Multi-level inverters for Renewables and Industrial Drives Applications

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ABSTRACT

The electric power system in a sustainable future will augment the centralized and large grid dependent system of today with distributed smart grid based energy generation system. To achieve this world is increasingly adopting renewable energy sources e.g. solar, wind, tidal and fuel cells. The expanded utilization of power electronic devices has expanded the pressure on power system as it prompts generation of voltage and current harmonics and it additionally builds the reactive current. These days, power electronic devices are utilized by the ventures for some, reasons like variable voltage, variable frequency and current control so as to get accurate controllability, better and higher proficiency, quicker reaction and in particular to make the devices compact in estimate.

Key words- power electronic device, Photovoltaic System, MPPT

1. INTRODUCTION

The basic issue here is the non-sinusoidal current of rectifiers and inverters that contain the essential segment as well as the harmonic parts. The principle issue emerges as a result of the switching actions which these power hardware devices show, for example, MOSFET, BJT, SCR, IGBT and so forth. In view of this switching action these devices acts as non-direct loads. The displacement and distortion factors additionally wind up poor as these devices draw driving/slacking and non-sinusoidal current from the supply, in this way bringing about infusion of harmonics in the distribution systems. The harmonic current at that point begins streaming across the line and source impedance and this causes distortion of voltages, intemperate power loss and voltage drop.

1.1 Multiple Output Converters

DC-DC converter with single yield is deficient in numerous applications. For doubly fed machines like electric tractor locomotives or lifts are required to work from one input source. Different yields with wide range applications in cross breed electric vehicles, LED lighting, dc based nano-grids, remain by power supplies and so on. Moreover, the setup where two loads can be worked from a similar source diminish the massiveness of the customary converters and give more compactness, cost adequacy and have higher productivity. Single input double yield buck converters were additionally investigated for both unidirectional and bidirectional tasks and use of power switches. H. Wang et al., [1], in this examination work, angular modulation list (AMI) actualized through an altered space vector modulation for the dual voltage source inverters (VSI) is implemented with the fundamentally meaning to lessen switching losses. G. Farivar et al. [2], the standards of the controlling strategy and switching loss, which is decreased at any rate by half, are hypothetically assessed. Y. Yu et al. [3] a four-level five-phase open-end winding (OeW) drive topology is presented in this investigation. J. I. Leon et al. [4], the impact of dead time on the drive execution is talked about, and it is demonstrated that synchronous PWM switching of the two inverters can prompt debased yield phase voltage waveforms. Y. Yu et al. [5], this work investigates the dual inverter driven open-end perpetual magnet synchronous engine (PMSM) system and proposes control technique which can produce most extreme yield power in general speed extend for incorporated starter/alternator. H. Snani et al. [6], in this investigation, modulation strategy for expanding yield power of inverter and engine with decreased harmonic and loss is implemented. Bayhan et al. [7], a dual-inverter with an open-end winding motor setup is an attractive technique to supply a higher voltage to an engine for electric vehicle (EV) applications. R. J. Waiet al. [8], a near-state three-dimensional space-vector modulation (NS 3-D SVM) switching plan, which means to diminish the basic mode commotion in a three-phase four-leg voltage source inverter, is implemented.

1.2 PWM CONVERTERS AND ELECTRIC MACHINES

Fig. 1 demonstrates the parasitic coupling ways in an electric drive system. Capacitive coupling ways are appeared between the stator windings and rotor body, the rotor body and the grounded stator body and between the rotor body and the orientation. Other coupling ways, for example, between the stator windings and the grounded stator body exist yet are ignored here for straightforwardness. The normal mode voltage created by the power converter concerning ground has been displayed as a switching voltage source. Aside from the issue of basic mode voltage switching, ordinary drive systems use cumbersome electrolytic capacitors in the power converters. These have constrained lifetime when contrasted with whatever is left of the segments and add to the system size and weight, eventually influencing cost. This theory endeavors to address these two issues. Open-end winding machine setups are investigated to tackle the normal mode issue. Conventional three-phase machines are either star-or delta-associated and have three terminals to which voltages are connected. It is conceivable to open this star or delta association. The machine now has six terminals. It is conceivable to drive these machines utilizing power converters while diminishing basic mode voltages when contrasted with star-or delta-associated machines. This was secured for the two-level inverter. The blend of the power converters driving this open-end winding machine was named double two-level inverter. This drive arrangement is investigated in detail in this proposition and issues with remaining regular mode voltage and coursing currents are recognized and broke down in detail.

