

AC/DC and DC/AC Multilevel Converter and DC Voltage Regulation. Applied To the Asynchronous Machine

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Abstract. This work is based on spectral analysis of the current and the performance of each type of rectifier is two or three-level PWM-controlled strategy. This work is done through waterfalls consist of two three-phase rectifiers and three-level PWM inverter and a three-phase three-level NPC structure, which feeds an induction motor considered a balanced three-phase load. We approach our work the modeling of both types of rectifiers, then we show the positive effect of increasing levels of voltage rectifiers on the signal quality of the network. We end by showing the imbalance between the voltages supplying the voltage inverter at three levels and the value of having a stable voltage at the terminals of the machine. The results obtained in the simulation are very promising.

Keywords: Neutral-Point-Clamped-(NPC), three level inverter, pulse-width modulation (PWM), Clamping Bridge, three level rectifiers.

1. Introduction

The rectifier is considered a non-linear load that generates harmonics to the network, which influences the shape and quality of reports of the current supplied by the network. For this we will discuss in this article one of the procedures to improve the signal quality of the current drawn by the rectifier. The procedure consists of first powered inverter with three level NPC structure by two two-level rectifiers connected in series then the second place by a rectifier at three levels, will be shown at the beginning of the performance and the role of the rectifier three levels in improving the rate of harmonic distortion THD current rectifiers over two levels. It ends with solving the problem of unstable voltages at the input of the DC source voltage of the inverter at three levels by providing a bridge balancing clamping of said bridge which allows for a system stable voltage across the machine.

2. Modeling of Rectifiers

2.1 Rectifier Two-Levels [1][2]

The model of two-level rectifier is presented in Fig.1 A the order further used, is:

$$B_{K1} = \overline{B}_{K0} \quad (1)$$

K: number of arms rectifier (K=1, 2, 3).

The voltages at the input of the rectifier are given by the following system (2)

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} F_{11} \\ F_{21} \\ F_{31} \end{bmatrix} U_{red} \quad (2)$$

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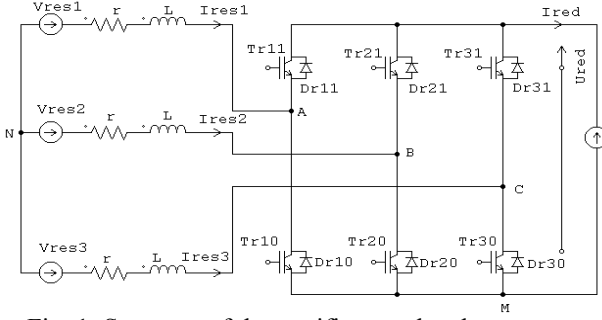


Fig. 1: Structure of the rectifier two-level

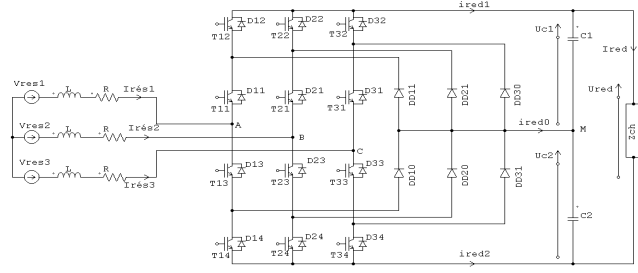


Fig. 2: Structure of the NPC rectifier three-level

2.2 Rectifier Three Level [1][3][4][8].

Figure.2 shows the structure of the NPC rectifier current three levels. Three orders are possible for this rectifier. The most optimal is given by the relationship (3).

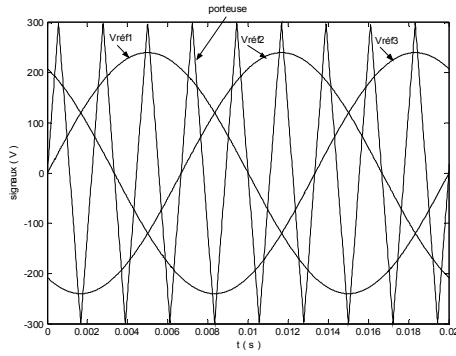
$$\begin{aligned} B_{K1} &= \overline{B_{k4}} \\ B_{K2} &= \overline{B_{K3}} \end{aligned} \quad (3)$$

with B_{KS} control of the base of the transistor T_{KS} . In command mode, the voltages for the rectifier expressed thanks to the functions of half-arm connections, depending on the system (4).

