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# Maximum Power Extraction in Grid Connected DFIG Using 3 Level Diode Clamped Inverter

**Abhishek Kumar[1], Akshneel Sharma[2], Arjun Kumar GB[3], Arun Kumar[4]**

Under Graduate Student, SVCE Bangalore [1,2,4]

Assistant Professor, SVCE Bangalore[3]

**Abstract:** Wind energy is one of the most dependable renewable source of energy in modern era where the exploitation of the fossil fuel is more. The Double Fed Induction Generators are used to obtain maximum output from the wind turbine at any wind speed change. In a Doubly Fed Induction Generator (DFIG), the stator is directly connected to the AC mains, while the wound rotor is fed from a back-to-back converter via slip rings to allow the DIFG to operate at a variety of speeds in order to accommodate changing wind speeds. Here we have used a method to maximize the output power of the wind energy system that is by use of the 3-Level Diode Clamped Inverter circuit that generates output in the stepped form. The 3-Level Diode Clamped Inverter circuit includes capacitor, diode and a switch that can be an IGBT, transistor or MOSFET. Following are the features of the Multilevel Invertor Circuit:- that reduces the stress on the bearings of turbine.  Reduces harmonics.  they can operate at lower switching frequency.  they can draw input current having low distortion.  Generate output with low distortion  Generates a COMMON-MODE VOLTAGE.

**Keywords:** DFIG, PWM, Multilevel Inverter, Wind Turbines, Global Warming, Greenhouse effect.

## INTRODUCTION

In today's world the rate at which the fossil fuels or the non-renewable source of energy are getting exploited, it is creating a major impact on the environmental issues like Global Warming, greenhouse effect, rise in carbon dioxide level. Due to the following issues the focus has been shifted to the Non- Renewable source of energy and government is taking proper steps to implement these resources. Non-Renewable source of energy includes Wind Power, Solar Power, and small Hydro- Electric Plants. Due to rising fuel prices and fast depletion of the resources the Non-Renewable resources have become one of the major key elements to supply power. Out of the above mentioned Non-Renewable source of energy the wind power have been more efficient due to cleanliness and cost effective.

Wind speed is being unpredictable since the speed of wind varies at any point of time due to which the output of the wind power varies. This can be rectified by applying mechanical solutions like adjustable gear box, to adjust the speed. The power electronic converter and the control module are also being used to achieve the adjustable output voltage. To obtain the output at variable wind speed an Induction Generator is used since it has flexible rotor speed characteristics. During the early stages of the wind power development the widely used generator was the fixed speed/non-adjustable speed Generators that could only work for the constant speed making its efficiency low. To improve the efficiency DFIG were used to obtain the maximum power output and improved efficiency. Today the power electronic converters are widely used in order to extract maximum power output from the Wind Turbine.

## DOUBLE-FED INDUCTION GENERATOR

A Double-Fed Induction Generator/Variable speed Generator is directly connected to the ac mains. DFIG operate at variable speed so that it could produce the required power output at any wind speed. The slip power can flow in both directions from the supply to the rotor and hence the speed of the machine can be controlled by rotor or stator side. By usage of the Pulse Width Modulation the three phase inverters will generate a voltage level between neutral and ground called common mode voltage act as source of many unwanted problems in driving mode for example like shaft voltage.

Here the PWM techniques is one of the method that can either reduce or eliminate common mode voltage would be a cheap solution that can attract the attention of the many industry. This paper presents the common mode voltage strategy based on the elimination of the switching vectors and generates maximum voltage by keeping all the necessary condition at observable limits.

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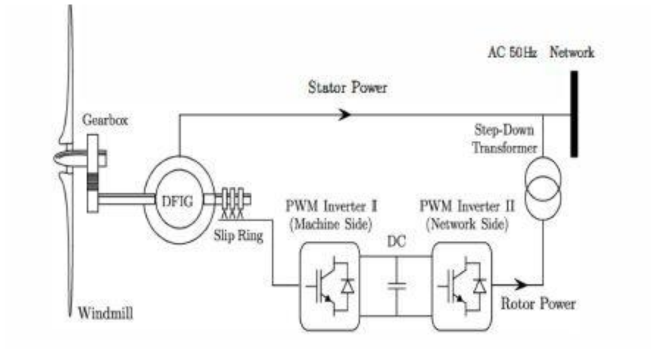


**FIG 1:- GRID CONNECTED DFIG**

## MULTILEVEL INVERTER

Multilevel inverter includes an array of semiconductor devices and capacitor that generates the output voltage in stepped waveform. Commutation process of switches allows them to add the capacitor voltage. Fig 1 shows the schematic diagram of the one phase leg of inverterswith different numbers of level for which the semiconductor is shown by the ideal switch with several positions.