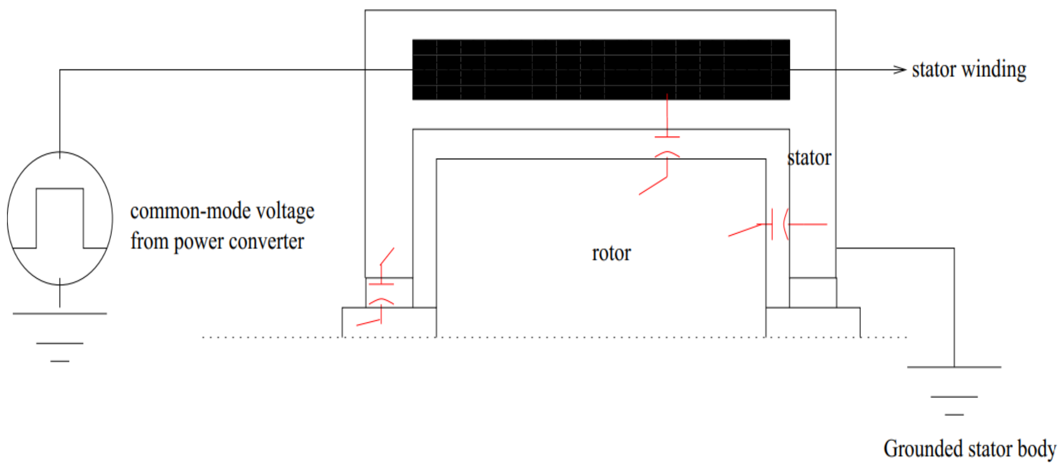

Figure 1: Passive coupling in an electric drive system

2. HARMONIC ANALYSIS METHODS

A photovoltaic system uses one or more solar modules or panels to convert solar energy to electrical energy. Basically, its components include solar panels, mechanical and electrical connections and means of modifying the electrical output we get.

HVDC converters carry on as a wellspring of harmonic currents of requests (np±1) on the AC side, and harmonic voltages of requests (np) on the HVDC side, with equivalent to the pulse number of the converter, and "n" a whole number.

The DC voltage waveform created by a perfect bipolar HVDC converter contains an AC swell superimposed over a mean DC esteem, delivered by the switching action of the converter valve. Switching happens at each 60° interim in a six-pulse converter, and each 30° out of a twelve-pulse converter which is for a six pulse converter. This composite voltage waveform is comprised of simply sinusoidal sections for perfect conditions.

Power system harmonics originate from an assortment of sources, the dominant ones within transmission networks being large power converters such as those used for bipolar HVDC links and large industrial processes. The harmonics created by these devices can be partitioned into three classifications:

- Integer harmonics; are integer multiples of the power frequency.
- Inter-harmonics; period and whole number products of some base frequency, they regularly result from cross-modulation of the whole number harmonics of two systems with various power frequencies.
- Non-whole number harmonics; are the frequencies that don't fit both of the over two classifications. They are not whole number products of a base frequency and may not be periodic.

The last two classes as a rule return from to-back HVDC joins (periodic), cyclo-converters (periodic) and circular segment furnaces (non-periodic) and are fundamentally more complex to model.

2.1 Basic MLI Topologies and its Comparisons

The Basic MLI topologies are classified with single and multiple DC source. The following three MLI topologies are successfully implemented in many renewables and industrial drives applications;

- Neutral Point Clamped multilevel inverter (NPC-MLI) with single DC sources.
- Capacitor-clamped multilevel inverter (FC-MLI) with single DC sources
- Cascaded H-Bridge MLI with separate DC sources

2.1.1 Construct of Established Inverters

Serious contention currently exists between the use of new converter topologies that use medium-voltage devices and the conventional power converter topologies that use high-voltage semi-conductors. The idea of building the inverters through the serial addition of devices is depicted in figure 2. In the past, the only practicable options for the medium-power and the high-power applications were these inverters are used. However, immature and continually developing conventional power inverters that use high-power semi-conductors are currently facing stiff competition from multilevel technology that utilize medium-voltage semiconductors. . The requirements of high-power levels cannot be accomplished by classical inverters, although they are good for low-power applications. The knowledge of multilevel technology and its virtues are essential for the retrieval of shortcomings of conventional inverters. Multilevel inverters can attain high-power by utilizing mature medium-power semiconductor technology and can therefore prove to be a better alternative for power applications. When compared to well-known and classic two-level converters, the advantages offered by the multilevel inverters prove to be far better.

