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Analysis of Total Harmonic Distortion for Grid Connected Photovoltaic Systems

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Abstract---This paper deals with analysis of Total harmonic distortion (THD) for grid connected photovoltaic (PV) systems. In the utility grid, four different inverter topologies like Z-Source Inverter, Voltage Source Inverter, Current Source Inverter, and Multi-level Inverter are connected together and Total Harmonic Distortion (THD) analysis are obtained in MATLAB SIMULINK and simulation outputs are presented.
Keywords---THD, PV, Z-Source, VSI, CSI, MLI

I. INTRODUCTION

The continuously increasing energy consumption, overloads the distribution grids by creating problems such as outages, grid instability, deterioration of power quality, power security etc. To balance the energy demand and generation, renewable energy resources such as Photovoltaic (PV), Wind, and Biomass could be a good solution. Among these, solar energy is considered to be one of the most useful sources because it is free, abundant, pollution free and maintenance free. Since the generated voltage from PV is DC, we need inverter for converting DC voltage from PV to AC before connecting it to grid. Grid is a voltage source of infinite capability. The output voltage and frequency of inverter should be same as that of grid frequency and voltage. The inverter can be of any topology like Quasi Z-Source Inverter, Voltage Source Inverter, Current Source Inverter, Multi-level Inverter. By connecting inverters to the Utility Grid harmonics can be injected into the grid. There is a need of analyzing the amount of harmonics fed by the inverters to the Utility so that remedy can be done.

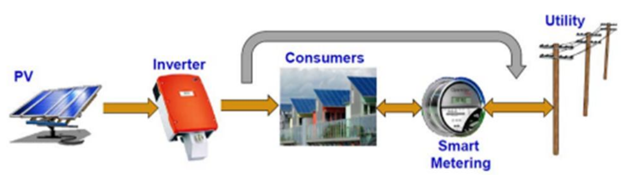

Fig.1 Grid-Connected Solar Inverter System

II. Z-SOURCE INVERTER

The Z-source inverter overcomes the voltage limitation of the traditional inverter. The main advantage of Z-source inverter is the system able to work with a low DC input voltage to generate higher AC output voltage by using only single stage converter. In order to employ the voltage boost ability with single stage converter, both switches in the same inverter phase leg must turn "ON" in same time (shoot-through state). Due to exist of the shoot-through state, the short circuit across any phase leg of inverter is allowed therefore the reliability of the system is greatly improved. Furthermore, with this configuration, inverter output power distortion is reduced, since there is no need to phase leg dead time. Comparing with the BC-VSI configuration, the Z-source inverter is higher performance, higher efficient and lower cost due to uses fewer active components and control circuit [4].

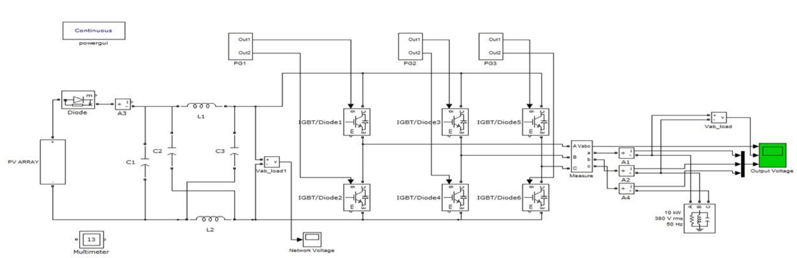

Fig.2 Z-Source Inverter

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III. MULTILEVEL INVERTER

With the increasing higher power quality requirements for numerous industrial applications and renewable energy sources such as photovoltaic, wind, and fuel cells, classical three-level inverters have difficulty in meeting these requirements of clean non polluted sinusoidal waveforms and a minimal distortion factor [6]. As a result, multilevel inverters have been introduced as an alternative in high power quality situations. For several attractive features, such as near-sinusoidal staircase output voltage waveforms, reduced *dv/dt* stress, operating with a lower switching frequency stress, etc., multilevel inverters, as an alternative solution, have been receiving much attention. As a result, many different topologies and a wide variety of control strategies have been proposed. Based on the SC technique that has been applied in many applications, a novel multilevel inverter topology connecting a multilevel dc–dc converter and a full bridge is presented in this paper. With the proposed topology, only one dc voltage source is required, and many other problems, such as voltage balancing, numerous active switches, and complex gate driver circuits, are avoided. The dc–dc conversion section is the key point of the whole topology, which is designed by connecting multiple SC cells. Each SC cell consists of a capacitor, an active switch, and two diodes. Consequently, the output voltage levels of the proposed inverter could be flexibly varied by employing different numbers of SC cells.

