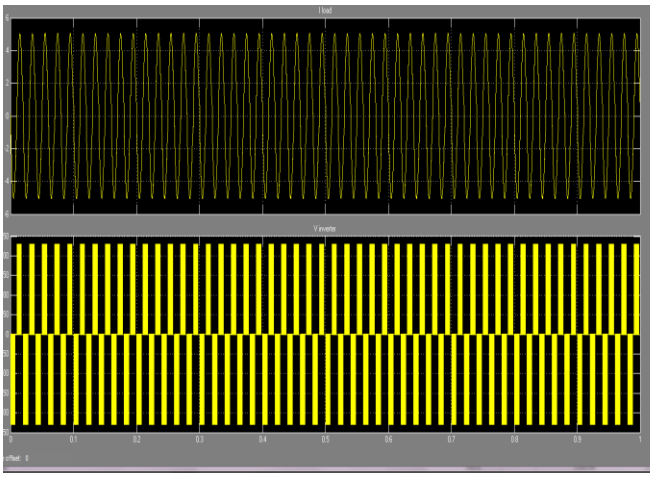

Figure 13: Voltage and Current Curve of Proposed HCC Inverter - Block-II

C. SIMULATION OF PRPOSED HCC INVERTER - BLOCK-III

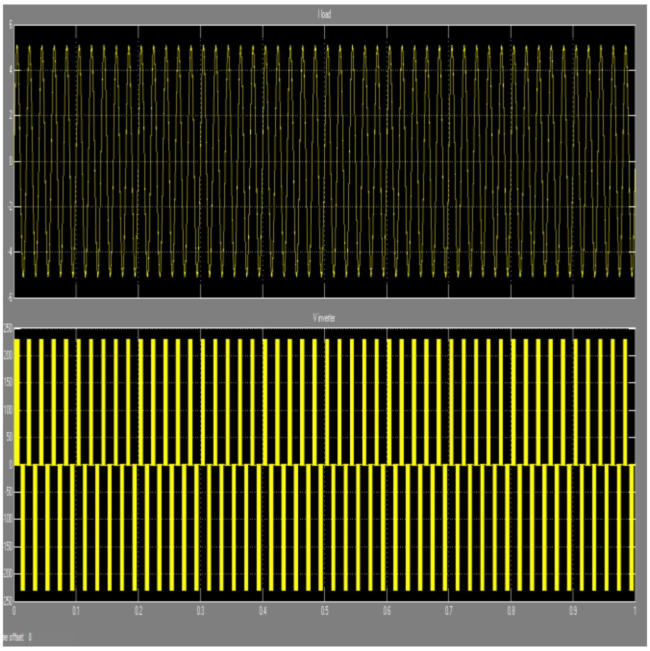

Figure 14: Voltage and Current Curve of Proposed HCC Inverter - Block-III

RESULTS ANALYSIS

Simulated results of hysteresis current controller has been plotted. FFT ananlysis for the different controllers have been found out using the MATLAB simulink softwares and result windows are shown in the Figure. From the analysis THD factors are noted.