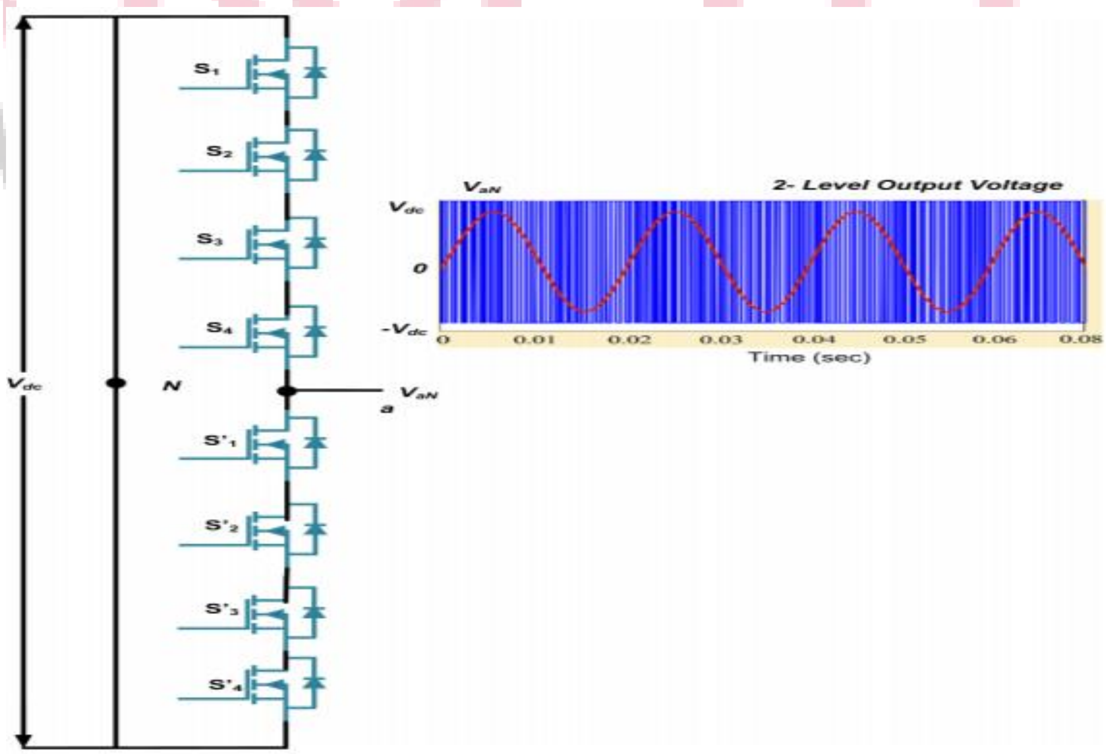

Figure 2: Classic Converter and the Output Waveform

A graphic diagram of the inverters single phase with various quantities of levels is depicted in Figure 3.8, for which an ideal switch with many positions represents the action of the power semi-conductors. It can be observed that an output voltage possessing twin levels of values (regarding the negative terminal of the capacitor) is generated by a two level inverter (Figure 3). Three voltage levels are generated by the three-level inverter and nine-level output voltages are generated by a nine-level inverter.