IV. VOLTAGE SOURCE INVERTER

Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium- to high-power applications. The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal voltage waveforms (e.g., ASDs, UPSs, FACTS, var compensators), arbitrary voltages are also required in some emerging applications (e.g., active filters, voltage compensators). The standard three-phase VSI topology is shown in Fig. 3 and the eight valid switch states are given in Table I. As in single-phase VSIs, the switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. Of the eight valid states, two of them (7 and 8 in Table I) produce zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components. The remaining states (1 to 6 in Table I) produce nonzero ac output voltages. In order to generate a given voltage waveform, the inverter moves from one state to another. The selection of the states in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states. Out of many modulating techniques like Sinusoidal pulse width modulation, Selected harmonic elimination technique, Space vector Modulation etc, Space vector modulation technique is used in VSI presented in this paper. The SV-based modulating technique is a digital technique in which the objective is to generate PWM load line voltages that are on average equal to given load line voltages. This is done in each sampling period by properly selecting the switch states from the valid ones of the VSI (Table I) and by proper calculation of the period of times they are used. The selection and calculation times are based upon the space-vector transformation [7].

TABLE I
VALID SWITCH STATES FOR A THREE-PHASE VSI

State	State	v_{ab}	v_b	v_a	Space Vector
$_1$, $_2$, and $_6$ are on and $_4$, $_5$, and $_3$ are off	1	v	0	$-v$	$\mathbf{V}_1 = 1 + j0.5$
$_2$, $_3$, and $_1$ are on and $_5$, $_6$, and $_4$ are off	2	0	v	$-v$	$\mathbf{V}_2 = j1.155$
$_3$, $_4$, and $_2$ are on and $_6$, $_1$, and $_5$ are off	3	$-v$	v	0	$\mathbf{V}_3 = -1 + j0.5$
$_4$, $_5$, and $_3$ are on and $_1$, $_2$, and $_6$ are off	4	$-v$	0	v	$\mathbf{V}_4 = -1 - j0.5$
$_5$, $_6$, and $_4$ are on and $_2$, $_3$, and $_1$ are off	5	0	$-v$	v	$\mathbf{V}_5 = -j1.155$
$_6$, $_1$, and $_5$ are on and $_3$, $_4$, and $_2$ are off	6	v	$-v$	0	$\mathbf{V}_6 = 1 - j0.5$
$_1$, $_3$, and $_5$ are on and $_4$, $_6$, and $_2$ are off	7	0	0	0	$\mathbf{V}_7 = 0$
$_4$, $_6$, and $_2$ are on and $_1$, $_3$, and $_5$ are off	8	0	0	0	$\mathbf{V}_8 = 0$