A.THD ANALYSIS OF SPWM INVERTER

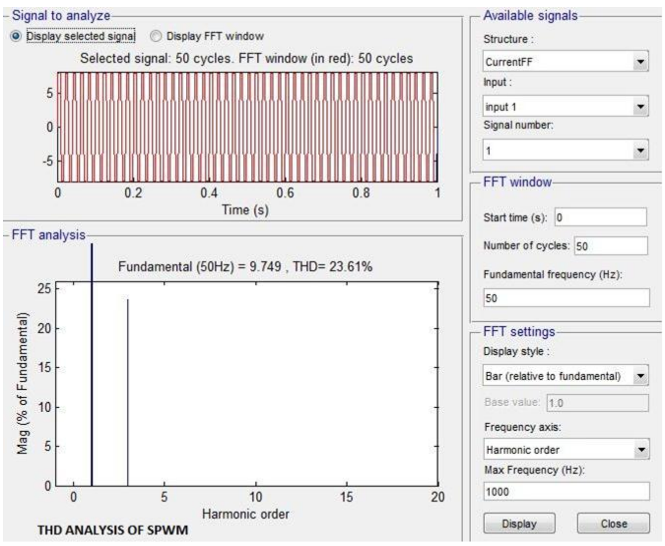

Figure 15: THD Analysis of SPWM Inverter

B. THD ANALYSIS OF CONVENTIONAL HCC INVERTER – GRID CONECTED

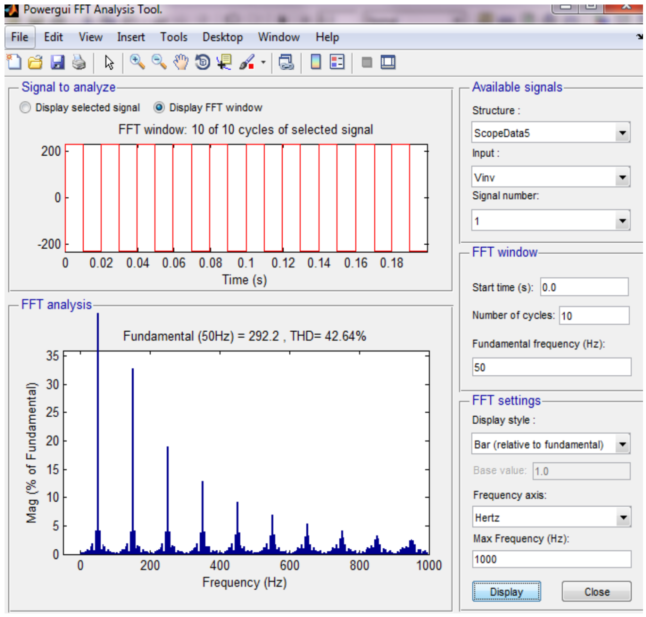

Figure 16: THD Analysis of Conventional Hcc Inverter – Grid Conected

C.THD ANALYSIS OF PROPOSED HCC INVERTER – BLOCK I

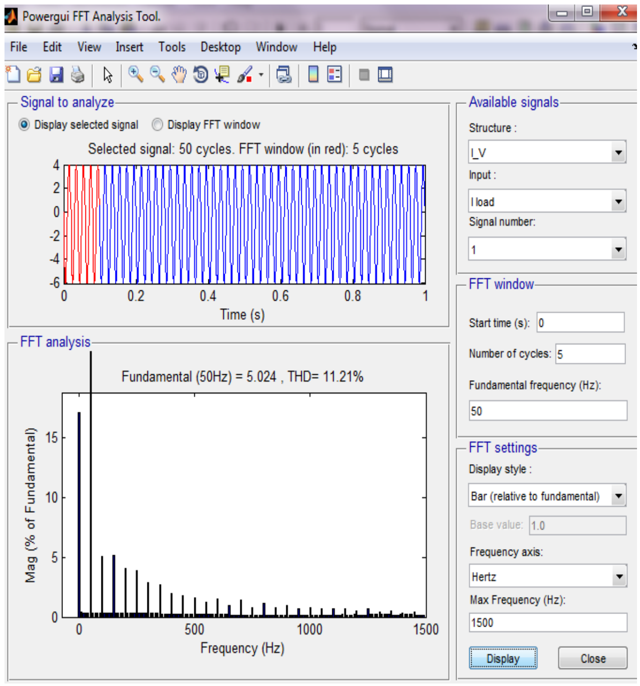

Figure 17: THD Analysis of Proposed HCC Inverter – Block I

D. THD ANALYSIS OF PROPOSED HCC INVERTER – BLOCK II

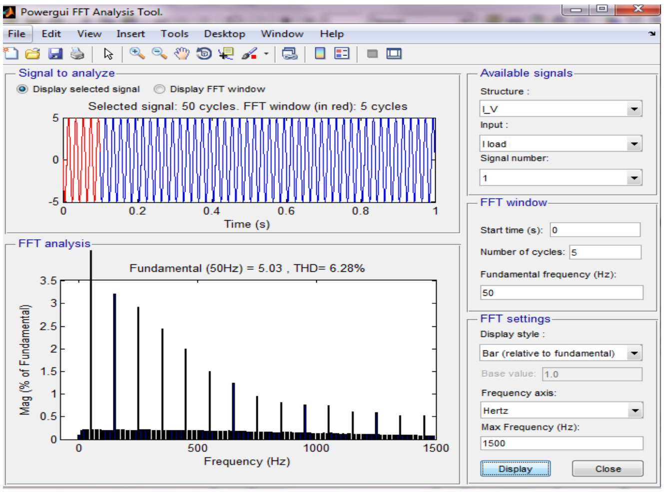

Figure 18: THD Analysis of Proposed HCC Inverter – Block II

E. THD ANALYSIS OF HCC INVERTER – BLOCK III

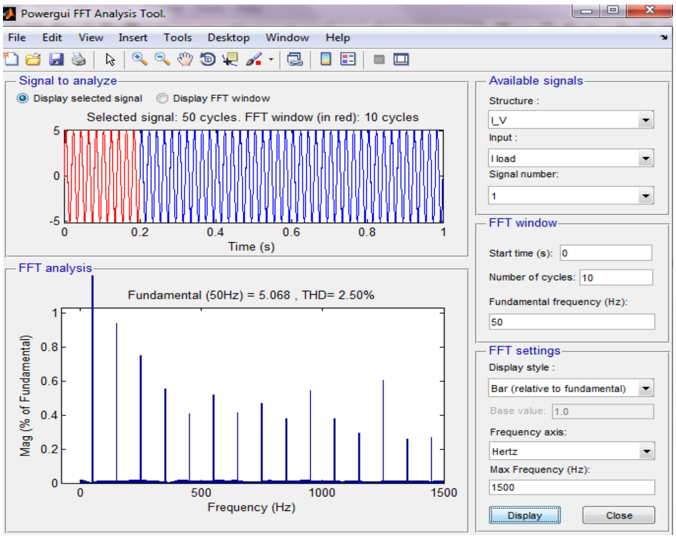

Figure 19: THD Analysis of Proposed HCC Inverter – Block III

CONCLUSION

Controller	Input Voltage (V)	Output Voltage (V)	Output Frequency (Hz)	Output Current (A)	THD (%)
SPWM	230	230	50	5	23.61
Conventional HCC	230	230	50	5	42.64
Proposed HCC – BLOCK I	230	230	50	5	11.21
Proposed HCC – BLOCK II	230	230	50	5	6.28
Proposed HCC – BLOCK III	230	230	50	5	2.5

Proposed Hysteresis current controller have less THD value compared to the other traditional current controllers. Since the proposed hysteresis current controller have better THD result it may be used for the gating signal control in single phase inverters.

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