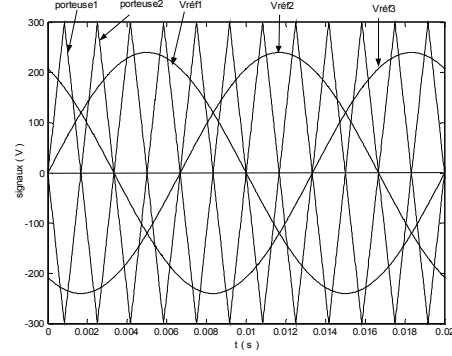
$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = 1/3 \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \left\{ \begin{bmatrix} F_{11}^b \\ F_{21}^b \\ F_{31}^b \end{bmatrix} U_{c1} - \begin{bmatrix} F_{10}^b \\ F_{20}^b \\ F_{30}^b \end{bmatrix} U_{c2} \right\} \quad (4)$$

3. Strategies of Command

The two-level three-phase rectifier is controlled by the PWM strategies with a single triangular carrier pole, and then the three-level rectifier and the inverter are controlled by the same strategy but with two carrier's triangular bipolar (figure. 3). [5]



Two level (m = 9, r = 0.8)



Three levels (m = 6, r = 0.8)

Fig.3: Signals of the strategy three-phase PWM rectifier with two and three levels

4. Study and Simulation of Cascades

4.1 Cascade Two Rectifier's Current at Two Levels -Inverter at Three Levels - Three phase Asynchronous Motor

Network parameters remain unchanged during the simulations of cascades studied in this paper [6][7].Figure .4 shows the structure of this cascade.

4.1.1. Application and simulation results

The three-phase three-level inverter is controlled by the PWM strategy with two carriers (m = 16, r = 0.8). The two rectifiers are connected in series, and each is powered by a 115 V rms and a frequency of 50 Hz, which aims to keep the same voltage = 600V rectified uredinia. The two bridges are controlled by a

PWM carrier strategy bipolar ($m = 15, r = 0.8$). Figures 5 show the simulation results of the waterfall that feeds the engine $C_r = 12 \text{ Nm}$.

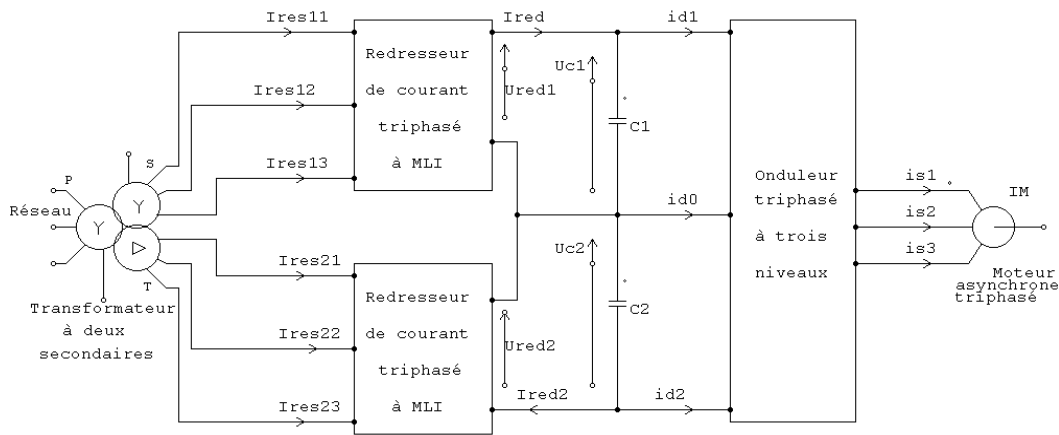


Fig.4: Cascade of a three-phase rectifier at two levels - inverter at three levels - three-phase asynchronous motor