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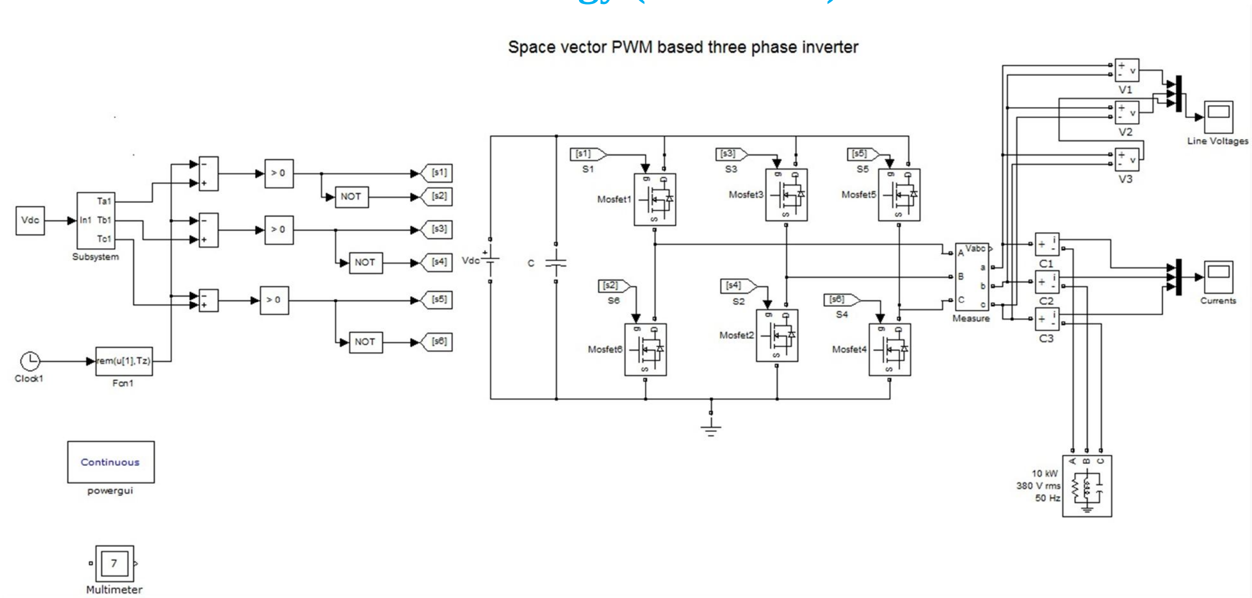

Fig.3 Three-Phase VSI Inverter

V. CURRENT SOURCE INVERTER

The main objective of these static power converters is to produce ac output current waveforms from a dc current power supply. For sinusoidal ac outputs, its magnitude, frequency, and phase should be controllable. Due to the fact that the ac line currents ioa, iob, and ioc (Fig. 4) feature high di=dt, a capacitive filter should be connected at the ac terminals in inductive load applications (such as ASDs). Thus, nearly sinusoidal load voltages are generated that justifies the use of these topologies in medium-voltage industrial applications, where high-quality voltage waveforms are required. Although single-phase CSIs can in the same way as three-phase CSIs topologies be developed under similar principles, only three-phase applications are of practical use and are analyzed in the following. In order to properly gate the power switches of a threephase CSI, two main constraints must always be met: (a) the ac side is mainly capacitive, thus, it must not be short circuited; this implies that, at most one top switch (1, 3, or 5 (Fig. 4)) and one bottom switch (4, 6, or 2 (Fig. 4)) should be closed at any time; and (b) the dc bus is of the current-source type and thus it cannot be opened; therefore,there must be at least one top switch (1, 3, or 5) and one bottom switch (4, 6, or 2) closed at all times. There are nine valid states in three-phase CSIs. The states 7, 8, and 9 (Table II) produce zero ac line currents. In this case, the dc link current freewheels through either the switches S1 and S4, switches S3 and S6, or switches S5 and S2. The remaining states (1 to 6 in Table II) produce nonzero ac output line currents. In order to generate a given set of ac line current waveforms, the inverter must move from one state to another. Thus, the resulting line currents consist of discrete values of current, which are ii , 0, and ÿii . Out of Many Modulating Techniques Space Vector PWM technique is used similar to VSI.