A two level inverter generates an output voltage with two value w.r.t negative terminal of the capacitor while a 3-level inverter generates three level voltages. Let us consider “s” as the number of phases w.r.t to negative terminal of the inverter then the number of steps in voltage between two phase of the load “k” is given by

k=2s+1------------ (1)

and the number of steps in the phase voltage of a 3-phase load is given by p=2k-1--------(2)

Here by above equations we can conclude that by increasing the number of level in the inverter the output voltage have more stepped waveform generates a staircase waveforms.

Here there are three topology proposed for the multilevel inverter i.e. shown in fig 2 below.

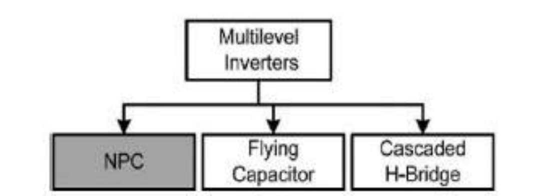


**FIG 2:- TOPOLOGIES OF MULTILEVEL INVERTER**

## DIODE CLAMPED INVERTER

A three-level diode-clamped inverter is shown in the Fig-3; the clamping diode is used to connect the neutral point ‘N’ to the midpoint of the transistor. The neutral point generates an additional voltage level and hence yields the name “Three Level Inverters”. In the circuit; the dc bus voltage is split into 3-level by two series connected bulk capacitors, C1 and C2. The middle point of the two capacitors can be defined as the neutral point.

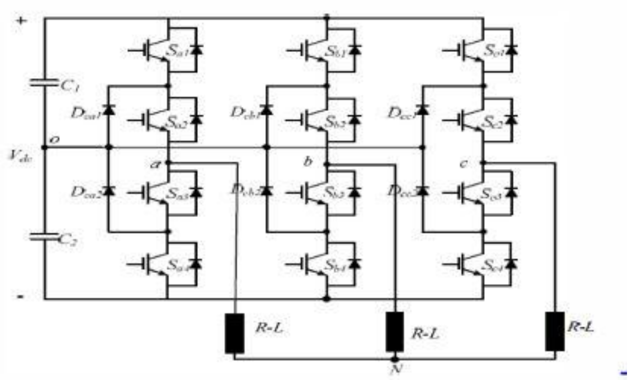


**FIG 3:- TOPOLOGY OF 3-LEVEL DIODE**

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**CLAMPED INVERTER**

The output voltages has three states $V_{dc/2}$, 0, -$V_{dc/2}$. For voltage level $V_{dc/2}$, switch S1 and S2 are turned ON; for the -$V_{dc/2}$ switch S1 and S2 needs to be turned ON and for the voltage level zero S1 and S2 are needed to be turned ON.The key components that distinguish this circuit from a conventional two-level inverter are Dl and D2. These two diodes clamp the Switch voltage to half the level of the dc-bus voltage. When both S1 and S2 are turned ON, the voltage across a and 0 is $V_{dc}$, i.e. $V_{a0}$=$V_{dc}$. Now D1 balances the output voltage sharing between S1 and S2 with blocking the voltage across C2. Notice that output voltage $V_{an}$ is AC and $V_{a0}$ is DC.

