MADA the Performance When Fed with Two Different Inverters Controlled by PWM

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***Abstract* —This paper present is a comparative study between two inverters from two different levels of a doubly fed induction machine and controlled by PWM.**

This work aimed to control active and reactive power delivered to the electrical networks and satisfying the distribution requirements improve the working efficiency of the doubly fed induction machine and increase its capacity and efficiency on energy production. A performance evaluation is performed every time using spectroscopy to calculate the total harmonic distortion (THD).Simulation results have showed that the harmonic rate (THD) is reduced. Therefore; the quality of the produced power by this type of wind chain is efficient.

The results showed that using a three-phase inverter to feed the rotor of the machine is more efficient and effective to produce energy and lower THD means reduction in peak currents leading emissions and core loss and motors.

***Keywords*— Component; DFIM, PWM, THD, NPC, Multilevel Modeling.**

I. INTRODUCTION

The doubly fed induction machine (DFIM) is an asynchronous machine with wound rotor; the stator and the rotor winding are both fed with two different supplies. also slip-ring generators are electric motors or electric generators, Instead of the usual field winding fed with DC, and an armature winding where the generated electricity comes out, there are two three-phase windings, one stationary and one rotating, both separately connected to equipment outside the generator. Thus, the term doubly fed is used for this kind of machines.

One winding is directly connected to the output, and produces 3-phase AC power at the desired grid frequency. The other winding (traditionally called the field, but here both windings can be outputs) is connected to 3-phase AC power at variable frequency. This input power is adjusted in frequency and phase to compensate for changes in speed of the turbine.[1]

The voltage inverter is the most essential In this research. It is well known that increasing the levels number of the inverter is a better solution in stability performance DFIM [2].

The three-level voltage source inverter controlled by PWM with NPC structure is more efficient in terms of its lower switching frequency, reduced stress across the semiconductors, less harmonic content, and lower voltage distortion compared to 2 LVSI [3].

By feeding adjustable frequency AC power to the field windings, the magnetic field can be made to rotate, allowing variation in motor or generator speed. This is useful, for instance, for generators used in wind turbines.[4] DFIM-based wind turbines, because of their flexibility and ability to control active and reactive power, are almost the most interesting wind turbine technology.[5][6]

Doubly fed generators are an The several of recently researches are focused in this kind of machines due to the high performance and they are used in high-power drives [7], also it has a solution for variable speed operation and it ensures a very low speed [8]. However, the performances of the speed control are sensitizing at motor parameters variations [9] - [10]

This paper is organized as fallows. In section 2 the modelling of doubly fed induction machine. Then, the modeling in two level inverter in section 3. After, the modeling tree level inverter controlled by PWM with NPC structure in section 4. The simulation results are presented and discussed in section 5. Finally, the conclusion is presented in the last section.

II. THE SYSTEM MODELISATION

A. *Modeling of MADA*

In this section we are describing dynamic modeling DFIM in an d,q frame after Pack transformation in order to build numerical simulation in Matlab/ Simulink environment to apply this model was based on simplifying assumption[11].

- Winding is assumed distributed so as to give a sinusoidal EMF if powered by sinusoidal currents.
- The hysteresis, eddy currents and the skin effect is neglected and operation is not in the saturated regime.
- In the end the zero sequence system is zero because the neutral is not connected.

The dynamic model of the DFIG is expressed by the following expressions [12]:

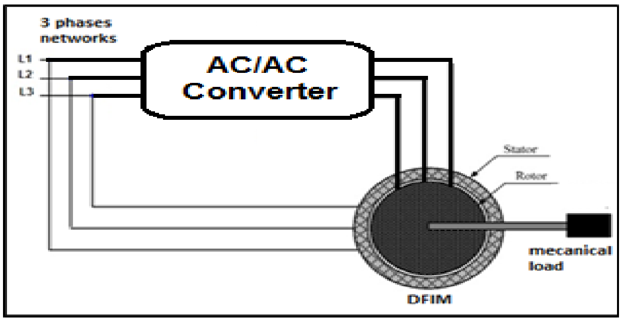

Figure 1.The DFIM's Power Supply[13]

