

# Contribution to Improving the DFIG Control Using a Multi-Level Inverter

Imane El Karaoui, Mohammed Maaroufi, Hamid Chaikhy

**Abstract**—Doubly Fed Induction Generator (DFIG) is one of the most reliable wind generator. Major problem in wind power generation is to generate Sinusoidal signal with very low THD on variable speed caused by inverter two levels used. This paper presents a multi-level inverter whose objective is to reduce the THD and the dimensions of the output filter. This work proposes a three-level NPC-type inverter, the results simulation are presented demonstrating the efficiency of the proposed inverter.

**Keywords**—DFIG, multilevel inverter, NPC inverter, THD, Induction machine.

## I. INTRODUCTION

NOWADAYS the cheapest production of large-scale renewable energy is the wind power. It's about producing electricity from the natural energy of the wind. The wind energy has become a viable solution for the production of energy. Today we have a higher number of fixed speed wind turbines, however, those with variable speed continue to increase [1].

Actually, variable speed scheme are being used for system operation with higher efficiency, absence of speed command, and reduced flicker [2], [3]. In most cases doubly fed induction generators are used for variable speed wind energy conversion systems. The power converter, in the case of DFIG, needs to provide only 21%-31% of the output power [2]-[4], so the system can use converters as well as filters with lower ratings.

The stator of DFIG is directly connected to the power grid while its rotor is connected to the power grid through back-to-back converter. DFIG can supply the constant frequency power to the grid without reference to wind speed variation, and control the power factor at the connection point [5].

The control strategies of these machines and their possible interfaces to the network make possible to achieve maximum energy over a wide range of possible fan speed variation in order to improve the profitability of wind installations.

There is a terrific challenge in front of the power system operates and planners to guarantee secure, reliable and stable power supply with appreciable contribution of wind energy-based power plants. The large wind turbines of the range of 3 to 5 MW range are mostly based on variable-speed operation with pitch control mechanism using a synchronous generator without interfacing gearbox or a doubly-fed induction generator (DFIG) [6].

The variable-speed wind energy conversion systems operational with doubly-fed induction generators (DFIG) amount to almost 50% of the total installed wind turbines globally as they have noticeable advantages such as, reduced cost, lower power rating of the power converters, wide speed span, decoupled power control, and reduced power [7].

Multilevel inverters have made revolutionary changes in power electronics in high voltage and high power applications [8]. The basic principle involves generating output waveforms from small voltage steps by using series connected capacitors or isolated DC sources [8]. Comparing the two types of inverters it is deduced that for multilevel inverters produce low voltage steps in the output voltage whose harmonic distortion is lower than that of the two-level inverters and with a higher efficiency [8], [9].

The use of 3L-NPC inverters in the various high and medium voltage applications continues to grow [10], [11]. The major disadvantage of this structure is the unequal loss distribution among the switches; and also the limitation of the maximum output power of the inverter because of the inequality of temperature distribution it generates [12] and the uneven switching of the semiconductor devices increases, if the levels of the inverter increase, thus it causes the generation of the voltage unbalance between the voltage DC link capacitors. As the neutral point is actively piloted, three levels neutral point piloted inverter (3L\_NPP) (Figure.2) is an important topology capable of solving the unequal distribution of losses of the 3L-NPC inverter and improving the capacity power [13]-[15]. In 3L-NPP inverter topology two switches connected in series are added for the purpose of clamping instead of clamping diodes as in 3L-NPC. In this work, 3L-NPC, 5L-NPC and NPP inverter will be presented in detail compared by simulation.

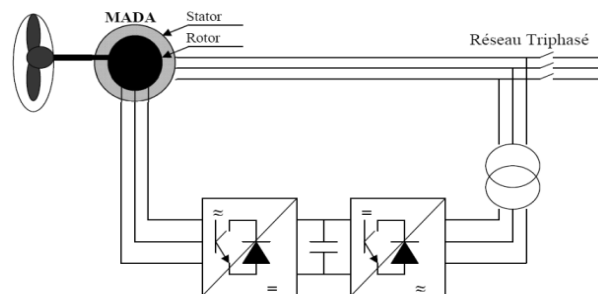


Fig. 1 Doubly Fed Induction Generator based Wind Energy Converter

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With multilevel voltage source converter configuration, it is possible to obtain the higher voltage with components of standard power rating. Further the size of the filters is also reduced by incorporating multi-level construction. This is obtained by arranging a greater number of switches than in the conventional two level converters to configure more complicated converter technologies.

Basic H-bridge switching model is extended to generate higher level of voltages. The output voltage of Multi-level inverter is more sinusoidal in quality with reduced harmonic content. The level of the inverter is decided by the number of nodes to which it is accessible. By multilevel inverter the need for the step-up transformer can be eliminated. It is found that voltage clamping network consisting of diodes could enhance the dc bus voltage beyond the voltage rating of an individual power to increase the kV A rating of the system [7].