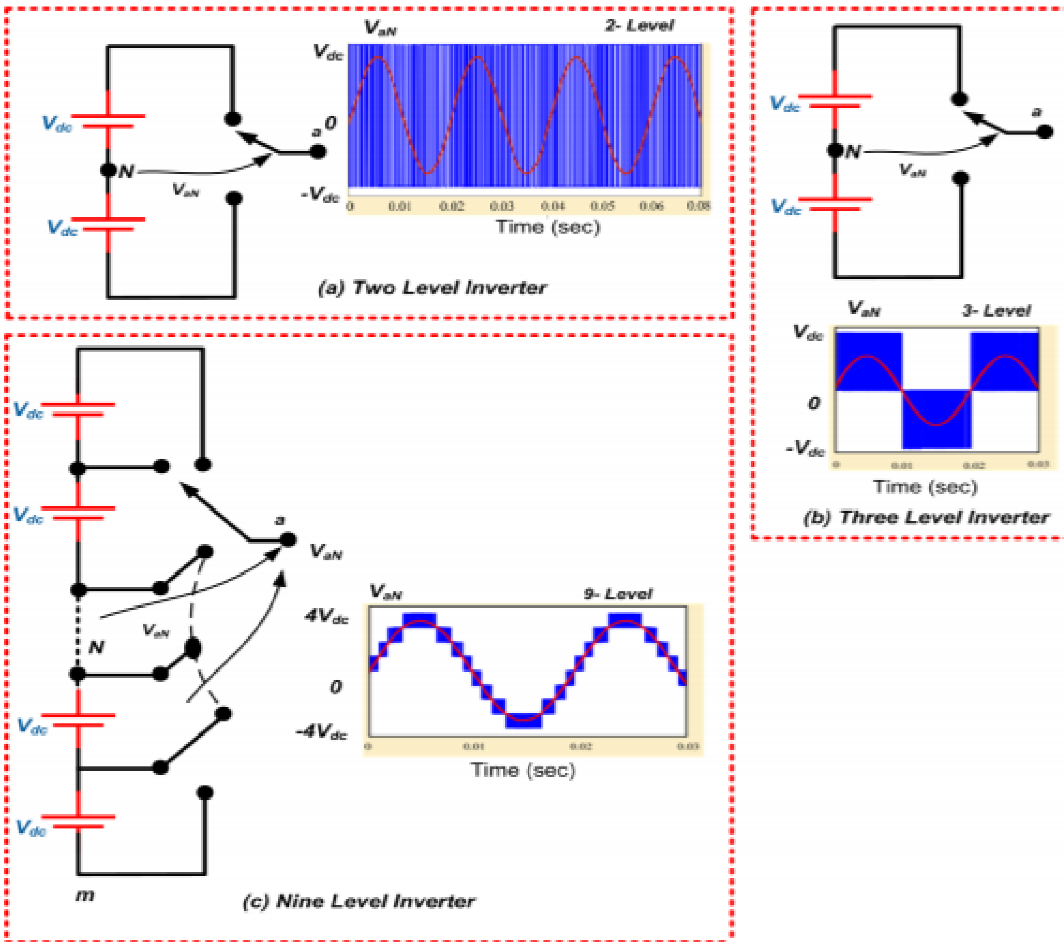

Figure 3: Waveforms of converter output voltage (a) 2-level (b) 3-level (c) 9-level

The industry's most utilized and popular multilevel topologies are the cascade H-bridge (CHB) MLI and the 3L-NPC-MLI. It is imperative to observe that 7L to 17L-CHB-MLI possess a complicated circuit structure and 3L-Neutral-Point-Clamped (NPC) MLI possess poor quality of power as shown in Figure . Therefore, it would only be unfair to compare these two commercially available multilevel inverters.

- Low-voltage insulated-gate bipolar transistors (LV-IGBTs) are solely utilized by CHB-MLIs, whereas medium- or high-voltage devices (medium- or high-voltage IGBTs and integrated gate-commutated thyristor (IGCT)) are utilized by NPC-MLIs.
- Higher power levels and higher voltage are attained by CLB-MLIs.

- A higher quantity of devices is required by CHB-MLIs for attaining a three-phase two-level voltage source inverter (VSI) per cell (regenerative option); whereas, NPCMLIs are more appropriate for use in back-to-back regenerative applications.
- Although expensive, the quality of the input power is improved by the confirmation of a 36-pulse rectifying system, which is possible through a phase-shifting transformer utilized by CHB-MLIs.
- Contrastingly, a smaller footprint is created by NPC-MLIs that possess an uncomplicated structure of circuitry.

2.1.2 Advantages of Multilevel Inverters

The advantages of using multi-level inverters over classic inverters will now be highlighted. Several advantages are associated with multi-level inverters, as high switching frequency pulse width modulation (PWM) is used by traditional converters (two-level). The utmost apparent characteristics of multi-level inverters are summed up below.

- Quality of staircase waveform: Apart from generating output voltages with negligible distortion, multi-level inverters also decrease the dv/dt stresses, thereby resulting in the reduction of electromagnetic compatibility (EMC) issues.
- Common mode (CM) voltage: The motor bearings stress, linked to a multi-level motor drive, could be decreased because smaller common mode voltage is generated by multi-level inverters. Moreover, advanced strategies of modulation, such as the one suggested in (Choi et al. 1991), can be employed in the termination of the CM voltage.
- Input current: The input current with a negligible distortion can be drawn by multilevel inverters.
- Frequency of switching: The functioning of multilevel inverters is possible at rudimentary switching frequency as well as high switching frequency (PWM). It is imperative to bear in mind that higher efficiency and lower switching loss can be derived from lower switching frequency.

