



DESIGN OF NPC INVERTER USED IN HYBRID RENEWABLE ENERGY SYSTEM

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Abstract: A neutral point clamped multi-level inverter is used to convert the rectified voltage from ac mains and dc voltage from PV panels into a variable frequency voltage to supply the rotor of wind energy generator. This paper details the design, construction and preliminary testing of a Neutral Point Clamped (NPC) power Inverter. The inverter is designed to have a three phase output connection and a neutral point connection. The inverter is designed around insulated gate bipolar transistor as the power switching devices. This design employs generation of the gate signals for the power switches, gate driver circuits to ensure reliability and insulation between the high power and low power circuitry. The inverter produces a three level line-to-neutral voltage waveform and a five level line-to-line voltage waveform.

Keywords: NPCI, Wind energy conversion system, Gate pulse, IGBT, Levels of voltage

I. Introduction

Non-conventional energy sources are considered for power generation because of the limited availability of conventional sources. Most abundant and attractive sources in non-conventional are wind and solar power. In wind energy conversion there are systems like fixed speed systems using squirrel cage induction generator, variable speed systems are employed. In general doubly fed induction generators (DFIGs) are used for variable speed wind energy conversion systems (WECSs). It is necessary for the sources to behave like conventional power plants in the aspect of voltage, frequency and good power quality. The load or grid is directly connected to the stator of the DFIG and the rotor injection is controlled using an ac-dc-ac converter in most of the DFIG-based WECSs. A diode rectifier followed by an inverter can also be used in place of two back-to-back converters. Pulse width modulation (PWM) converters are used where the grid side PWM rectifier is controlled to provide a constant dc link voltage and the rotor side PWM inverter controls the generator to provide required real and reactive power in systems having only rotor-side converter. All these systems, the mechanical and electrical frequencies are decoupled to ensure the variable speed operation. Some research tried the Back to back multilevel inverters for higher capacity installation.

This paper proposes a 3-phase diode rectifier followed by a boost regulator as grid side converter and a multilevel neutral point clamped (NPC) inverter to supply variable frequency voltage to the rotor for power conditioning the DFIG-based WECS. Solar Photo voltaic (PV) panels can also be used to supply the boost regulator and reduce the power drawn from the utility. The proposed system involves voltage feedback to regulate the output voltage from the DFIG.

II. Proposed System

Figure 1 Block diagram of neutral point clamped inverter

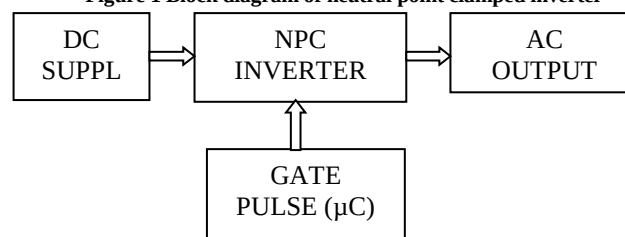
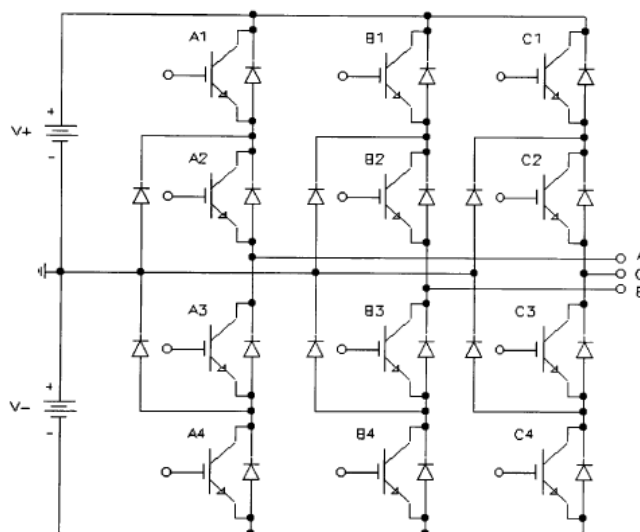


Figure 1 shows the block diagram of proposed NPC inverter. In this paper we are using two DC supply has 100 volts each. DC voltage block implements an ideal DC source. The positive terminal is represented by a plus sign on one port. You can modify the voltage at any time during the simulation. Gate pulses are given to the multilevel inverter by using sinusoidal pulse width modulation technique. The carrier triangular wave produced by using Matlab function block and the carrier signal is compared with the sine wave to generate the pulse for gate signal of the semiconductor switches.

