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Harmonics Minimization of Multilevel Inverter Connecting Source Renewable Energy

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Abstract- This paper presents the possibility of improving the quality of the output voltage delivered by a multi-level inverter for interconnection between a renewable energy generator and the electricity grid. For this purpose, we use the Newton Raphson algorithm for solving nonlinear equations to determine the optimal switching angles. In our study, we consider multilevel inverters with output voltages of odd levels. Finally, we evaluate the rate of distorting harmonics (THD) of obtained voltages, according to various indices of adjustment.

Keywords- Harmonics; renewable energy; multilevel inverters; simulation.

1. Introduction

The development of high voltage converters is growing rapidly in recent years and multilevel source voltage and matrix converters (MC) seem to be the standard solution for medium voltage applications [1]. Modern power electronics have contributed a great deal to the development of new powerful applications and industrial solutions; but at the same time, these advances have increased the harmonic contamination present in line currents, which ends up distorting the voltage waveforms [2]. The main advantage of multilevel converters and its topology is that it can generate almost perfect current or voltage waveforms, because it is modulated by amplitude instead of pulse-width. That means that the pulsating torque generated by harmonics and power losses into the machine due to harmonic currents can be eliminated. Another advantage of this kind of drive is the switching frequency and power rating of the semiconductors is reduced considerably [3].

The generators of renewable energy are developing, although their connection to the case in terms of electrical operation of the technical implications to the distribution network [4][5]. The integration of the renewable energy generators in power systems has identified several priorities; the most important is to address the quality of energy injected into the grid [6].

So to place the interest of this paper, we begin to show in Fig. 1. It illustrates an interface system connected with a energy source to the network. To this end, two converters are used: an energy converter and a electronics converter used to adapt the electrical quantities.

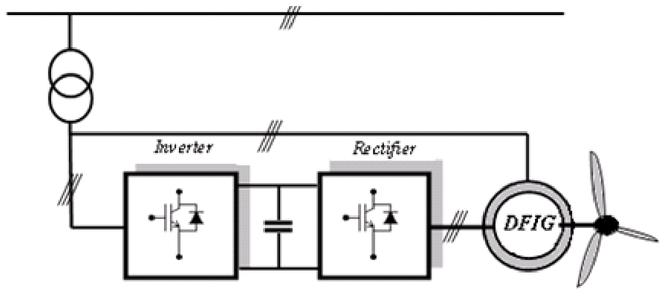


Fig. 1. Wind turbine based of DFIG

The latter may consist of one or more conversion stages. However, the top level which provides the network connection is necessarily a voltage inverter [7, 8].

Furthermore we can distinguish a control system that ensures control of the extracted power and that the electrical, mechanical, and finally the power interface that reinforces the constraints of the network connection and better use of the generator.

For more details, we present Fig. 2; illustrate a wind turbine based on double-fed induction machine [9]. Where one sees much interest in the use of the inverter and the need to ensure a clean output voltage.

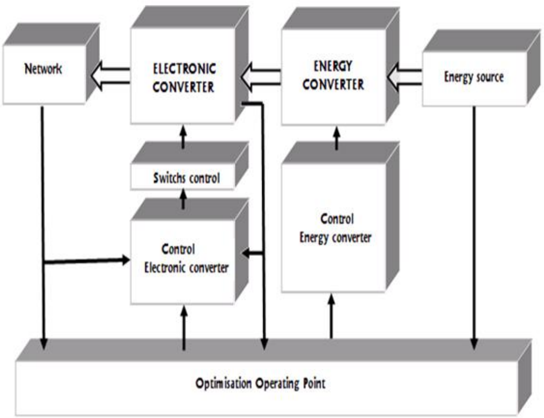


Fig. 2. Production device

For the power returned to the network is improved. So, consider that it is multilevel allows increased DC bus voltage by series connection of capacitors of the DC bus and transit and more power and the ratio of redundant vectors in balancing the DC bus and the possibility of connecting multiple generators on the DC bus by increasing the number of capacitors (each generator can be connected across a capacitor), and it can improve the quality of the output voltages of inverter, in turn aside the maximum residual harmonics by the technique of choice for pre-calculated switching angles [10]. Generally the more levels of voltage generated by the converter, the greater will be its low total harmonic distortion.