The electrical equations of the DFIM in the (d–q) Park reference frame are given:

$$\begin{cases} V_{ds} = R_s.I_{ds} + \dfrac{d\varphi_{ds}}{dt} - \omega_s.\varphi_{qs} \\ V_{qs} = R_s.I_{qs} + \dfrac{d\varphi_{qs}}{dt} + \omega_s.\varphi_{ds} \\ V_{dr} = R_r.I_{dr} + \dfrac{d\varphi_{dr}}{dt} - (\omega_s - \omega).\varphi_{qr} \\ V_{qr} = R_r.I_{qr} + \dfrac{d\varphi_{qr}}{dt} + (\omega_s - \omega).\varphi_{dr} \end{cases} \quad (1)$$

$$\begin{cases} \varphi_{ds} = L_s.I_{ds} + M.I_{dr} \\ \varphi_{qs} = L_s.I_{qs} + M.I_{qr} \\ \varphi_{dr} = L_r.I_{dr} + M.I_{ds} \\ \varphi_{qr} = L_s.I_{qr} + M.I_{qs} \end{cases} \quad (2)$$

With: $\theta_s = \theta + \theta_r$

$$\frac{d\theta_s}{dt} = \omega_s = 2.\pi.f_s \; ; \frac{d\theta_r}{dt} = \omega_r = \omega_s - \omega = \omega_s - p.\Omega \, ;$$

From Eqs. **1** and **2**, the state space of the system can be as follows:

$$\begin{cases} x(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) \end{cases} \quad (3)$$

With $x = [\varphi_{ds}, \varphi_{qs}, \varphi_{dr}, \varphi_{qr}]^T$

$u = [V_{ds}, V_{qs}, V_{dr}, V_{qr}]^T \qquad y = [I_{ds}, I_{qs}, I_{dr}, I_{qr}]^T$

The equations of the active and reactive powers at the stator and rotor are written as:

$$\begin{cases} P_s = V_{ds}.I_{ds} + V_{qs}.I_{qs} \\ Q_s = V_{qs}.I_{ds} - V_{ds}.I_{qs} \\ P_r = V_{dr}.I_{dr} + V_{qr}.I_{qr} \\ Q_r = V_{qr}.I_{dr} - V_{dr}.I_{qr} \end{cases} \quad (4)$$

The mechanical equation of the system can be characterized by:

$$\dot{\Omega}_{mec} = \frac{1}{J}.T_{em} - \frac{1}{J}.T_L - \frac{1}{J}.Kf.\Omega_{mec} \quad (5)$$

The electromagnetic torque is expressed as:

$$\begin{cases} T_{em} = p \cdot (\Phi_{qr} \cdot I_{dr} - \Phi_{dr} \cdot I_{qr}) \\ T_{em} = p \cdot (\Phi_{ds} \cdot I_{qs} - \Phi_{qs} \cdot I_{ds}) \\ T_{em} = p \cdot M \cdot (I_{dr} \cdot I_{qs} - I_{ds} \cdot I_{qr}) \\ T_{em} = p \cdot \dfrac{M}{L_r} (\Phi_{dr} \cdot I_{qs} - \Phi_{qr} \cdot I_{ds}) \end{cases} \quad (6)$$

p is the number of pole pairs.

$$\begin{cases} \varphi_{ds} = L_s.I_{ds} + M.I_{dr} \\ \varphi_{qr} = L_s.I_{qs} + M.I_{qr} \\ \varphi_{dr} = L_r.I_{dr} + M.I_{ds} \\ \varphi_{qr} = L_r.I_{dr} + M.I_{qs} \end{cases} \quad (7)$$