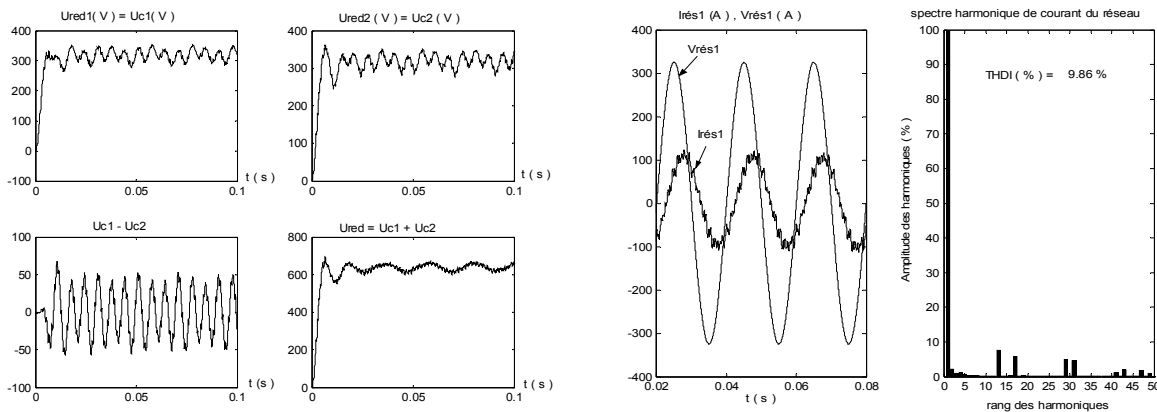


Fig.5.a

Fig.5.b

Fig.5.a: Voltages righted Ured1 Ured2 and two bridges rectifiers phase two levels and their difference $U_{c1} - U_{c2}$.

Fig.5.b.: Spectre harmonic current $I_{rés1}$ absorbed by the two bridges rectifiers and voltage $V_{rés1}$

4.1.2. Interpretation

Figure 5.a. shows the two strains recovered issued by the two bridges rectifiers phase two levels and we note that $U_{red} = U_{red1} + U_{red2}$ with $U_{red1} = U_{c1}$ and $U_{c2} = U_{red2}$. The difference between the two voltages U_{c1} and U_{c2} is not zero; the inverter is subjected to unstable voltages. From Figure 5b, we see that the series connection of two rectifier two levels will improve the THD of grid current, which is about 9.86%. Even and odd harmonics multiple of three are zero. Harmonics that exist are small in amplitude, compared with a single bridge rectifier two levels and are grouped into families always centered around the multiple frequencies of the carrier. The shape of current is enhanced and the phase difference still exists between the current and voltage of the network is around 45° which explains the stress phase and consumption of reactive power.

4.2 Cascade Rectifier Current Three phase at Three Levels-Inverter at Three Levels - Three phases Asynchronous Motor

The waterfall model is shown in Figure 6. En combining three-phase rectifier three-level NPC structure in three-phase inverter at three levels in NPC structure; we obtain the indirect frequency changer.

4.2.1. Application and simulation results

The rectifier and inverter are controlled by the same strategy PWM two carriers triangular bipolar ($m = 16, r = 0.8$). This waterfall feeds a three-phase induction motor ($C_r = 12 \text{ Nm}$). Figures 7 show the simulation results of the cascade shown in fig. 6.

4.2.2. Interpretation

Tensions UC1 and UC2 illustrated in Figure 7.a. are very close and the voltage difference (UC1 - UC2) oscillates around a value small compared to that of UC1 and UC2. This difference is most important capabilities of low value, causing the instability of the input voltage to the inverter, and which affects the motor supply. The decrease of the difference in voltages (UC1 - UC2) is possible by increasing the carrying capacity. It can be seen from Figure 7.b. that the use of three-level rectifier can improve much more the network side current THD of about 4.11%. Harmonics that exist are very small in magnitude compared to the harmonic spectrum with two rectifier bridges at two levels. The current speed is greatly improved compared to the current drawn by the rectifier at two levels. The phase current-voltage network side will always persist in the order of 45 °.

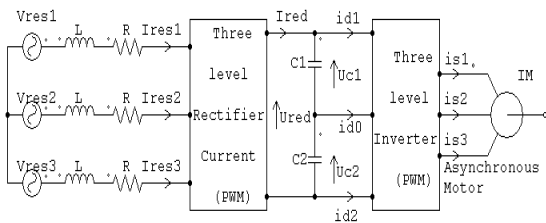


Fig.6

Structure of rectifié	PWM Rectifier D'IGBT		
	A bridge rectifier two-level	Two bridges rectifiers at two levels in series	Rectifier three-level
THDI (%)	28.27	9.86	4.11

Table the different rectifiers and THD

Fig. 6: Cascade rectifier current three-phase three-level - inverter three levels - three-phase asynchronous motor.

