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A ZERO HARMONIC DISTORTION & IMPROVEMENT OF POWER QUALITY USING CASCADED H-BRIDGE

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Abstract-
In reactive power compensation cascaded voltage source converter with separated dc sources seems to be the most feasible topology for many reasons. The cascaded converter is constructed with a number of identical H-Bridge inverters. This modular feature makes the cascaded converter very attractive. The cascaded converter topology not only specifies hardware manufacture ability, but also makes the entire system flexible in term of power capability. In Multilevel converter has become attractive in the power industries and it can be applied in many applications especially on improvement of the power quality and distortion of zero harmonic components. This paper also presents the generation of triggering signals used to control the cascaded H-bridge multilevel converter. As the number of levels increases, the synthesized output waveform adds more steps, producing a staircase which approaches the sinusoidal wave with minimum harmonic distortion. Ultimately, a zero harmonic distortion of the output wave can be obtained by an infinite number of levels. One of the major limitations of the multilevel converters is the voltage unbalance between different levels. The techniques to balance the voltage between different levels normally involve voltage clamping or capacitor charge control. This paper presents the cascaded multi (nine and eleven) level converter to improving the voltage sharing problems.
Keywords— **Multilevel Converter, Multilevel Inverter, Cascaded Multi (nine and eleven) Level Converter, Power Converter, Matlab.**

I. INTRODUCTION

Recently the “multilevel converter” has drawn tremendous interest in the power industry. The general structure of the multilevel converter is to synthesize a sinusoidal voltage from several levels of voltages, typically obtained from dc voltage sources. The multilevel converters start from three levels. A three level converter, also known as a “neutral-clamped” converter, consists of two capacitor voltages in series and uses the centre tap as the neutral. Each phase leg of the three-level converter has two pairs of switching devices in series. The center of each device pair is clamped to the neutral through clamping diodes. The waveform obtained from a three-level converter is a quasi-square wave output.

The diode-clamped method can be applied to higher level converters. As the number of levels increases, the synthesized output waveform adds more steps, producing a stair-case wave which approaches the sinusoidal wave with minimum harmonic distortion. Ultimately, a zero harmonic distortion of the output wave can be obtained by an infinite number of levels. More levels also mean higher voltages can be spanned by series devices without device voltage sharing problems. Therefore, we used the cascaded multilevel converter to improving the voltage sharing problems. A three phase CHB multilevel converter circuit is designed and simulated using the MATLAB SimPowerSystems software.

II. CONVERTER TOPOLOGY

A power converter is an electrical or electro-mechanical device for converting electrical energy. It may be converting AC to or from DC, or the voltage, or frequency, or some combination of these.

Amongst the many devices that are used for this purpose are-

- Switched-mode power supply
- Rectifier
- Inverter
- Motor generator set
- DC-DC converter
- Transformer

But in this paper, we considered a multilevel inverter. So, first of all define the single inverter and then also explain the multilevel inverter. A device that converts dc power into ac power at desired output voltage and frequency is called an inverter. Some industrial applications of inverters are for adjustable-speed ac drives, induction heating, stand by air-craft power supplies, UPS (uninterruptible power supplies), for computers, HVDC transmission lines etc. Phase controlled converters, when operated in the inverter mode, are called line-commutated inverters. But line-commutated inverters require at the output terminals an existing ac supply which is used for their commutation. This means that line-commutated inverters can’t function as isolated ac voltage sources or as variable frequency generators with dc power at the input. Therefore, voltage level, frequency and waveform on the ac side of line-commutated inverters cannot be changed. On the other hand, force commutated inverters provide an independent ac output voltage of adjustable voltage and adjustable frequency and have therefore much wider applications.

Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application.

However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected.

A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

- Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the d v/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.
- Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies.
- Input current: Multilevel converters can draw input current with low distortion.
- Switching frequency: Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

Unfortunately, multilevel converters do have some disadvantages. One particular disadvantage is the greater number of power semiconductor switches needed. Although lower voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex. To date, the MOSFET, GTO/Diode semiconductor switches are used to solve above problems. The cascade converter has drawn more interest lately as research shows its remarkable advantages over its counterparts. The simple repetitive modular structure of the converter allows high modification flexibility and greatly simplifies control designs. The technology also permits easy troubleshooting and packaging.