There are certain disadvantages associated with multilevel inverters. The need of a large quantity of power semiconductor switches is a prominent shortcoming. An associated gate drive circuit is required by each switch despite the latent utilization of low voltage rated switches in multilevel inverters, consequently resulting in the increase of complicatedness and costs of the system. It is important to observe that the advantages of multilevel inverters outweigh the disadvantages, rendering them a definitive edge over conventional inverters (two-level).

3. DESIGNING OF T-TYPE INVERTER

In this work proposed a T-type inverter which is suitable to connect PV and transmit a power to the grid. Proposed inverter generates a three-level at the output of the inverter as Vdc/2, 0, -Vdc/2. Proposed topology is represented in figure 4. This topology has2 unidirectional switch and 1 bidirectional switch and it have 2 capacitors as a dc-bus capacitor which is connected after the first stage which is DC-DC boost converter. Levelled voltage as a three-level voltage occurs at the output of the inverter. By connected three modules in the cascaded form we can create 7-level as a levelled output of the inverter. This cascaded T-type system provides a levelled voltage as 1.5Vdc, 1Vdc, 0.5Vdc, 0, -0.5Vdc, -1Vdc, -1.5Vdc.

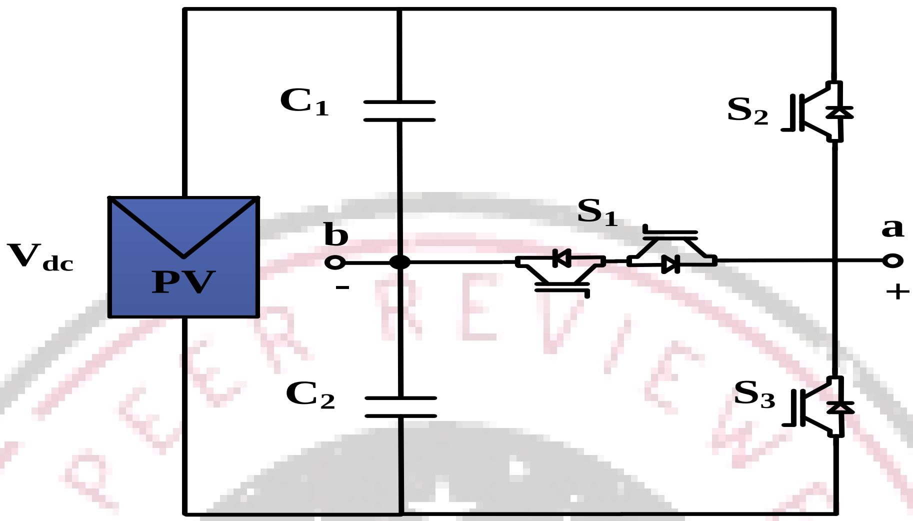

Figure 4: Proposed T-type inverter topologies

3.1.1 +0.5Vdc Level

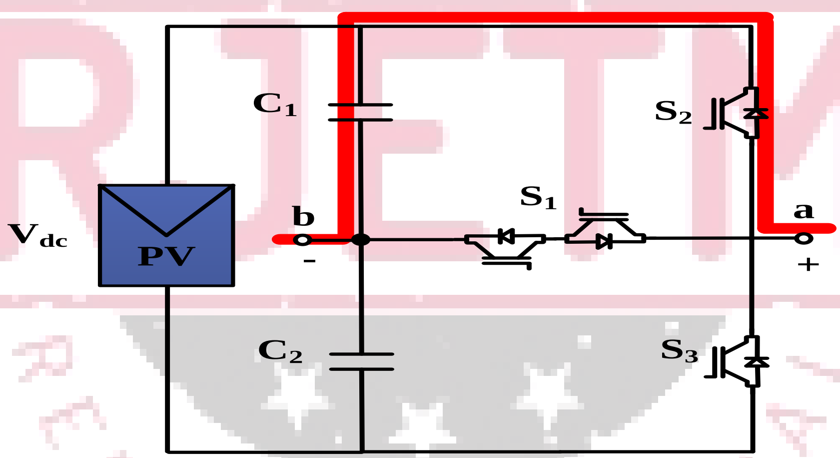

Figure 5: +0.5V_{dc} Level

By turning ON switch S2 and other switch OFF, capacitors C1 is connected in series through the load and C2 is by passed, it gives +0.5Vdc voltage at the output of inverter. This stage specified in Figure 5.

4. RESULTS AND ANALYSIS

The number of PV installations has an exponential growth, mainly due to the governments and utility companies that support programs that focus on grid-connected PV systems.