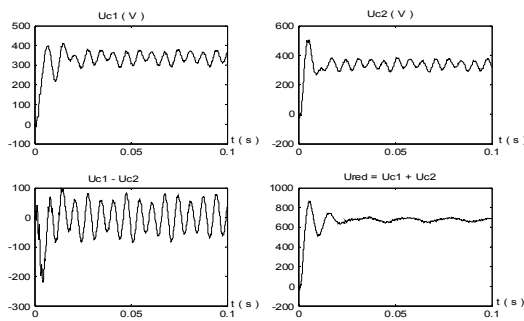


Fig.7.a

Fig7.a: Voltages Uc1 and Uc2 at the entrance to the inverter at three levels and their differences Uc1 - Uc2
Fig7.b: Specter harmonic current Irés1 absorbed by the rectifier current three levels and voltage Vrés1

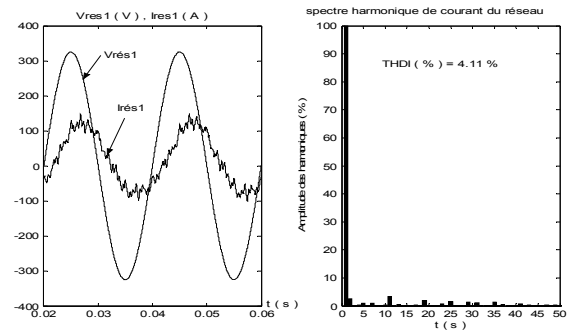


Fig.7.b.

5. Regulation of Source Continuous Inverter

To minimize the imbalance between the two input voltages of the inverter DC source, it is proposed to insert a bridge balancing, said clamping bridge, consisting of a transistor and a resistor across the terminals of each capacitor [6][7]. The transistors are controlled in such a way as to maintain equal voltages UC1 and UC2. Thus the new filter intermediary between the rectifier and the three-level voltage inverter at three levels is shown in Figure 8.

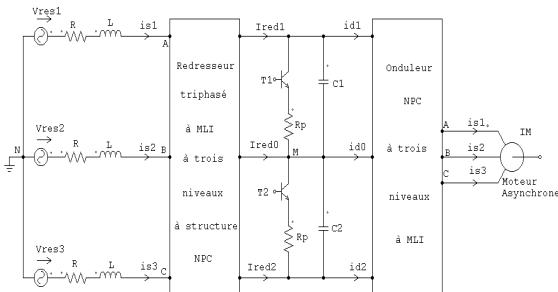


Fig. 8: Structure of the cascade rectifier current three - Levels- clamping bridge - inverter at three levels – asynchronous motor

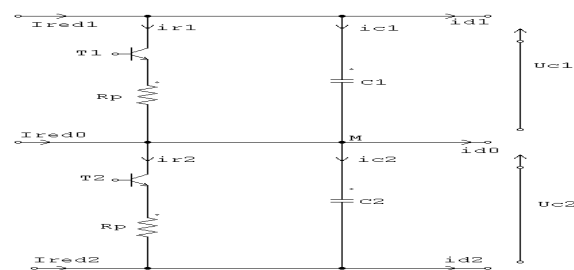


Fig.9: Structure of the bridge clamping

The model of these filters is defined by the following system;

$$\begin{aligned}
C1 \quad \frac{dU_{c1}}{dt} &= I_{c1} = I_{red1} - I_{d1} - I_{r1} \\
C2 \quad \frac{dU_{c2}}{dt} &= I_{c2} = I_{d2} - I_{red2} - I_{r2}
\end{aligned} \tag{5}$$

$$\begin{aligned}
I_{r1} &= T_1 \frac{U_{c1}}{R_p} \\
I_{r2} &= T_2 \frac{U_{c2}}{R_p}
\end{aligned} \tag{6}$$

The algorithm command of transistors is defined as follows:

$$\Delta U_{12} > 0 \Rightarrow I_{r1} = 0 \text{ et } I_{r2} \neq 0 \Rightarrow B_1 = 0 \text{ et } B_2 = 1$$

$$\Delta U_{12} < 0 \Rightarrow I_{r1} \neq 0 \text{ et } I_{r2} = 0 \Rightarrow B_1 = 1 \text{ et } B_2 = 0$$