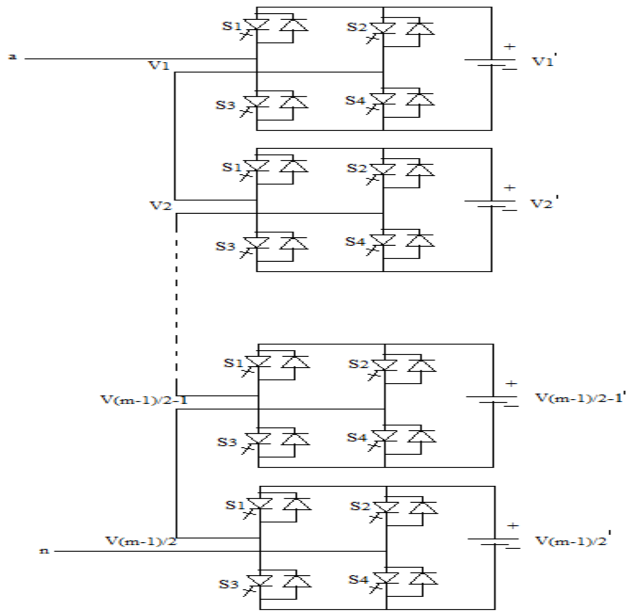

Fig.1 Schematic of a 1-phase cascaded-multilevel converter

In this circuit, a single-phase structure of an m-level cascaded inverter with SDCSs is illustrated in Figure 1. A relatively new converter structure, cascaded-inverters with separate dc sources (SDCSs) is introduces here. This new converter can avoid extra clamping diodes or voltage balancing capacitors. Each separate dc sources (SDCSs) is connected to a single-phase full-bridge, or H-bridge, inverter. The ac terminal voltages of different level inverters are connected in series. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $–V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $–V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels ‘m’ in a cascade inverter is defined by m=2s+1, where s is the number of separate dc sources. Each single-phase full bridge inverter can generate three level outputs, $+V_{dc}$, 0, and $–V_{dc}$. This is made possible by connecting the dc sources sequentially to the ac side via the n gate-turn-off devices. Similarly, the ac output voltage at each level can be obtained by controlling the conducting angles at different inverter levels.

The phase output voltage is synthesized by the sum of individual inverter outputs, i.e.,

$$V_{an}=V_1+V_2+V_3+\ldots\ldots\ldots\ldots V_n$$

Therefore, the phase voltage for 11-level cascaded inverter is,

$$V_{an}=V_1+V_2+V_3+V_4+V_5$$

For a stepped waveform such as the one depicted in Fig.5 with s steps, the Fourier Transform for this waveform-

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The conducting angles,**Error! Reference source not found.**, **Error! Reference source not found.**……..**Error! Reference source not found.** can be chosen such that the voltage total harmonic distortion is a minimum. Generally, these angles are chosen so that predominant lower frequency harmonics, 5^{th}, 7^{th}, 11^{th}, and 13^{th}, harmonics[2].For the 11-level case the 5^{th}, 7^{th}, 11^{th} and 13^{th} harmonics can be eliminated with the appropriate choice of the conducting angles. One degree of freedom is used so that the magnitude of the output waveform corresponds to the reference amplitude modulation index m_a which is defined as V_L^*/V_{Lmax}, where V_L^* is the amplitude command of the inverter output voltage, and V_{Lmax} is the maximum attainable amplitude of the converter, i.e., $V_{Lmax} = s.V_{dc}$.

Let the equation from above H(n) be as follows:

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The set of nonlinear transcendental equations (5) to (9) can be solved by iterative method such as the Newton-Raphson method. For example, using a conducting angles-

$$\theta_1 = 0^\circ$$
$$\theta_2 = 18^\circ$$
$$\theta_3 = 36^\circ$$
$$\theta_4 = 54^\circ$$
$$\theta_5 = 72^\circ$$

Therefore the modulation index m_a =0.73.