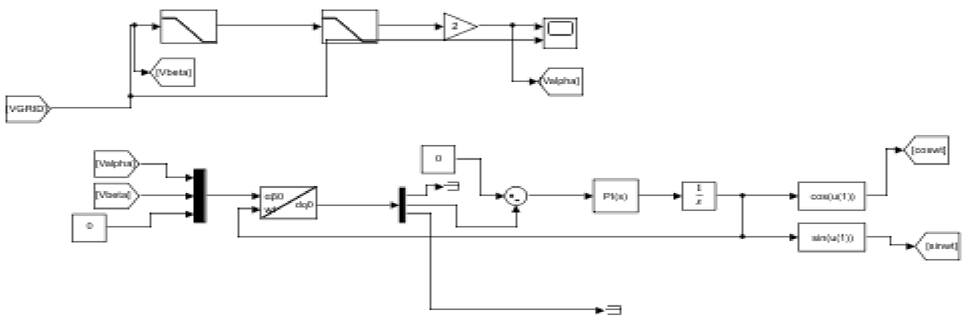

Figure 6: Simulation of PLL

Level shifted high frequency PWM technique use to generate switching pulses. As shown in figure 6, each carrier is responsible for generating pulses for associated voltage levels and switching states. Furthermore, the corresponding switching pulses for three cycles of the modulated waveform have been shown as fixed switching frequencies in each cycle. Generation of PWM signal for the proposed converter is described in Table 1.

TABLE 1: Switching States Of The Proposed T-Type Converter

State	Voltage Level	S1	S2	S3
1	+Vdc/2	0	1	0
2	0	1	0	0
3	-Vdc/2	0	0	1

PR controller used to regulate the voltage where output power equals to the sum of proportion and integration coefficients. It provides zero control error and is insensitive to interface of the measurement channel. Simulation diagram of the used PR controller is shown in figure 7.

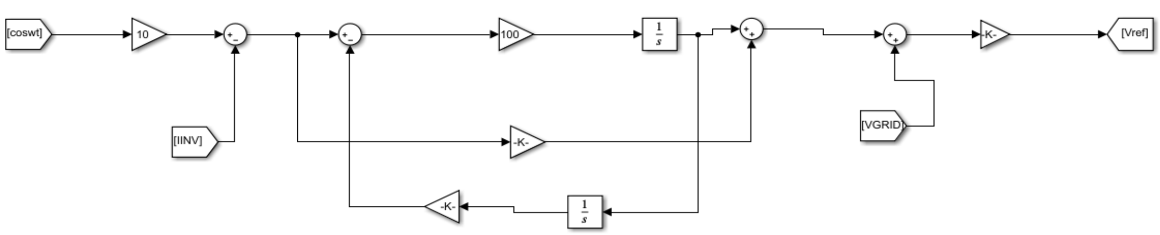

Figure 7: Proportional resonant (PR) controller

The PR Controller disadvantage is slow reaction to disturbances. To adjust the PR Controller, you should first set the integration time equal to zero, and the maximum proportion time. By decreasing the coefficient of proportionality, achieve periodic oscillations in the system.

In the case of control structure implemented in natural frame, the complexity of the control can be high if an adaptive band hysteresis controller is used for current regulation. A simpler control scheme can be achieved by implementing a dead-beat controller instead. Again, as in the case of stationary frame control, the phase angle information is not a must.

This three-level inverter generates a levelled AC voltage as a form of +Vdc/2, 0, -Vdc/2. For increasing power of the system introduce a cascading method but it increases the output voltage peak of the system. By using T-type inverter we can reduces the peak of the voltage because it’s worked in a buck-mode here peak of the output voltage is Vdc/2. Three-level output voltage of the T-type converter shown in figure 5.5. PWM switching pulsed which is applied to operates a three-level inverter shown in figure 8. By the cascading of these three-module generates a seven-level at the output of the system which is shown in figure 9.