The difference between $V_{AN}$ and$V_{ao}$is the voltage across C2, which is ($V_{dc}$/2). If the output voltage is removed out between "a" and"0" then the circuit becomes DC-DC converter, which has 3-level $V_{dc}$, $V_{dc/2}$ and zero. Modulation and control strategies for 3-level NPC inverters are of three main methods to establish to control the behavior of fundamental voltage generated by the 3-Level inverter to the load as follows:-

1. Carrier based PWM
2. Space Vector Modulation (SVM) and
3. Selective harmonics elimination(SHE)

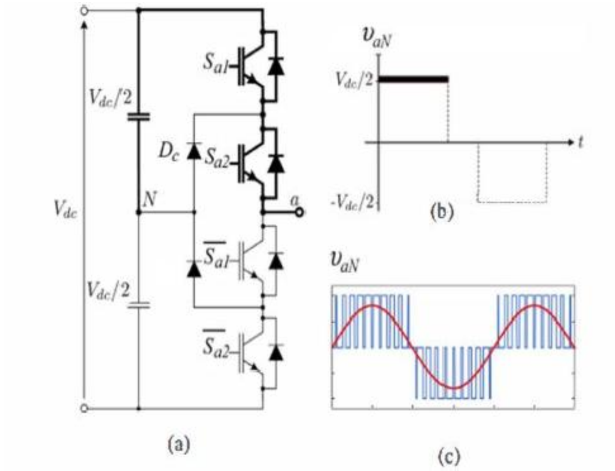


**FIG 4:- WORKING PRINCIPLE OF THREE LEVEL INVERTER.**

**(a) CONDUCTION STATE TO GENERATE POSITIVE VOLTAGE**
**(b) POSITIVE LOAD VOLTAGE**
**(c) COMPLETE VOLTAGE SHOWING THREE LEVEL**

**Carrier Based Three Level Modulation**:

This is the most highly popular method based on the comparison of the sinusoidal reference $v^*$ with two carrier $V_{cr1}$ and $V_{cr2}$ as given in fig below

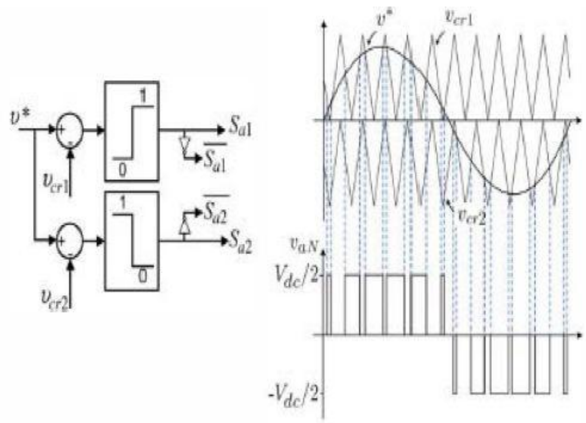


**FIG 5: CARRIER BASED THREE LEVEL MODULATION**

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The logic is very simple if $v^* > v_{cr1}$ $S_{a1}$=ON, $S_{a2}$=ON, $V_{an}=V_{dc/2}$ if $v_{cr2}<v^*<v_{cr1}$ $S_{a1}$=ON, $S_{a2}$=ON, $V_{an}=0$ if $v^*<v_{cr2}$ then $S_{a1}$=ON, $S_{a2}$=ON, $V_{an}=-V_{dc}/2$
This modulation method is focused on the search for Optimal switching sequences, operation at low modulation index, adaption to new topologies, and reduction of common mode voltage.

**Features of Multilevel inverters**:
• They can generate output voltages with extremely low distortion and lower dv/dt.
• They draw input current with very low distortion.
• They generate smaller common-mode (CM) voltage, thus reducing the stress in the motor bearings. In addition, using sophisticated modulation methods, CM voltages can be eliminated.
• They can operate with a lower switching frequency.

## SIMULATIONS OF THE MULTILEVEL INVERTER

The torque developed by the wind turbine depends on the wind velocity and thrust coefficient. The power captured by the wind turbine is the cube of the wind velocity. Thus the power captured by the wind turbine is maximum when the wind velocity is 12m/s to15rn/s is shown in the fig 6