Three level converters have been incorporated in wind energy conversion systems as they offer the lower voltages stress on switching devices, lower total harmonic distortion (THD), and reduced active and reactive power variations [8]. Various studies in the literature have introduced a threelevel NPC converter with active clamping switches converter to overcome the drawback of unbalanced loss distribution in traditional NPC converters [9]. When voltage is smaller thus the stress in cables and machine is smaller [10].

To overcome the different drawbacks of two levels inverter, the 3L-NPC inverter is presented.

#### A. Three Levels NPC Inverter

##### 1) Structure

The structure of the three levels NPC inverter is shown in Fig. 2:

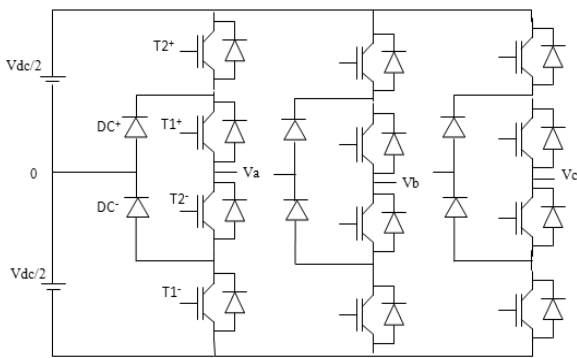


Fig. 2 Three levels NPC inverter

##### 2) Principle

The following table (Table I) summarizes switching states which gives three levels voltage.

TABLE I  
BASIC SWITCHING OF NPC INVERTER

Voltage level	Voltage Va	Switching state			
		T2+	T1+	T2-	T1-
1	Vdc/2	1	1	0	0
0	0	0	1	1	0
-1	-Vdc/2	0	0	1	1

#### 3) Control Strategy

In pulse width modulation PWM technique three sine waves and two high frequency triangular carrier wave are used to generate PWM signal [5].

Generally, three sinusoidal waves are used for three phase inverter. The sinusoidal waves are called reference signal and they have 120 phase difference with each other. The frequency of these sinusoidal waves is chosen based on the required inverter output frequency (50 Hz). The carrier triangular wave is usually a high frequency (in several KHz) wave. The switching signal is generated by comparing the sinusoidal waves with the triangular wave

As shown in Fig. 3, a pulse width modulation with two triangular carriers is used to control the switches as presented in Table I.

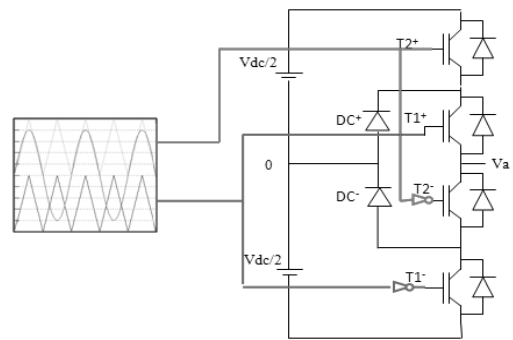


Fig. 3 Two carriers PWM control strategy of 3L-NPC inverter

## II. SIMULATION RESULTS AND DISCUSSION

Here we developed a three-level inverter NPC in Simulink / MATLAB environment. For generation of PWM pulses the technique was used comparing three sinusoidal voltage references 50 Hz with two triangular waveform 2 KHz, and a 600 V DC bus. The load is simulated by a branch RL which represents the three-phase networks (Fig. 4).

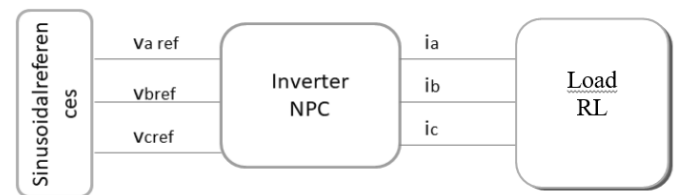
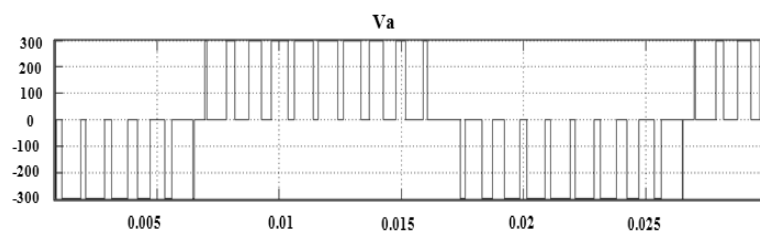