2. Structure of Multilevel Inverter

Figure 3, shows the diagram of a three-phase asymmetrical multilevel inverter. It has a cascade structure formed by the connection of inverters in each partial phase [11].

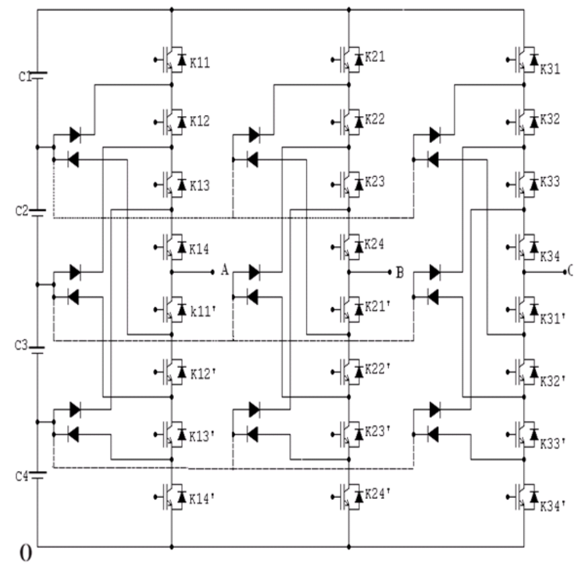


Fig. 3. Three-phase asymmetrical multilevel inverter

Generally the output voltage presents two fold symmetry with respect to a quarter of the voltage and the other over the half period as shown Fig. 4.

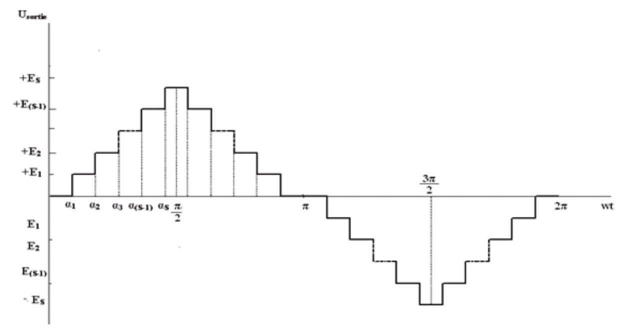


Fig. 4. Shape of the output voltage of an arm

This part of the tension is characterized by the number of slots per rotation. This number is odd or even, it also represents the number of switching angles per quarter period. Therefore, these angles are sufficient to determine the width of all slots. These switching angles are predetermined so as to eliminate certain harmonics defined previously [9].

In this study, we focus on the elimination of harmonics 5, 7, 11, 13 and 17. Thus the Fourier series will be simplified and the study will be limited to only one quarter of the period. Are the following expression:

$$f(\alpha) = V_s(\alpha) = \sum_{n=1}^{\infty} a_n \sin(n\alpha) \tag{2}$$

Where:

$$a_n = \frac{4}{\pi} \int_0^{\pi/2} f(\alpha) \sin(n\alpha) d(\alpha) \tag{3}$$

With: $\alpha = \omega t$

After integration, with some calculations, we obtain an algebraic system of nonlinear equations admit many solutions. The Newton-Raphson [12] is usually more used to solve such a system, which becomes:

$$\begin{cases} Cos(\alpha_1) - Cos(\alpha_2) + ... \pm Cos(\alpha_C) = \frac{\pi}{4U} h_1 \\ Cos(5\alpha_1) - Cos(5\alpha_2) + ... \pm Cos(5\alpha_C) = \frac{5\pi}{4U} h_5 \\ \dots\dots \quad \dots\dots\dots\dots \\ Cos(n\alpha_1) - Cos(n\alpha_2) + ... \pm Cos(n\alpha_C) = \frac{n\pi}{4U} h_n \end{cases} \quad (4)$$

With, n: odd number multiple of three; U: supply voltage; h_1 : fundamental output voltage U; h_i : harmonic i and α_i : switching angle.