B. Voltage converter modeling

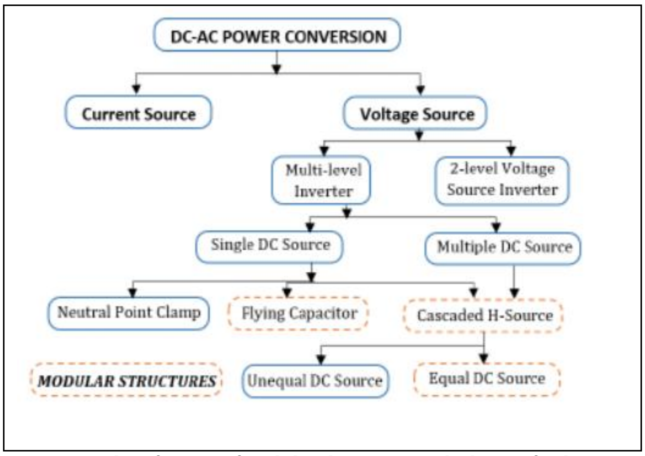

Figure 2. Classification of Multilevel Inverter on the basis of voltage source [14]

Comparison of conventional two level inverter and multilevel inverter

two level inverter	multilevel inverter
Higher THD in output voltage	Low THD in output voltage
Not applicable for high voltage applications	applicable for high voltage applications
Higher voltage levels are not produced	Higher voltage levels are produced
Higher switching frequency is used hence switching losses is high	lower switching frequency can be used and hence reduction in switching losses
Power bus structure, control schemes are simple	control schemes becomes complex as number of levels increases

Table 1 gives comparison between conventional and multilevel inverter in which multilevel inverter is better than conventional inverter [15].

1) The model of the two level converter with standard IGBTs is defined as[16]:

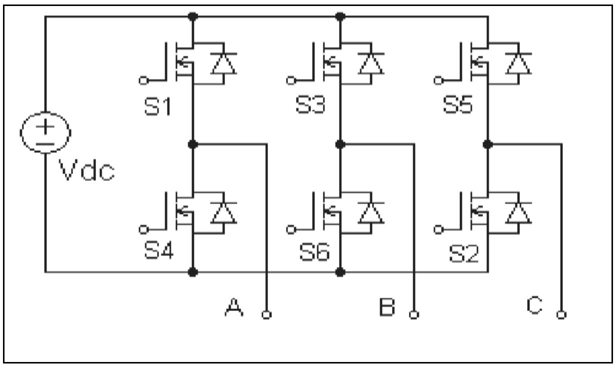

Figure 3 Structure of the two level converters with standard IGBTs

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} S_a \\ S_b \\ S_c \end{bmatrix} \quad (8)$$

Where S_a, S_b, and S_c are the command signals, V_{an}, V_{bn}, and V_{cn} are the output voltages and V_{dc} is DC bus voltage.

2) The model of the three level converters with standard IGBTs with NPC structure is defined as

Figure 4 shows the structure of a three-phase three-level voltage inverter with NPC structure. We start by defining the F_{ki} connection function of the switch.it is equal to 1 if the switch is closed and 0 otherwise.in controllable modes, the connection functions of the inverter are linked by relation (9).[17]

$$\begin{cases} F_{K1} = 1 - F_{K4} \\ F_{K2} = 1 - F_{K3} \end{cases} \quad (9)$$

With k=1, 2 or 3, represents bra number.

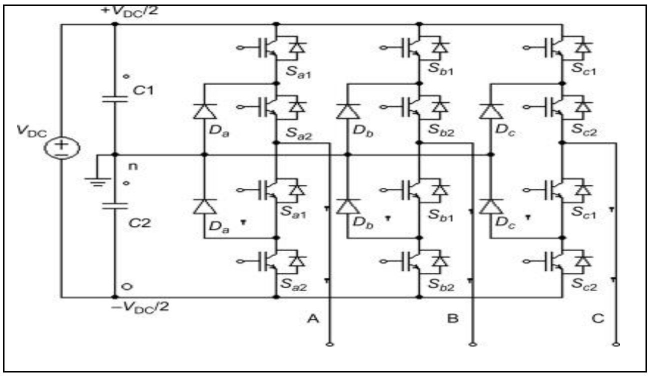

Figure 4: Three-level inverter with NPC structure

Figure 4 shows the structure of a three-phase three-level voltage inverter with NPC structure. We start by defining the F_{ki} connection function of the switch.[18]
It is equal to 1 if the switch is closed and 0 otherwise.
In controllable mode, the connection functions of the inverter are linked by relation (10).