This means that, if the inverter output is symmetrically switched during the positive half cycle of the fundamental voltage to $+V_{dc}$ at **Error! Reference source not found.**, $+2V_{dc}$ at **Error! Reference source not found.**, $+3V_{dc}$ at **Error! Reference source not found.**,$+4V_{dc}$ at **Error! Reference source not found.**, and $+5V_{dc}$ at **Error! Reference source not found.** and similarly in the negative half cycle to $-V_{dc}$ at **Error! Reference source not found.**, $-2V_{dc}$ at **Error! Reference source not found.**, $-3V_{dc}$ at **Error! Reference source not found.** ,$-4V_{dc}$ at **Error! Reference source not found.**, and$-5V_{dc}$ at **Error! Reference source not found.**, the output voltage of the 11-level inverter will not contain the 5^{th}, 7^{th}, 11^{th} and 13^{th} harmonic components. For a three-phase system, the output voltages of the three cascaded inverters can be connected in either star- or –delta configuration. Fig.2 illustrates the connection diagram for a star-configuration 11-level converter using cascaded-inverters with five SDC sources.

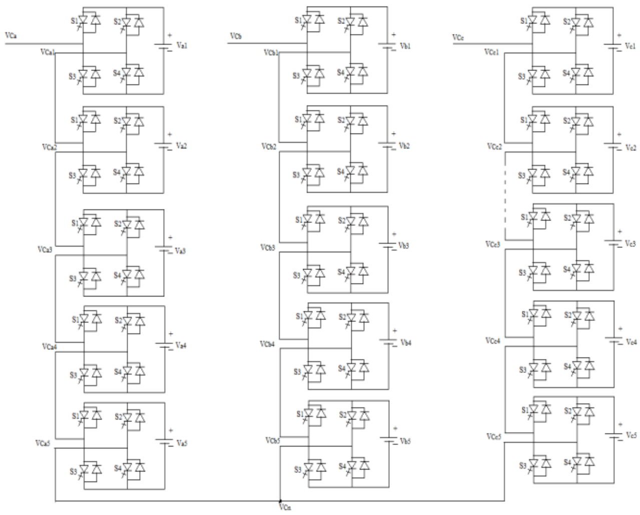
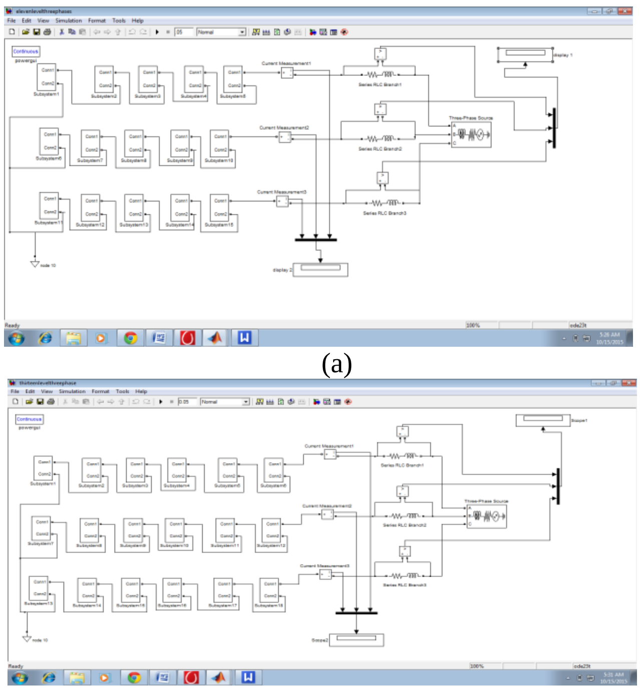


Fig. 2 Three phase 11-level CHB Multilevel converter

Single phase and Three phase Eleven Levels Cascaded H-bridge Multilevel Converter

This type of CHB cascaded multilevel converter has been designed and simulated using MATLAB SimPowerSystems. The multilevel circuits are illustrated in Fig.



(a)

(b)

Fig 3 (a) Simulation model of 3-phase Cascaded Eleven level converter (b) Simulation model of 3-phase Cascaded Thirteen level converter.

III. MERITS AND DEMERITS OF MULTILEVEL CONVERTER

The multilevel inverter approach allows the use of high power and high voltage electric motor drive systems.