However C-1 to eliminate harmonics of the output voltage we must impose the inequalities (6) and retain only the solutions satisfying the condition (6):

$$\begin{cases} Cos(\alpha_1) - Cos(\alpha_2) + ... \pm Cos(\alpha_C) = \frac{\pi}{4} r_1 \\ Cos(5\alpha_1) - Cos(5\alpha_2) + ... \pm Cos(5\alpha_C) = 0 \\ \dots\dots \quad \dots\dots\dots\dots \\ Cos(n\alpha_1) - Cos(n\alpha_2) + ... \pm Cos(n\alpha_C) = h_n \end{cases} \quad (5)$$

Where, $r_1 = \frac{h_1}{U}$: is the modulation rate.

$$\alpha_1 < \alpha_2 < ....\alpha_s < \frac{\pi}{2} \quad (6)$$

3. Newton-Raphson Algorithm Method

The resolution of the system (5) gives the switching angles suitable, which is obtained by considering the following steps [12]:

3.1. Propose a set of initial values

For j = 0

$$\alpha^j = \left[\alpha_1^{\,j}, \alpha_2^{\,j}, ..., \alpha_s^{\,j}\right]^T \quad (7)$$

This step requires the choice of initial angles. Therefore, it is the major problem of the method. So then, it is recommended to perform the method of choice for initial angles developed in [5, 12] which are calculated according to the following expression:

$$E_{ang} = \frac{2\pi}{3(C+1)} \quad (8)$$

E_{ang} and C represent respectively the angular and number of switching angles.

3.2. Calculation of the vector form condensed nonlinear equations of the system:

$$F(\alpha^j) = F^j \quad (9)$$

3.3. Linearization of equation (10) around α^j*:*

$$F^j + \left[\frac{\partial f}{\partial \alpha}\right]^j d\alpha^j = K \quad (10)$$

$$[\partial f / \partial \alpha]^j d\alpha^j = \begin{bmatrix} \partial f_1/\partial\alpha_1 & \partial f_1/\partial\alpha_2 & .... & \partial f_1/\partial\alpha_C \\ \partial f_2/\partial\alpha_1 & \partial f_2/\partial\alpha_2 & .... & \partial f_2/\partial\alpha_C \\ . & . & . & . \\ \partial f_C/\partial\alpha_1 & \partial f_C/\partial\alpha_2 & ..... & \partial f_C/\partial\alpha_C \end{bmatrix} \quad (11)$$

f : is the functions related to the harmonic switching angles. And,

$$d\alpha^j = \left[d\alpha_1^j, d\alpha_2^j, K, d\alpha_c^j\right]^T \quad (12)$$

3.4. Solve $d\alpha^j$ *from the equation (12) by:*

$$d\alpha^j = INV[\partial f / \partial \alpha]^j (M - F^J) \quad (13)$$

M: are the amplitudes of harmonics.

3.5. Change the initial values at each stage by:

$$\alpha^{j+1} = \alpha^j + d\alpha^j \quad (14)$$

3.6. Repeat the process of equation (9) to equation (12) until the process is satisfied.

4. Simulation and interpretation

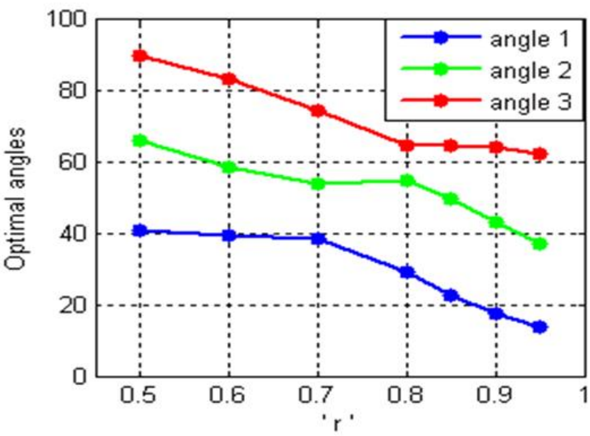
We consider three examples of multi-wave (at 7, 9 and 11) based on various indices of adjustment. To get started, we programmed in Matlab the Newton-Raphson algorithm. Through which we determined the optimal switching angles. That allowed us to visualize the shapes of voltages at the output of the inverter. Finally, their respective frequencies are presented for changing the rate of harmonic provisions of each case. To this end, we first calculated and presented in Fig. 5, 6 and 7. The solutions of optimal angles of the variation of the index adjustment (a) of their total harmonic distortion THD (b) for cases output voltage of inverter levels 7, 9 and 11 respectively.