III. Design of Three Level NPC Inverter

Figure 2 is an NPCI topology that allows for line-to-line waveforms with five voltage levels and line-to-neutral waveforms with three voltage levels. The three phase three level diode clamped multilevel inverter is designed for drive application. It is also useful in reactive power compensation as well as in UPS system.

Figure 2 NPCI topology



The phase outputs are the center point of a series connection of four IGBTs, and the DC bus input is connected to the top and bottom row of devices, A1, B1, C1, and A4, B4, C4, respectively. The center point of the DC bus is shown by a ground symbol and is connected between a pair of series connected diodes in each phase. These six clamping diodes connected to the neutral bus control the voltage distribution among the four IGBTs in each phase leg. A conventional inverter requires the switches to sustain the full voltage drop between the positive and negative DC buses. However, the voltage drop (stress) across each switch of the NPCI is one half of the voltage between the positive and negative bus since the switches on either side of the neutral bus are in series, and an actual neutral point exists. Each IGBT has an individual gate signal that must be referenced between the respective IGBT gate and emitter terminal. The diode shown between the collector and emitter of each IGBT is an internal "body diode" inherent to the IGBT device structure. The DC bus has a positive, negative, and neutral connection with large low frequency filter capacitors and smaller high frequency filter capacitors. The bus structure is discussed in more detail in the physical system section.

This specific NPCI topology uses 3-level switching instead of 2-level switching used in conventional 3-phase inverters. The three levels correspond to the positive, negative, and neutral buses. Taking leg A of Figure 2 as an example, the phase output A is connected to the positive bus by turning on switches A1 and A2. Turning switches A3 and A4 on connect the phase A output to the negative bus, and turning switches A2 and A3 on connects the phase A output to the neutral bus. The other two phases operate in the same manner, but with phase shifted results with respect to phase A.

Deciding number of levels of the inverter is important in THD of voltage waveform (THD %). More no. of levels gives good THD but losses in the inverter are increasingly high & control is also very complex. There must be tradeoff between THD, losses & control complexity. Therefore, 3-Level inverter is selected.

Voltage and current rating of switching devices are decided from the voltage and current ratings of load to be connected to the inverter. Here the load is considered to be a 2.2 KW induction motor which has voltage rating of 415V and current rating of 4.5A. The required voltage by the load is produced from the dc bus voltage. In 3-level topology two switches are in series when they are in off state. Therefore, the switching device has to withstand half of the dc bus voltage. Therefore, the MOSFET IRF840 are selected as they have voltage rating of 600V and current rating of 6.5 A.

Voltage and current rating of clamping diodes The working of 3-level diode clamped inverter is explained earlier. Clamping diodes are carrying the current same as the switching devices but the duration of the conduction is less than the switching devices. The current rating of the clamping diode would be one half that of the switching devices. Therefore, the switching characteristics of switching devices and clamped diodes must match. Two clamping diodes will be in series while conducting sharing the voltage on dc bus. They together have to withstand maximum reverse voltage of dc bus voltage. Therefore, an ultrafast diode of voltage rating of 1200V and current rating of 8A is selected.

Unipolar capacitors (electrolytic) can be used for the dc link capacitors. Just like the voltage rating of the active devices in the sum of the voltage ratings of the dc link capacitors should be greater than or equal to the overall dc link voltage. The design factor in this case would include the dc link voltage ripple plus any safety factor is

necessary to maintain the capacitors within their safe operating range. The capacitance of each capacitor in the dc link is determined by the equation;

$$C = \Delta q / \Delta V$$

Where, Δq is the change in charge and ΔV is the change in voltage over a specified period. The required capacitance of the dc link and the voltage ripple are inversely related to each other. An increase in the capacitance will decrease the amount of ripple in the dc voltage. By assuming that each level has the same voltage V_{dc} across it,