TABLE II
VALID SWITCH STATES FOR A THREE-PHASE CSI

State	State	*a*	*b*		Space Vector
$_1$ and $_2$ are on and $_3$, $_4$, $_5$, and $_6$ are off	1		0	–	$\mathbf{I}_1 = 1 + j0.5$
$_2$ and $_3$ are on and $_4$, $_5$, $_6$, and $_1$ are off	2	0		–	$\mathbf{I}_2 = j1.155$
$_3$ and $_4$ are on and $_5$, $_6$, $_1$, and $_2$ are off	3	–		0	$\mathbf{I}_3 = -1 + j0.5$
$_4$ and $_5$ are on and $_6$, $_1$, $_2$, and $_3$ are off	4	–	0		$\mathbf{I}_4 = -1 - j0.5$
$_5$ and $_6$ are on and $_1$, $_2$, $_3$, and $_4$ are off	5	0	–		$\mathbf{I}_5 = -j1.155$
$_6$ and $_1$ are on and $_2$, $_3$, $_4$, and $_5$ are off	6		–	0	$\mathbf{I}_6 = 1 - j0.5$
$_1$ and $_4$ are on and $_2$, $_3$, $_5$, and $_6$ are off	7	0	0	0	$\mathbf{I}_7 = 0$
$_3$ and $_6$ are on and $_1$, $_2$, $_4$, and $_5$ are off	8	0	0	0	$\mathbf{I}_8 = 0$
$_5$ and $_2$ are on and $_6$, $_1$, $_3$, and $_4$ are off	9	0	0	0	$\mathbf{I}_9 = 0$

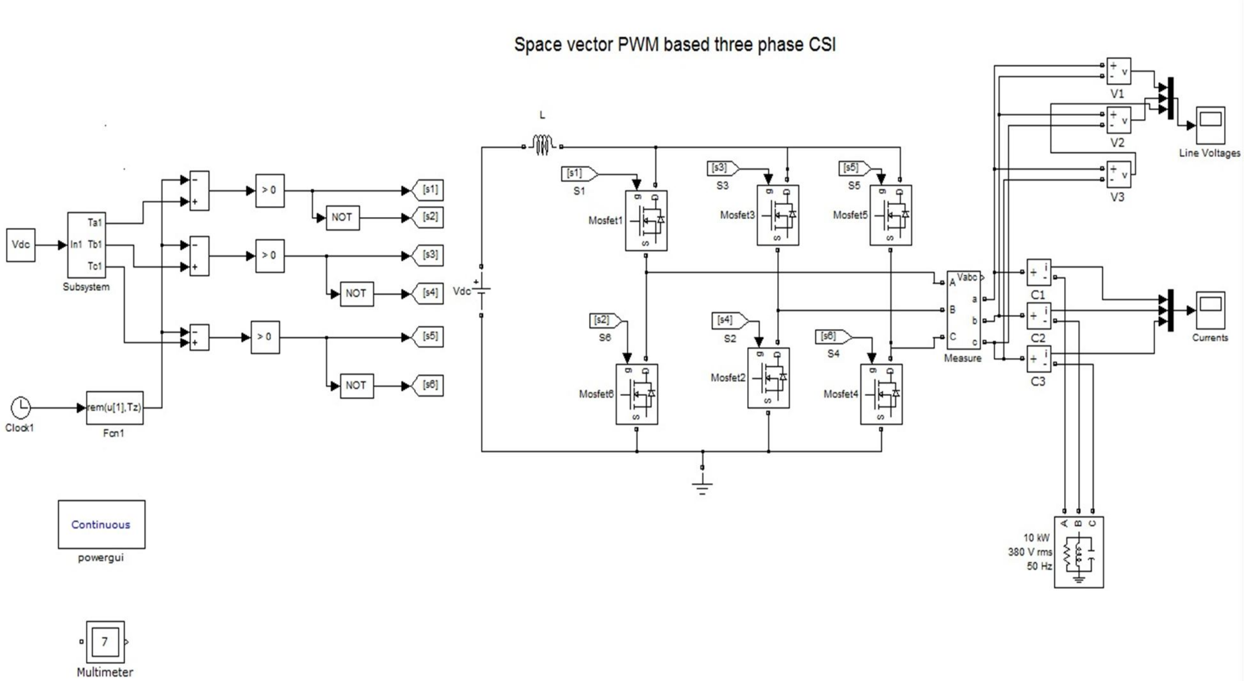

Fig.4 Three Phase CSI Inverter

VI. INVERTERS CONNECTED TO GRID

For this study four inverters (Z-Source inverter, Three Phase Voltage Source inverter, Three Phase Current Source Inverter, Switched Capacitor Multi-level Inverter) are connected to the Utility Grid and Total Harmonic Distortion is analysed. Each inverters are designed to drive load capable of 10 KW to 50 KW. In the Utility Grid, 10 KW Permanent magnet Synchronous Machine is connected as a load and its performance parameters are analyzed.