The results of programming for determining switching angles by the Newton Raphson giving different angles for different values of switching modulation rate (r) are given in Fig.5a, Fig. 6a and Fig. 7a for 7, 9 and 11 levels.

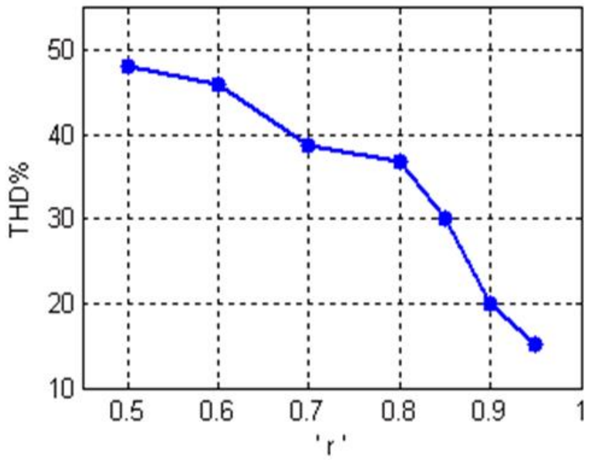
In most cases, there are probably more appropriate solutions to eliminate the same harmonics of the output voltage of the inverter; it needs a calculation of total harmonic distortion for different solutions. The final solution to be used is the one with the lowest THD. It was stinking up the following results in the same condition of supply voltages. After several test simulations and analysis, we have the following observations:

In general, the THD of the output voltage of the inverter is inversely proportional to the modulation rate. Increasing the number of low-level inverters. The elimination of harmonics 5.7.11 and 13 of the output voltage is ensured. The smaller the value of THD that has been observed in our survey. Is the multilevel 11 and r = 0.96, THD = 12.89%.

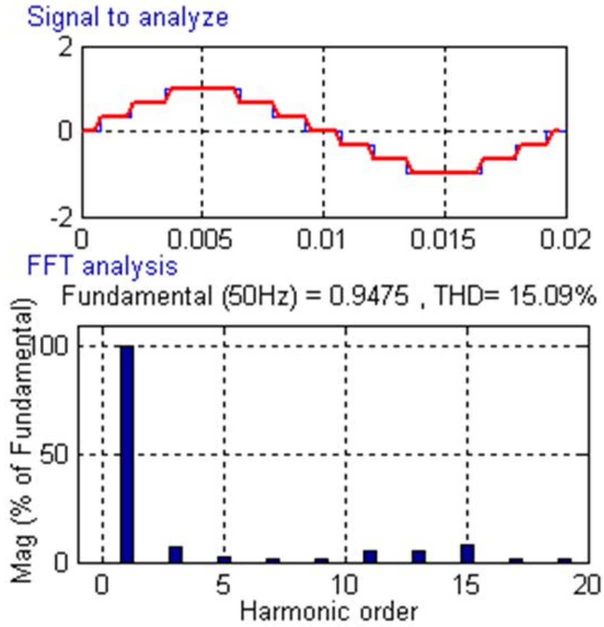
Group voltage whatsoever renewable energy generator same nature that is a set of wind or a set of solar panels or both are simultaneously (hybrid system) at the entrance of a single multi-level inverters. Voltage is treated by eliminating undesirable harmonic and others by reducing the number of inverter, the level of interconnection. For seven and nine levels inverter, the harmonics 5,7 (shown Fig. 5c) and 5.7,11 (Fig. 6c) are eliminated respectively and finally for 11 levels inverter the harmonics 5, 7, 11 and also 13 are illumined , shown Fig. 7c.