Advantages/ Merits:

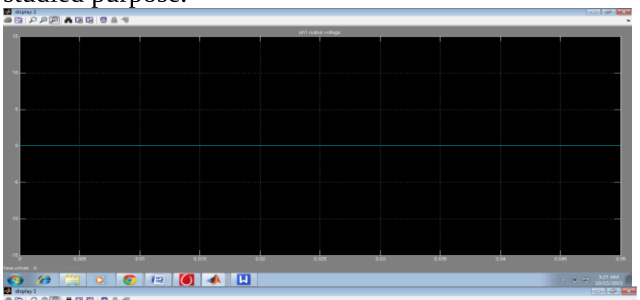
The number of possible output voltage levels is more than twice the number of dc sources (m = 2s+1).The series of H-bridges makes for modularized layout and packaging. This will enable the manufacturing process to be done more quickly and cheaply.

Disadvantages/Demerits:

Separate dc sources are required for each of the H-bridges. This will limit its application to products that already have multiple SDCSs readily available.

IV. SIMULATION RESULTS

The simulation results of the cascaded multilevel converter are taken on eleven level converters. And, the nine level cascaded multilevel converter is used for the studied purpose.



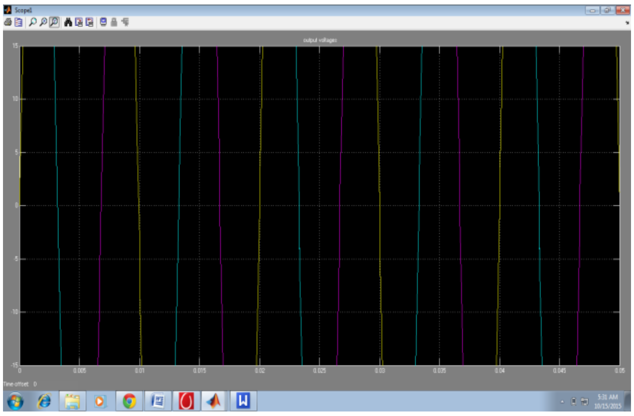


Fig.4 Out put results of Eleven and Thirteen Level

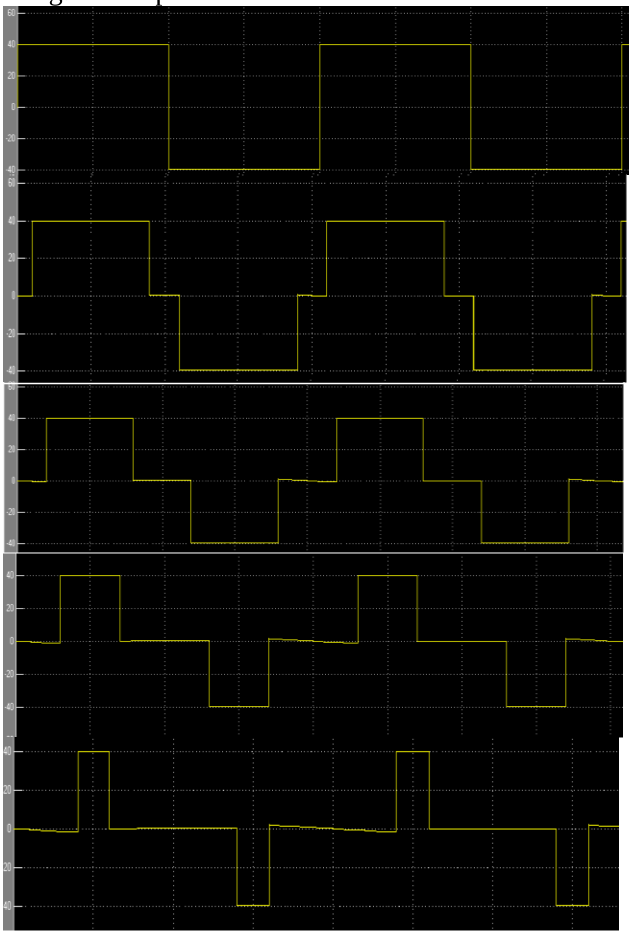
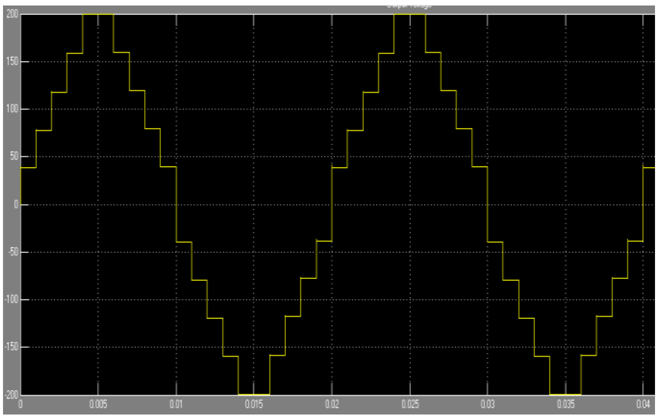