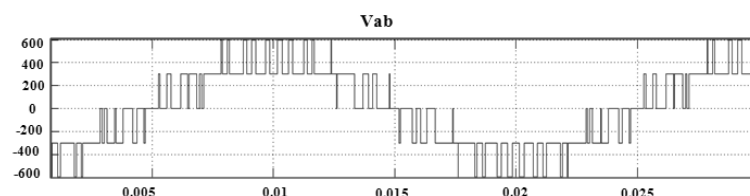
Fig. 4 NPC inverter simulation scheme

Fig. 5 shows the results of the simulation obtained, of which we represent the simple voltage Fig. 5 (a), the phase voltage Fig. 5 (b), the total harmonic distortion THD Fig. 5 (c) and the voltage at the terminals of the switches Fig. 5 (d).

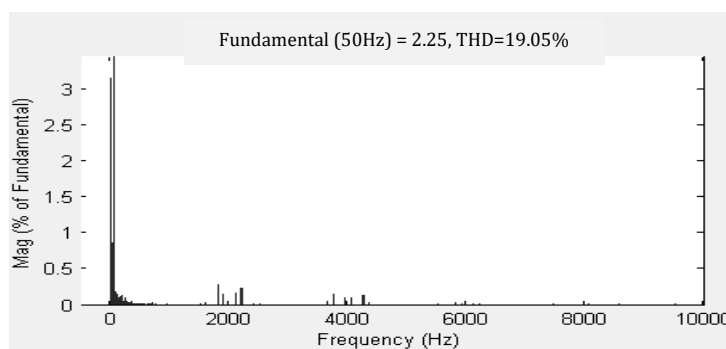
We can clearly observe the three voltage levels generated by the NPC inverter. Concerning THD, we note a low THD which will facilitate filtering at the output. For the voltage at the terminals of the switches we observe that it is equal to the half of the DC bus which will allow to use less powerful switch with higher switching frequencies.



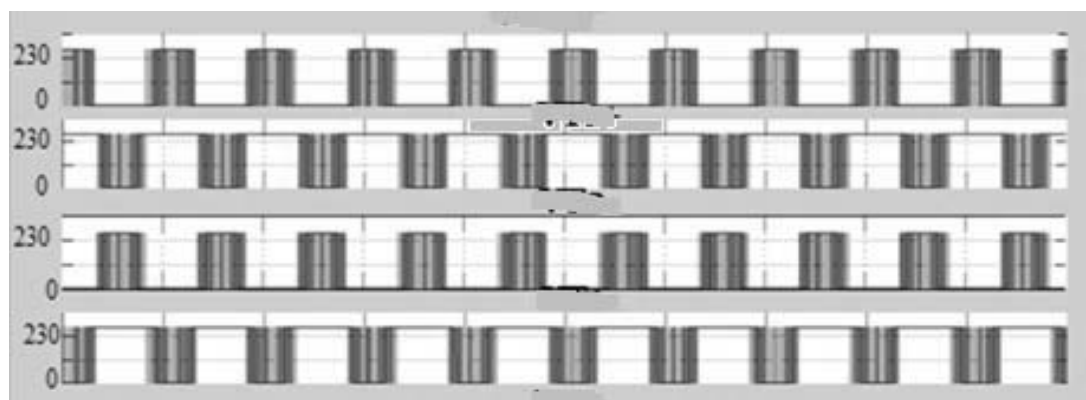
(a)



(b)



(c)



(d)

Fig. 5 Simulation results (a) simple voltage, (b) the phase voltage, (c) the total harmonic distortion THD, (d) the voltage at the terminals of the switches

The following table (Table II) summarizes the characteristics of the NPC inverter compared to the two-level inverter

### III. CONCLUSION

The demonstrating of the simulation results presented the efficiency of the proposed inverter in Doubly Fed Induction Generator (DFIG). The output voltage of Multi-level NPC

inverter is more sinusoidal in quality with reduced harmonic voltage.

The inverter proposed offers sinusoidal waveform of voltage than two levels inverter due to the fact that output voltage is formed by more than two voltage levels. This results in reduced total harmonic distortion and improved quality of power in compliance with the grid code.

TABLE II  
 BASIC SWITCHING OF NPC INVERTER

Performances	Two levels inverter	Three levels inverter
Total switches number	6	12
Off-state voltage	$V_{dc}$	$\frac{V_{dc}}{2}$
Voltage distortions	Not good	Good
Output Filter Dimensions	Big size	Small size
Complexity of implementation	simple	difficult

The other advantages of the inverter are that they can utilize fast switches with lower conduction losses resulting in reduced stress on cable, but to the detriment of a significant number of switches and a significant complacency of the control.

In the next article, we will compare the DFIG command using a two-level inverter with that using a three-level NPC inverter.

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