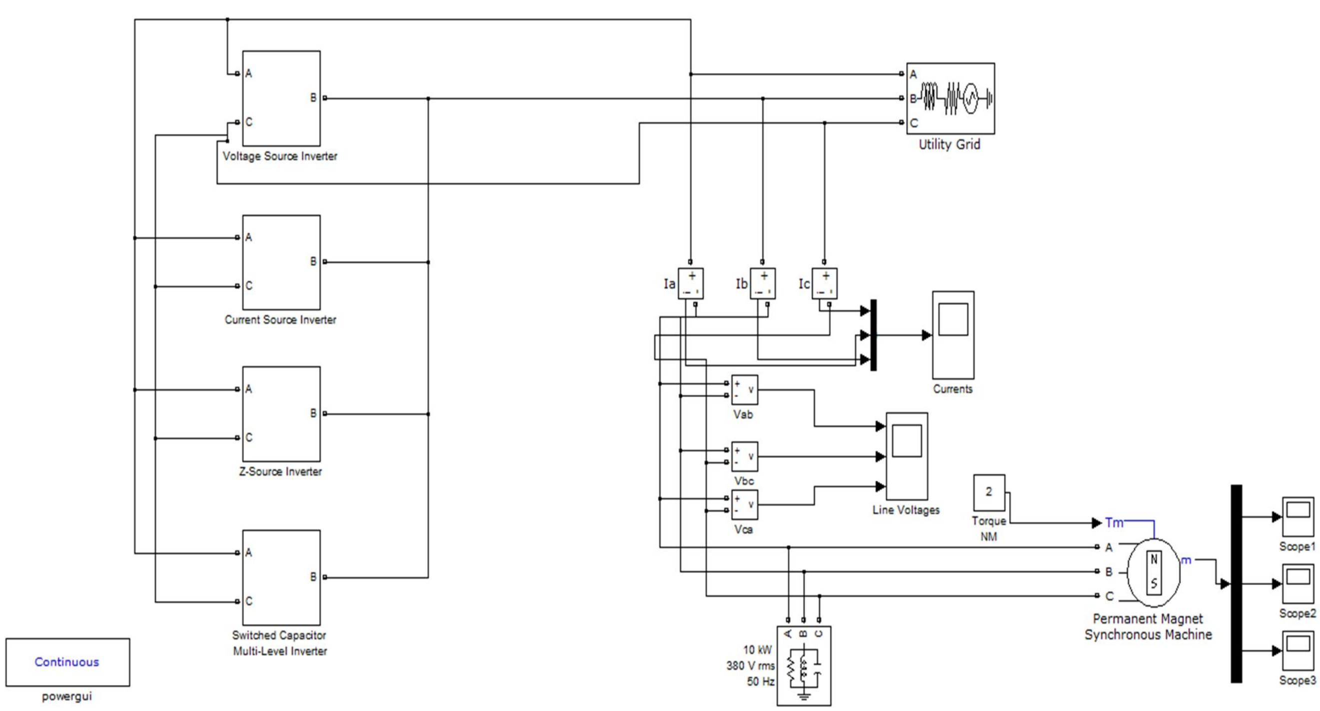

Fig.4 Inverters Connected to the Utility Grid

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VII. SIMULATION OUTPUTS

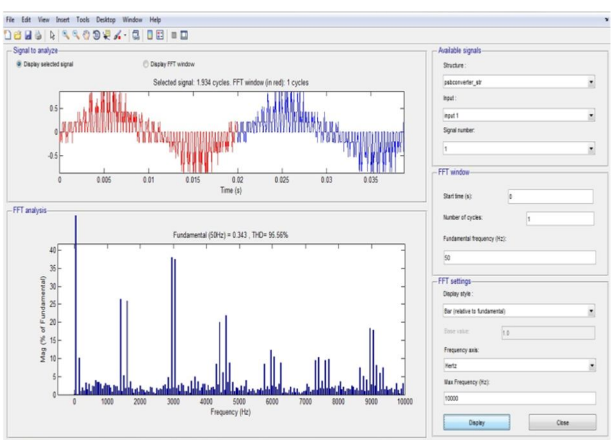

Fig.5 THD at R-Phase

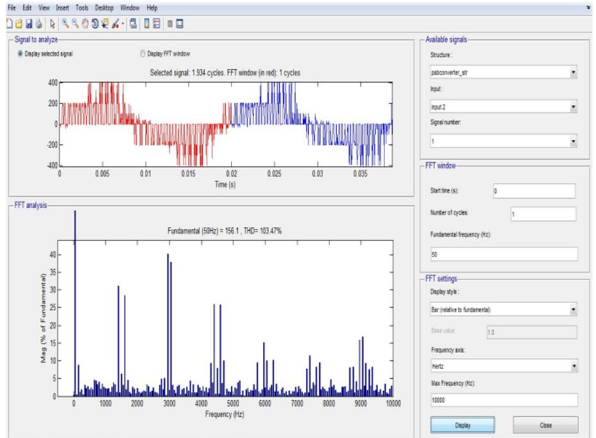

Fig.6 THD at Y-Phase

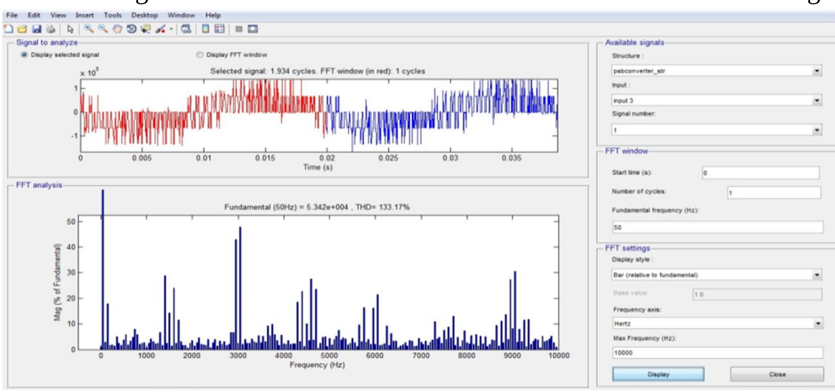

Fig.7 THD at B-Phase

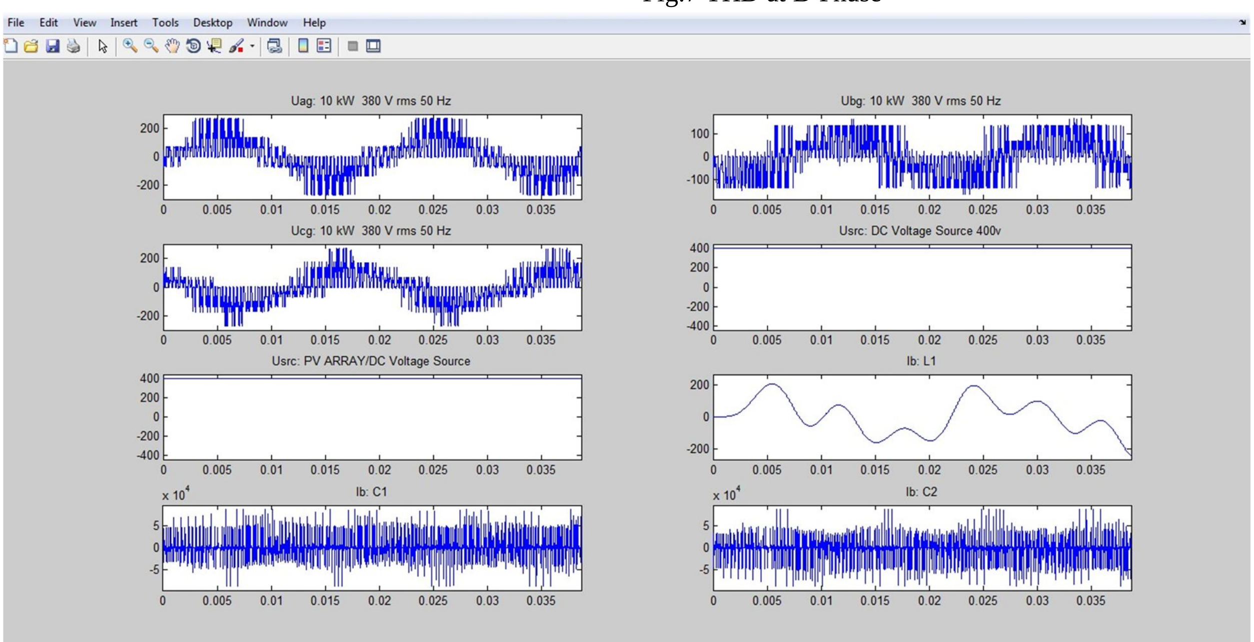

Fig.8 Output Parameters

Total Harmonic Distortion is analyzed for all the three phases of the Utility Grid and parameters of the Utility Grid are also plotted. If the Z-Source inverter, Three Phase Voltage Source inverter, Three Phase Current Source Inverter, Switched Capacitor Multi-level Inverter are

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connected the Total Harmonic Distortion at the grid is around 93.3%. The distorted waveforms at the grid phases are shown in the figure.

VIII. CONCLUSION