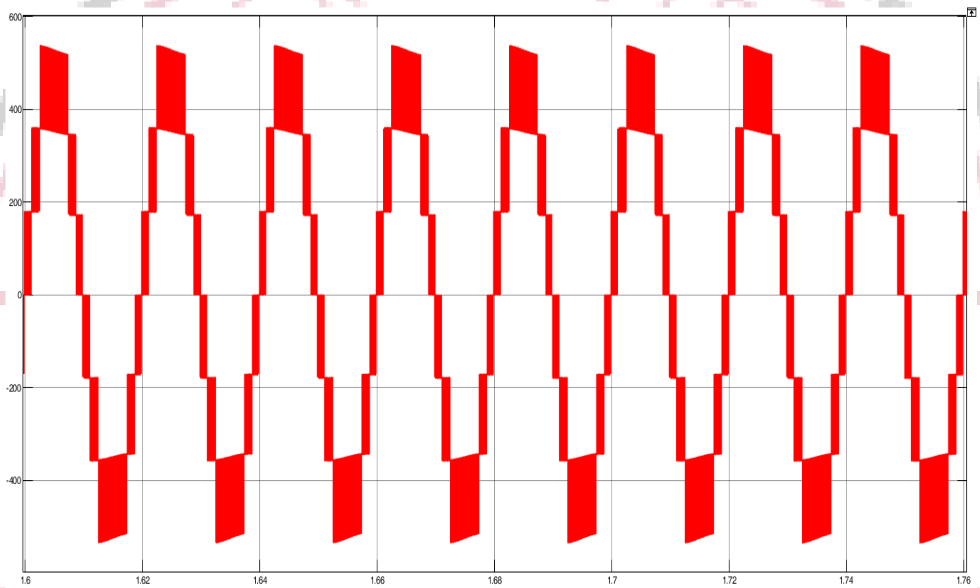

Figure 8: Cascaded seven-level output voltage waveform

This leveled AC voltage suitable for connect to the grid but due this ripple required a filter in between them. In this proposed work used a LCL filter which is described in a previous chapter. By the use of this filter transmit a power to the grid into the active form.

Figure 8 and figure 9 show the grid parameters. In the figure 8 shows a grid voltage grid current and inverter current respectively. It is shows have some ripple into the inverter current because of its measured before the LCL filter. Grid voltage and grid current show in the figure 9 at the same axis so it’s clearly shows as both voltage and current are in phase and transmit an active power to the grid. This grid connected system also achieves a PF near to unity i.e. 0.9905 at the grid side which is shown in Figure 10 and Figure 11.