We define the connection function b Half-arm F_{km} as follows:

$$\begin{cases} F_{K1}^{b} = F_{K1} \times F_{K2} \\ F_{K0}^{b} = F_{K3} \times F_{K4} \end{cases} \quad (10)$$

The sample output voltages are written:

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & 1 & 2 \end{bmatrix} \times \left\{ \begin{bmatrix} F_{11}^{b} \\ F_{21}^{b} \\ F_{31}^{b} \end{bmatrix} U_{c1} - \begin{bmatrix} F_{10}^{b} \\ F_{20}^{b} \\ F_{30}^{b} \end{bmatrix} U_{c2} \right\} \quad (11)$$

C. Control strategy Modeling

Multilevel inverter with PWM control is an effective solution for increasing power and reducing harmonics of AC waveforms. The advantages of PWM inverters are (i) control over output voltage magnitude (ii) reduction in magnitudes of unwanted harmonic voltages and (iii) improved power factor with unity displacement factor. Lowest order harmonic elimination is possible by proper choice of the number of pulses per half cycle.[19]

Although multilevel inverter offers several advantages, the control strategies of MLI are quite challenging due to the complexity to cater the transitions between the voltage levels (or steps). A number of modulation strategies are used in multilevel power conversion applications. [20]

For the types of PWM strategies we can find:
PD (Phase Disposition)
POD (Phase Opposition and Disposition)
APOD (Alternative Phase Opposition and Disposition)
COPWM (Carrier Overlapping) [16].

In this work I depend type (PD), the multi-carrier based phase disposition PWM scheme is used. Figure 6 demonstrates the sine-triangle method for a five-level inverter where in modulation or sinusoidal reference signal is compared with four (m-1 in general) triangle waveform when the number of output voltage level is 5 (= m), 4 (m –1) carrier waveforms are arranged so that every carrier is in phase.

1) The carriers are in phase across all the bands. For this technique, significant harmonic energy is concentrated at the carrier frequency but since it is a co-phasal component, it doesn't appear in the line-to-line voltage.

2) The frequency modulation index $m_f = \frac{f_c}{f_m}$ (12)

3) The amplitude modulation index $m_a = \frac{2A_m}{A_c(m-1)}$ (13)

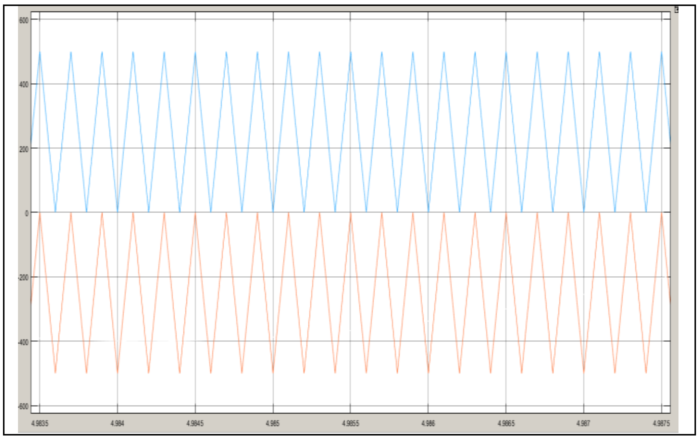

Figure 5. Sample multi-carrier arrangement for PDPWM strategy

III. RESULTS AND INTRPRETATION

Simulation of the proposed system was realized using MATLAB/Simulink. The following parameters values were used for simulations:

Rated values: 4kW; 220/380V, 50Hz

Rated parameters :

R_s : (Stator Resistance) = 1.2 Ω
R_r : (Rotor Resistance) = 1.8 Ω
L_s : (Stator inductance) = 1.2 Ω
L_r : (Rotor inductance) = 1.2 Ω
M : (mutual inductance) = 0.15 H

Mechanical Constants :

J (rotor inertia) = 0.2 kg.m2
Kf (friction coefficient) = 0.001S

A. The results of the performance of MADA simulation based on two level inverter controlled by PWM

The stator of DFIM is directly connected to the grid and the rotor was fed by a three level PWM NPC inverter. The results of simulations were obtained for the machine speed (1500 tr/min) In the permanent system. Figure 6.