Thus the Total Harmonic Distortion (THD) for Utility grid is analyzed with the help of Fast Fourier Transform using MATLAB SIMULINK. With the help of this analysis and output parameters, the design of inverters can be modified or topologies can be changed to reduce Total Harmonic Distortion.

REFERENCE

[1] Soeren Baekhoej, John K Pedersen & Frede Blaabjerg, ―A Review of single phase grid connected inverter for photovoltaic modules,‖ IEEE transaction on Industry Application , Vol. 41,pp. 55 – 68, Sept 2005.
[2] Frede Blaabjerg , Remus Teodorescu and Marco Liserre, ―Overview of control & grid synchronization for distributed power generation systems,‖ IEEE transaction on Industrial Electronics, Vol. 53, pp. 500 – 513,Oct- 2006.
[3] S. H. Song, S. Kang, and N. K. Hahm, "Implementation and control of grid connected AC-DC-AC power converter for variable speed wind energy conversion system," Appl. Power Electron. Conf. Expo.,voU, pp. 154-158, 2003.
[4] F. Z. Peng, "Z-source inverter", *IEEE Trans. Ind. Applicat.,* vol. 39, pp. 504-510, Mar/Apr. 2003.
[5] H. Sepahvand, J. Liao, M. Ferdowsi, and K. A. Corzine, "Capacitor voltage regulation in single-DC-source cascaded H-bridge multilevel converters using phase-shift modulation," *IEEE Trans. Ind. Electron.*, vol. 60, no. 9, pp. 3619–3626, Sep. 2013.
[6] J. Pereda and J. Dixon, "Cascaded multilevel converters: Optimal asymmetries and floating capacitor control," *IEEE Trans. Ind. Electron.*, vol. 60, no. 11, pp. 4784–4793, Nov. 2013.
[7] Pinheiro, H., Botteron, F., Rech, C., Schuch, L., Camargo, R.F., Hey, H.L., Grundling, H.A. and Pinheiro, J.R., "Space vector modulation for voltage-source inverters: a unified approach", IECON 02 [Industrial Electronics Society, IEEE 2002 28th Annual Conference of the] Volume 1, 5-8 Nov. 2002 Page(s):23 - 29 vol.1
[8] Carter, J., Goodman, C.J., Zelaya, H. and Tran, S.C., "Capacitor voltage control in single-phase three-level PWM converters", Power Electronics and Applications, 1993., Fifth European Conference on 13-16 Sep 1993 Page(s):149 - 154 vol.7