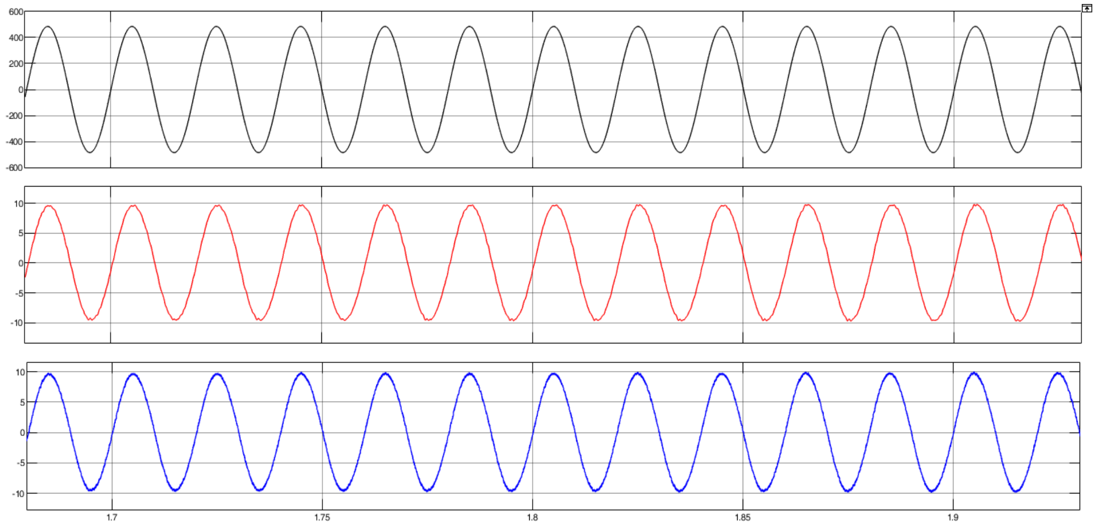

Figure 9: Grid voltage, grid current, inverter current

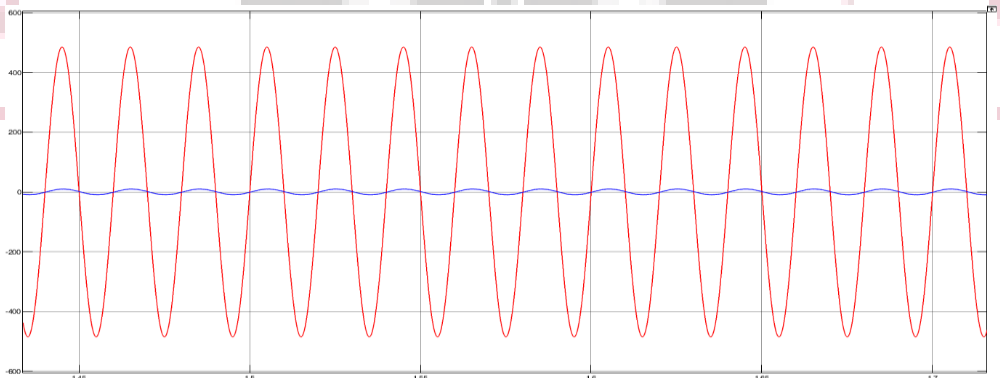

Figure 10: Grid voltage and grid current are in phase

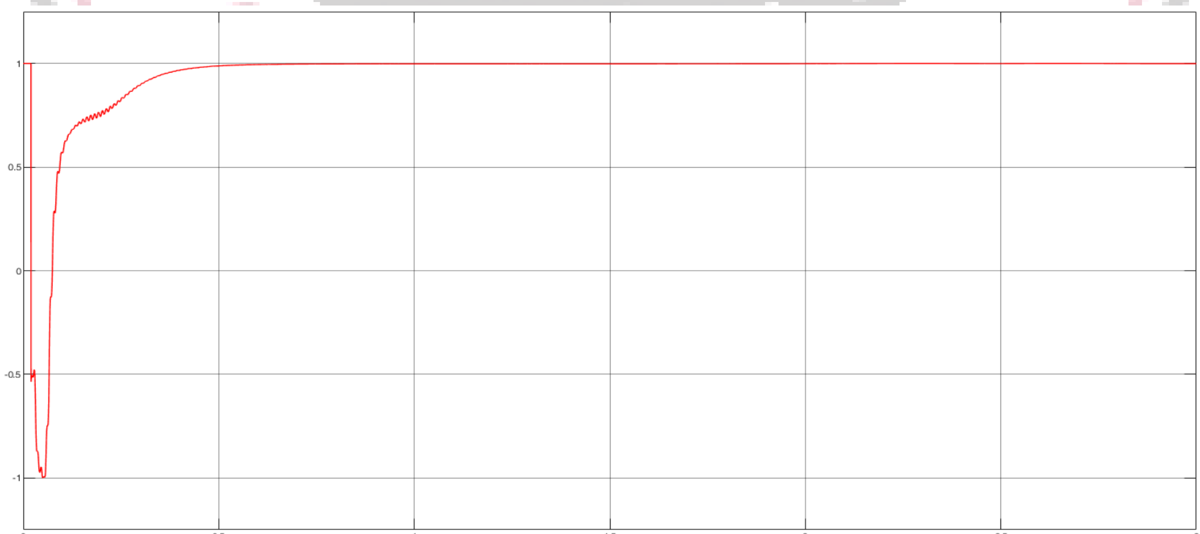

Figure 11: Unity power factor at the grid side

This proposed system simulates and design on 2.5kW power and inverter working on 10KHz switching frequency. At this high frequency and specific power justified that this system is highly efficient and reduces a power loss in between the power converter.

This work also reduces the harmonics of the grid current and grid voltage by the use of LCL filter at the grid side. For verification of reduced harmonics FFT analysis is done by using MATLAB platform. FFT analysis of grid voltage and grid current showed in figure 5.11 and figure 5.11 respectively. In an analysis of grid voltage harmonics only present fundaments component at the 50Hz frequency so 100% power presents in this component. Similarly in the grid current analysis maximum power component present in the same 50Hz frequency also second maximum component present at the 150Hz frequency but its only 0.9% so 99.1% component present at the grid frequency so its justified that its reduces the harmonics.

5. CONCLUSION

This paper presents a comparative analysis of different levels of inverter with respect to THD. It is evident from the result that the proposed seven-level boost ANPC inverter topology using maximum constant boost control technique generates a high-quality output voltage waveform, minimized THD and good reliability. The proposed 7-level inverter that works with the LSPWM strategy wherein the switching losses are negligible and with improved THD of the generated source, the overall efficiency of the system will be high.

For connection of renewable energy source to the grid required a power electronics converter. PV system generates a power in a form of DC so here required an inverter which is convert this dc power to the levelled AC power. It is a second stage of the proposed system in this stage convert DC voltage into the levelled AC voltage and cascaded T-type inverter used in this stage. By using of single T-type inverter generates a three-level at the output although cascaded of three modules through T-type inverter generates seven-level at the point of levelled AC output.

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