$$\text{With } \Delta U_{12} = U_{c1} - U_{c2}$$

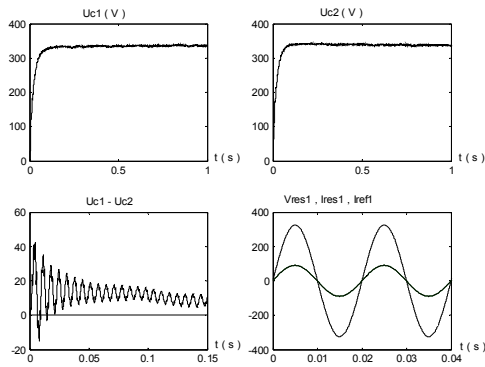


Fig.10.a

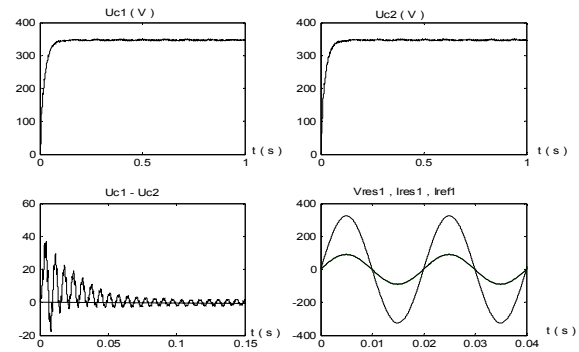


Fig.10.b

Fig.10.a: Forms of continuing voltage and bridge differences without Clamping

Fig.10.a: Forms of continuing voltage and bridge differences with clamping

5.1 Interpretation

This cascade has already been studied and simulated without clamping bridge and were obtained fig.7.a and the fig.10.a It was noted that the input voltages of the DC source (UC1 and UC2) are unstable and different values and the difference UC1 - UC2 is relatively large. To improve the voltage UC1 and UC2 minimizing the imbalance and the difference between these voltages, we studied the same cascade but this time we use a clamping bridge.

Figure 10b shows the shapes of the voltages delivered by balancing the bridge with a value of $R_p = 30\Omega$ and capacitance values $C1 = C2 = 20\text{mF}$. As we can see the difference between the input voltage of the inverter at three levels decreased significantly and vanishes at steady state. And tension becomes equal. The results are very promising for the use of this cascade in the fields of high power.

6. Conclusion

In this work we have shown in particular the application of the concept of multi-level three-phase rectifiers and their interest in improving the spectral quality of the current, and its better performance compared to rectifiers at two levels, as shown in table above.. This work also presents a contribution to the study of the stability of the input voltage of the inverter at three levels. This stability allows the proper functioning of the whole rectifier - inverter - induction motor.

While inserting a clamping bridge across each capacitor greatly reduces the fluctuation of input voltage of the inverter at three levels. The results were satisfactory using the filter capacitor value quite high. To decrease the value of these capacitors, while safeguarding the stability of the subjugation of the voltages at the input of the inverter is recommended.

7. References

- [1] E.M .Berkouk «Contribution to drive machines and single-phase asynchronous three-phase converters powered by

direct and indirect. Application to dimmers and inverters multilevel », Ph.D. thesis, C.N.A.M, Paris 1995.

- [2] JP Caron, JP Hautier "modeling and control of the machine asynchronous" edition technip 1995.
- [3] M.S, Djebbar and H. Benalla « Rectifiers comparative study between two levels and multilevel PWM order », International Journal of Electrical and Power Engineering 2(6):365-376, 2008
- [4] E.M.Berkouk, G.Manasse « Multi level PWM rectifier-multilevel inverter cascade. Application to the speed control of the PMSM », IEEE proceeding, international conference on control application, Trieste, Italy 1-4 September 1998.
- [5] Guedouani. R « control of a multilevel voltage inverter. Application to the conduct of the permanent magnet synchronous machine. » Thesis master, ENP, Algiers, Algeria May 1998.
- [6] F.Bouchafaa, E.Berkouk, M.S.Boucherit « Analysis and simulation of a cascade of two rectifier-inverter PWM multilevel NPC. Application to conduct a MSAP », 3rd Conférence on Electrical Engineering - Octobre 2004-Batna.
- [7] R.Gue Douani, E.M.Berkouk, B.Fiali, M.S.Boucherit « Analysis of the cascade rectifier-three-level voltage inverter with five levels. Application to the conduct of the permanent magnet synchronous machine », 3rd Conférence on Electrical Engineering -Octobre 2004-Batna.
- [8] P.Palanivel Subhransu SekherDash, «Phase Shifted Carrier Pulse Width Modulation for Three Phase Multilevel Inverter to Minimize THD and Enhance Output Voltage Performance», Power Electronics Laboratory, SRM University, Chennai, Tamilnadu, India - JES 2010