$$\Delta V = \%V_{\text{ripple}} \cdot V_{dc}$$

It is obvious that an unnecessarily strict tolerance on the voltage ripple of the dc bus will result in extraordinarily large capacitor values. For this reason, the maximum voltage ripple is normally chosen to be in the 5 to 10% range. The current that flows through the capacitor determines the change in charge Δq for a capacitor. This current is a function of what input and output voltage states the inverter progresses through during each cycle, and will largely be dependent on the control method implemented by the inverter in maintaining the voltage on the dc link. Although the current that flows through each capacitor that makes up the dc link will be different. Normally each of the capacitors will be identically sized such that can then be rewritten as,

$$C_{dc} = \frac{\max(\Delta q)}{\%v_{\text{ripple}} \cdot v_{dc}}$$

For an inverter to produce a line-to-line voltage of 70V the dc bus voltage must be $(415/0.612) = 678V$ say 680V. The nominal dc voltage for each level would be approximately 170V. For a design factor of 1.5, the design voltage for each level of the inverter would be approximately 255V. As per the voltage rating selected for the capacitor is 250V. For simulation & hardware $M_a = 1$ is selected. In simulation it is convenient to change its modulation, but which is cumbersome in hardware to modulation index. Therefore in simulation table of 2-Level, 3-Level inverter readings are taken for various modulation index & for hardware modulation index kept $M_a = 1$.