(a)

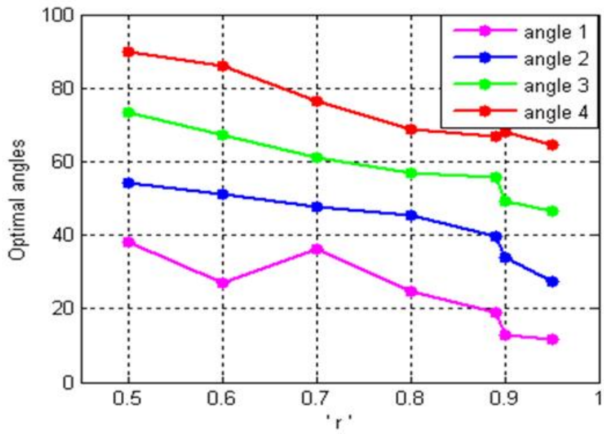


(b)

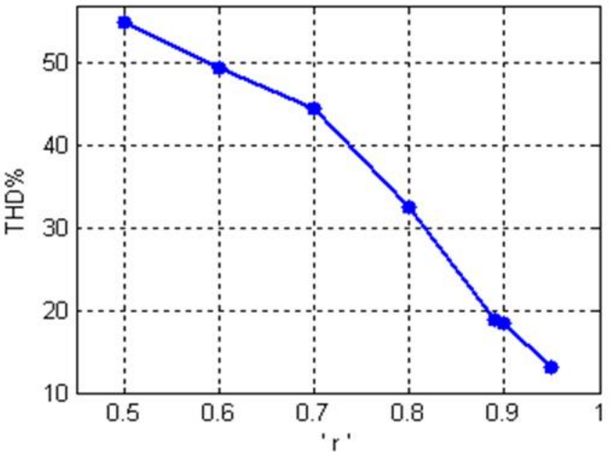


(c)

Fig. 5. Seven levels Inverter



(a)



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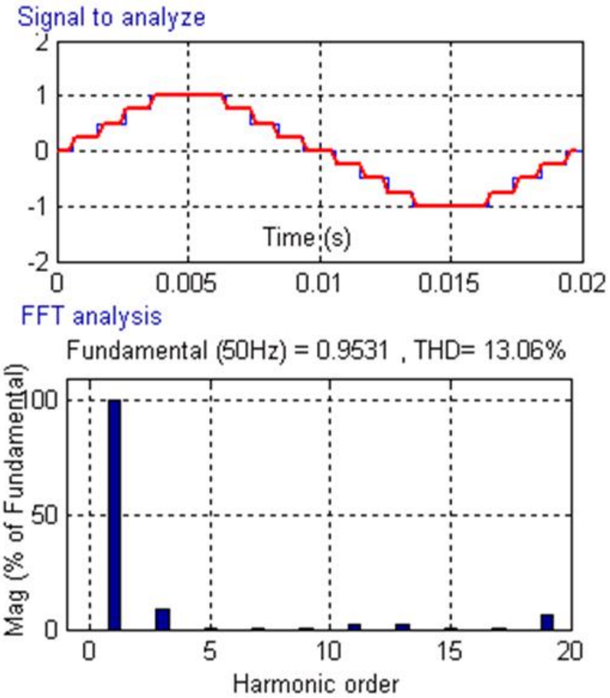
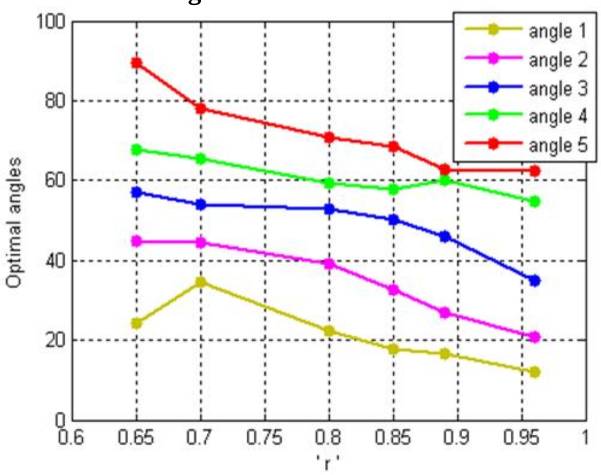
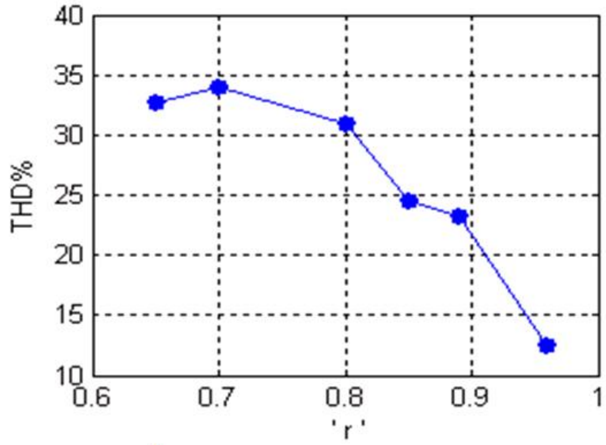