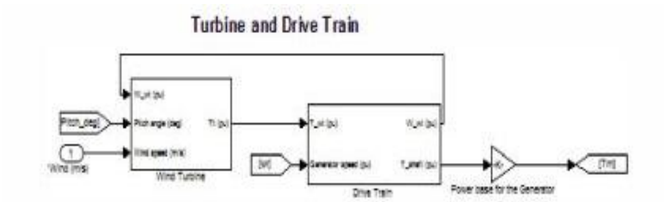


FIG 6: THE TURBINE AND DRIVE TRAIN

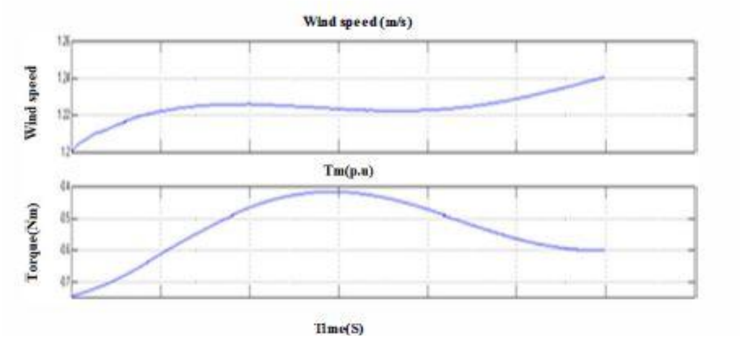


FIG 7: THE OVERALL SIMULATION

## RESULT OF THE TURBINE AND DRIVE TRAIN

### Multilevel inverter output

The output of the multilevel inverter for line voltage is as shown in the Fig 8

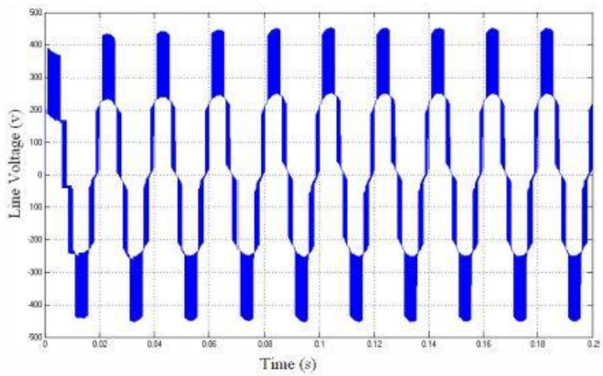


FIG 8: MULTILEVEL-DIODE CLAMPED INVERTER LINE VOLTAGE

The output from the wind turbine is a variable one. In order to obtain constant voltage and frequency, the proposed multilevel inverter is used and also it reduces the harmonic contents in the voltage which is obtained by increasing the level of inverter, in the proposed inverter a three level diode clamped inverter is used.

## POWER DEVELOPED IN DFIG

The power developed in the wind turbine depends on wind velocity. Thus the power captured by the wind turbine is the cubic function of wind speed.The Maximum power extracted from Wind turbine generator is 8 MW at a wind speed of 15m/s which is as shown in Fig9. Thus the output power of WTIG is uniquely determined by its operating speed. Wind speed changes do not affect the value of reactive power produced by generator, and active power follows the power speed curve of turbine. This clarifies the ability of controlling to separately the active and reactive power of stator.

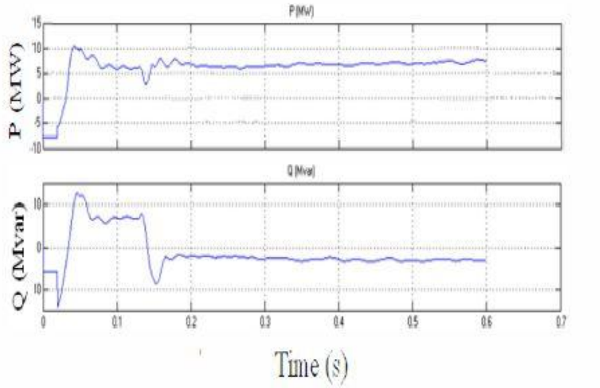


**FIG 9: POWER DEVELOPED IN PROPOSED TIME**

## CONCLUSION

Investigation in the wind farm needs a thorough Knowledge of nature of the wind variation over the particular site and complete understanding of the Doubly Fed Induction Generator is necessary. DFIG for grid-connected variable speed wind energy conversion system has been developed. With the proposed method, it is possible to control the reactive power, and compensate for the utility harmonics. The control strategy is capable of controlling the generated active and reactive power as well as the amount of harmonic compensation in the grid independently. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The DFIG technology has the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator. The multilevel inverter topology can overcome some of the limitations than the standard two-level inverter. Harmonics decreases as the number of levels in the output voltage is increased.

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