Figure 7, shows the speed of the machine we remark that it stabilize after three seconds of starting and the torque is distorted and inaccurate ;the same for torque Figure , because of the Higher percentage THD .Figure 8

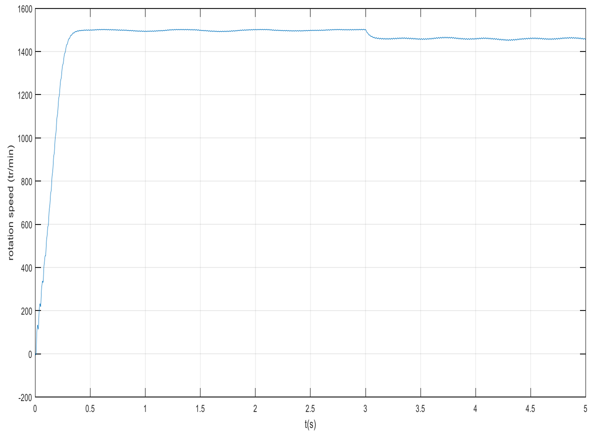

Figure 6. Rotation speed of a MADA powered by an inverter at two levels.

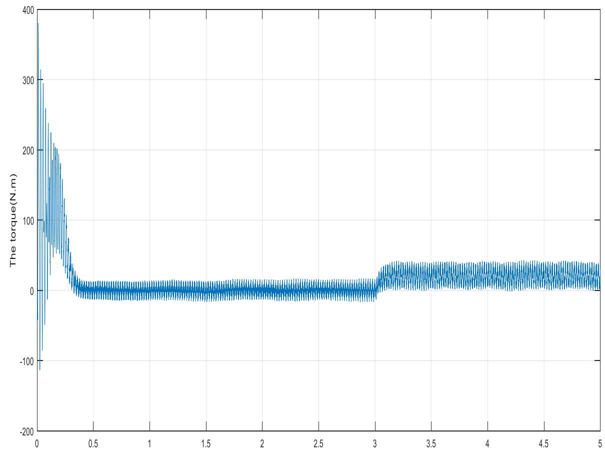

Figure 7. The torque of a MADA powered by an inverter at two levels.

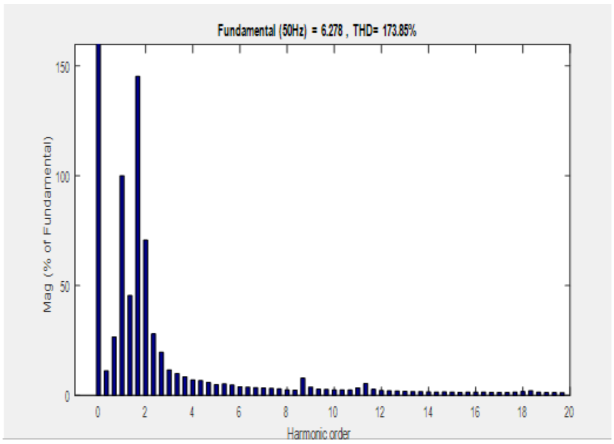

Figure. 8 Active power PHD of a MADA powered by two level inverter.

B. The results of the performance of MADA simulation based on three level inverter with NPC structure controlled by PWM

The DFIM supplied by a three level NPC inverter controlled by PWM for a frequency modulation index m=20 and amplitude modulation index r = 0.85. Figure 9.

Illustrates the Figure 10, and Figure 11.a shows the improve and stability in the rotor of machine. Also It is observed that Improve in total harmonic distortion is also reduced due to more output levels and precision controlled in PWM strategy.