Fig.5 Individual waveform of inverter (when delays are o^0, 18^0, 36^0, 54^0, 72^0 respectively)



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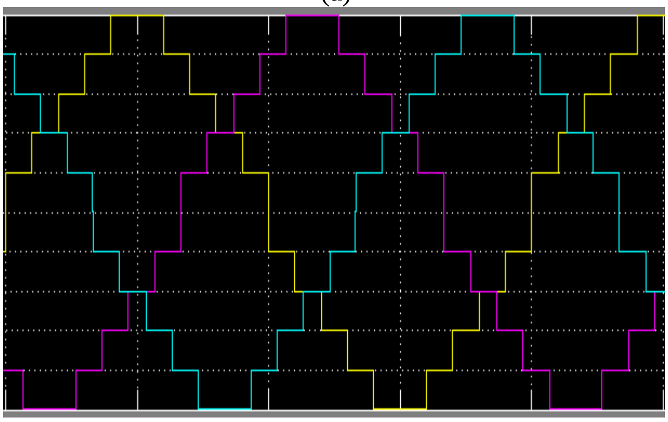

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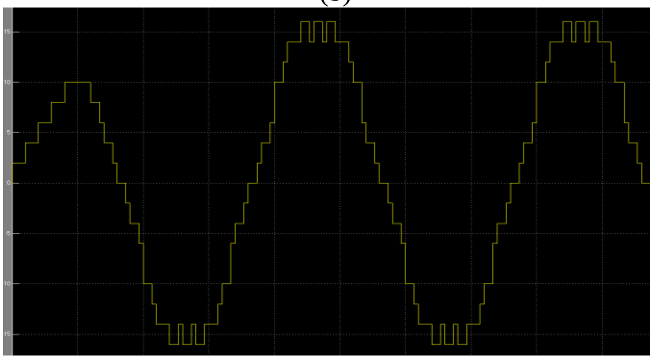
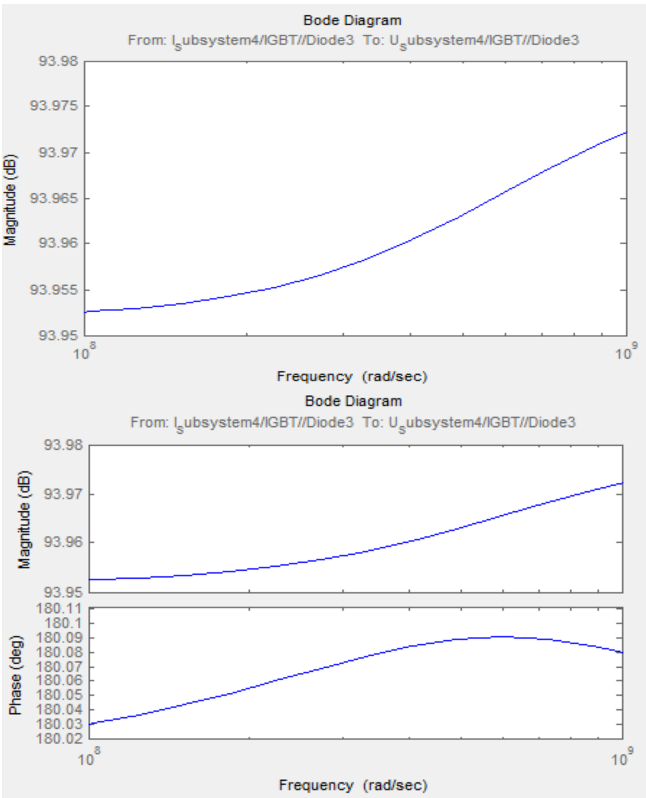


Fig.6 (a)Single-phase cascaded 11-level inverter waveform. (b) Three-phase cascaded 11-level inverter waveform. (c) line-to-line voltage