IV. Simulation Results

DC Link capacitors $C_1 \& C_2 = 4700 \mu F$

DC Link voltage $V_{dc} = 100V$

E. S. R. of dc link capacitor $C_1 \& C_2 = 0.07$

Switching frequency $f_s = 2 \text{ kHz}$

On state resistance of MOSFET $R_{on} = 0.27 \Omega$

On state resistance of Diode $R_{d on} = 0.2 \Omega$

Simulation Time $t = 0.05 \text{ sec}$

Figure 3 Simulink model of NPCI

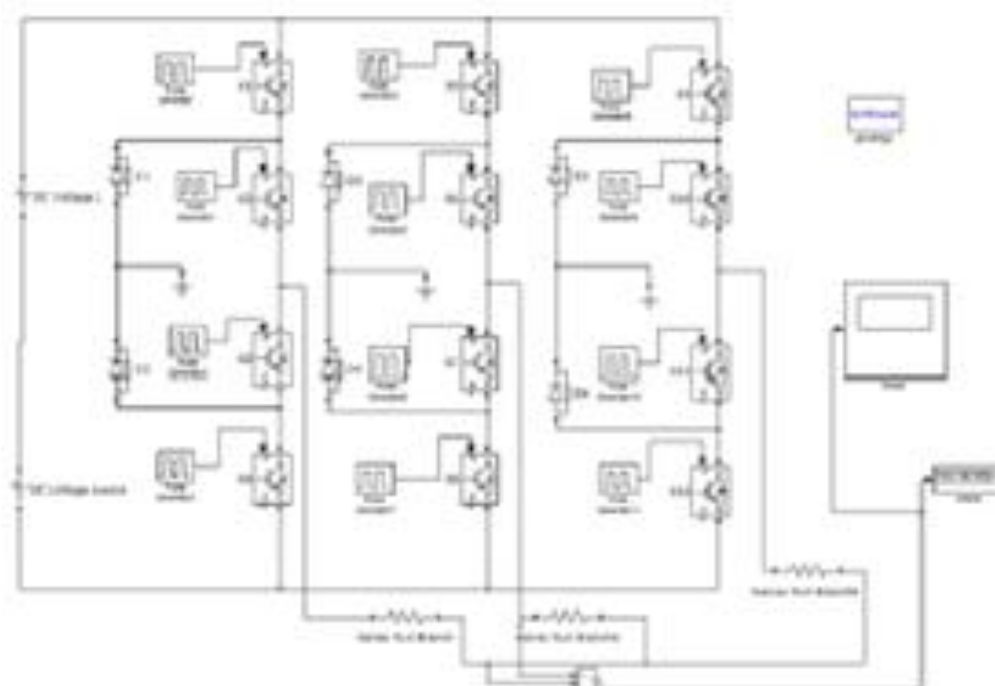


Figure 4 Generation of gate pulses V_{G1} & V_{G2} of 3level Inverter

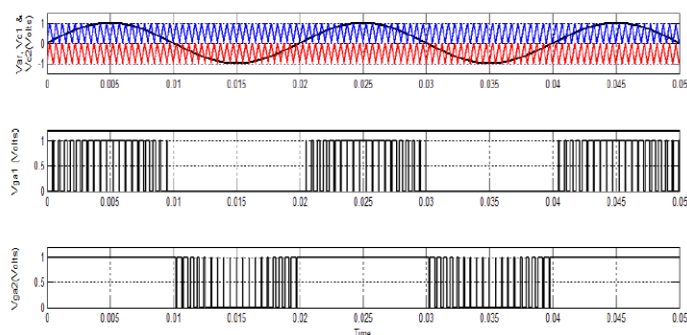


Figure 5 Line Voltage of 3-Level Inverter (no load)

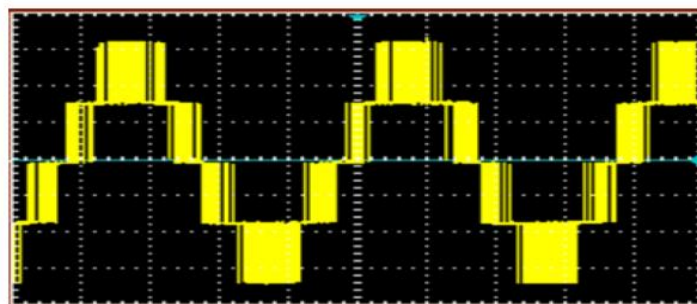


Figure 6 Line voltage of 3-Level Inverter (load)

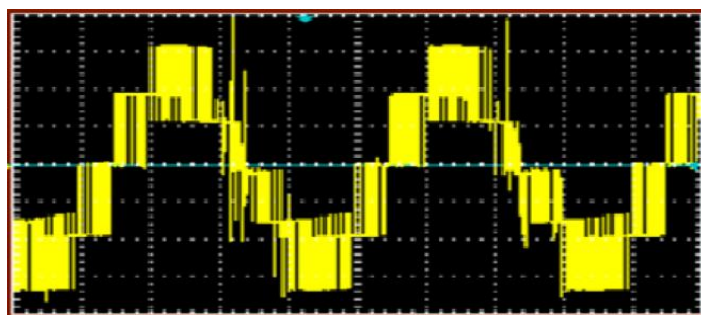


Figure 7 Hardware setup of NPCI



V. Advantages & Applications

The NPC topology offers the following advantages:

Reduced switching losses: Only the half the voltage have to be switched this half's also the switching losses in the transistor. In the shown NPC topology we are able to use 600V components instead of 1200V types. On top on that are in 600V technology much faster components available than in 1200V technique. This will lead to further reduction of the switching losses.

Smaller output current ripple: The NPC topology will have lower ripple in the output current and half of the output voltage transient. This will reduce the effort for filtering and isolation in the filter inductor.

The total +/- supply voltage is shared: The DC voltage is divided in a positive and in a negative voltage which supports the serial connection of DC-capacitors without problems of leakage compensation. The switching voltage of the vertical switches is $\frac{1}{4}$ th of the input DC voltage.

The NPP topology can be operated at high switching frequency compared to NPC inverter for the same load current (almost double). The inverter output wave-form is improved. This leads to the reduction of filter size.

These advantages have to face the drawback of a higher complexity. More components have to be handled (10 instead of 4) and the NPC topology requires 4 independent gate drives instead of 2 in the standard half bridge topology.

Applications: NPC inverter is used in the application of hybrid renewable energy system of solar and wind energy system.

VI. Conclusion

This paper details the design and construction of a neutral point clamped inverter. This NPCI topology can use either IGBTs or power MOSFETs (metal-oxide semiconductor field-effect transistor) as switching devices. Although there are other semiconductors available for higher power uses, they are not as easily controlled as IGBTs and power MOSFETs.

The NPCI is only a part of a power supply structure capable of use in any power grid given DC bus voltage limitations. The bus voltage limit is primarily dictated by the devices used for the switches. This same NPC topology can be used as a converter. A converter would take the place of the three phase rectifier and because of the converter's four quadrant operation and controlled rectification capability the power factor, the harmonics injected in the utility, and the direction of power flow could all be controlled.

VII. References

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