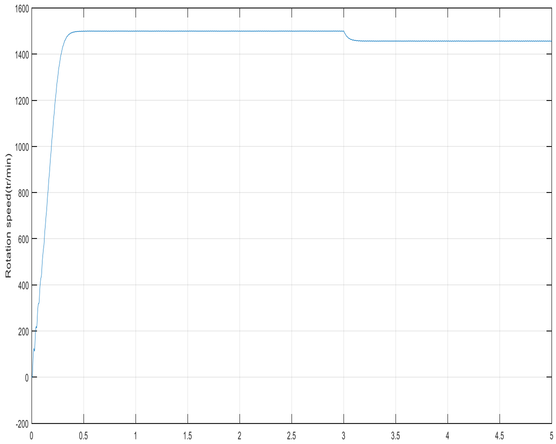

Figure 9. Rotation speed of an MADA powered by a three-level Inverter NPC structure

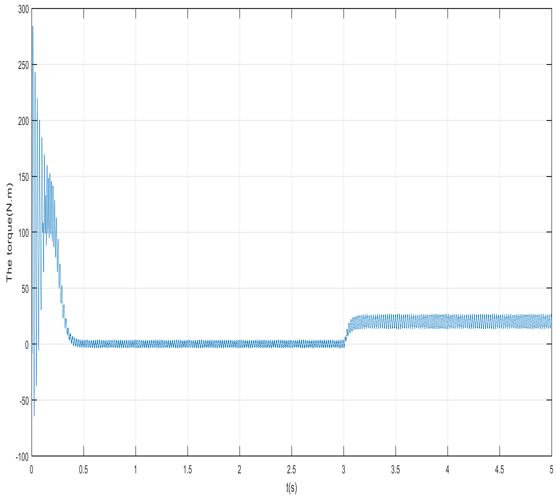

Figure 10. The torque of an MADA powered by a three-level Inverter NPC structure

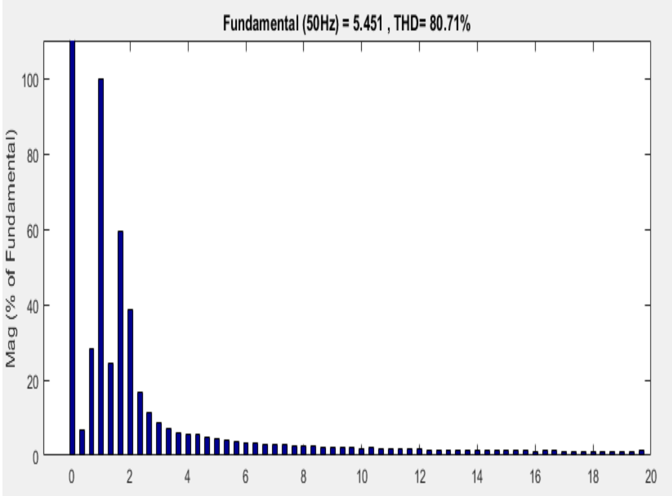

Figure 11. Active power PHD of a MADA powered by three-level Inverter NPC structure

IV. Conclusion

To improve the performance of the doubly-feed induction motor, the modeling and control of a inverter that supplies the rotor winding of DFIM.

Initially, the motor was fed for a two level inverter that was controlled by a PWM strategy; It controls its rotating currents.

Then, the same part was fed back into a three-level NPC inverter that equips the DFIM rotor in order to obtain harmonic distortion reduction.

For a three-level inverter controlled by PWM strategy ,the results showed that DFIM fed by a three-level inverter controlled by PWM had better results compared to DFIM fed on a two-level inverter controlled by PWM.

The comparison results showed that the multi-level inverter has greater amplitude of the modulation index and generates less Total Harmonic Distortion (THD) on the output voltage.

Multi-level inverters have showed significant advantages over the conventional inverter for medium and high power applications. This is due to their ability to meet the increasing demand of power ratings and power quality associated with reduced harmonic distortion, lower electromagnetic interference, and higher efficiency.

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