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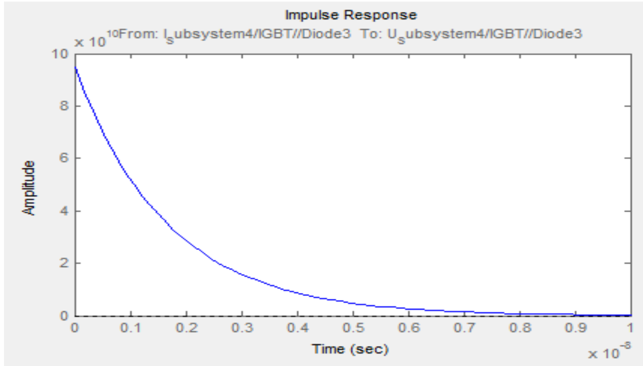

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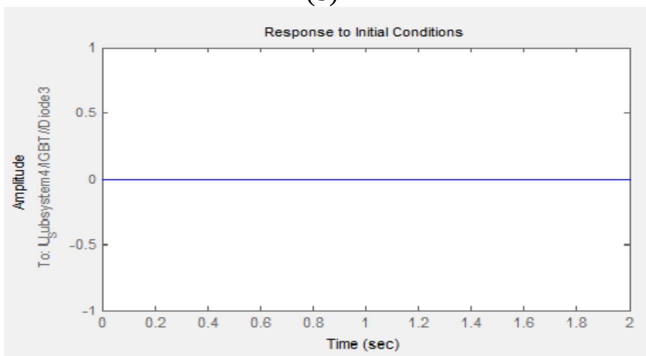

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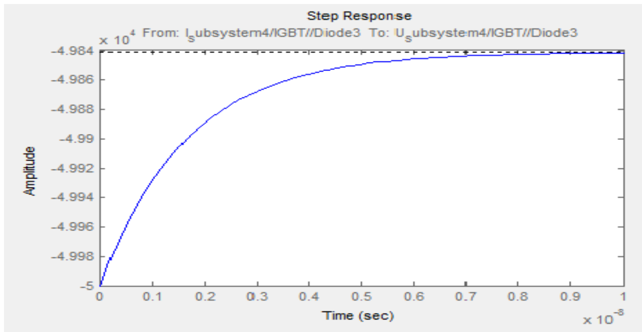

(d)

Fig. 7 (a) Bode Diagram and Response For Converter (b) Impulse Response for Converter (c) Response in initial conditions (d) Step response for converter

V. CONCLUSON

Among recently developed power converter topologies, multilevel converters have become an important technology and have been utilized in higher-power applications, especially for FACTS controllers. Several multilevel converter topologies have been developed to demonstrate their superiority in such applications. With converter modules in series, and with balanced voltage sharing among them, the lower-voltage switches can possibly be used in high-voltage systems. Thus, the low-voltage-oriented insulated gate bipolar transistor (IGBT) devices can be stacked for medium-voltage systems. For higher-voltage applications, however, efforts were made to use GTO-based devices for multilevel converters.

VI. REFERENCES

[1]. M. H. J. Bollen, "Understanding Power Quality Problems Voltage Sags and Interruptions," IEEE Press, New York, 2000.
[2]. J. Schlabbach, D. Blume and T. Stephanblome, "Voltage Quality in Electrical Power Systems," The Institution of Engineering and Technology, Stevenage, 2000.
[3]. R. C. Dugan, M. F. McGranaghan and H. W. Beaty, "Electric Power Systems Quality," 2nd Edition, McGraw Hill, New York, 2006.
[4]. A. Baggini, "Handbook on Power Quality," John Wiley & Sons, Hoboken, 2008.
[5]. IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, IEEE Std. 519-1992, Apr. 12, 1993.
[6]. Pedro Roncero –Sanchez, Jose Enrique Orgeta-Calderon,Aurelio Garcia-Cervada, "A Versatile Control scheme for a Dynamic Voltage Restorer For Power Quality Improvement", IEEE Transaction On Power Delivery, Vol.24,No.1, Jan 2009,PP.277-284.
[7]. K. Surin and M.T. Leon, "Multilevel power converters", Journal in the University of Tennessee, 2000, Vol.31,pp 150.
[8]. Jingsheng Liao, Keith Corzine and Mehdi Ferdowsi, "A new control Method for Single-DC-Source Cascaded H-Bridge Multilevel Converters using Phase-Shift Modulation".