(c)

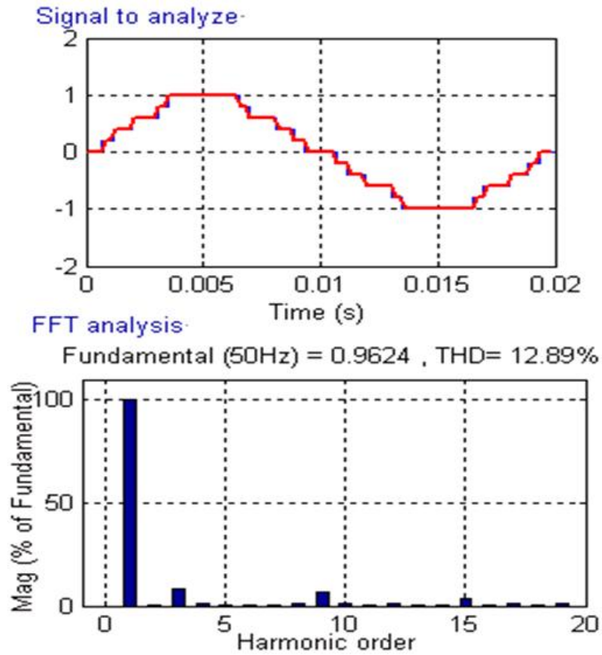
Fig.6. Nine levels Inverter



(a)



(b)



(c)

Fig. 7. Eleven levels Inverter

5. Conclusion

This study has enabled us to understand the principle of an alternative screening among several alternatives available to ensurproper connection Because each filtering method has advantages and disadvantages, we note that the technique of calculating switching angles corresponding multilevel inverters are eliminating certain harmonics which have the following advantages: the moments of order are known in advance; allows the selection of harmonics to be eliminated; also allows control of the amplitude of the fundamental and allows the reduction of the number of inverters at the interconnection. This improves the performance of the inverter-network Association.

The main drawback of the technique of Newton-Raphson method applied to solving systems of nonlinear equations of this technique is the difficulty of choosing initial values of switching angles. This technique can also be used to power the induction machines fed by inverters which are adopted primarily for medium and large motor power this technique provides good dynamic performance for our case, the torque ripple in the case of variable speed drives and opens an interesting field for the use of such strategy.

References

[1] Miguel López, Luis Morán, José Espinoza and Juan Dixon, "Performance Analysis of a Hybrid Asymmetric Multilevel Inverter for High Voltage Active Power Filter Applications", IEEE Industrial Electronics Conference, IECON'2003, Virginia, USA,, 2003.

[2] Micah Ortuzar, Rodrigo Carmi, Juan Dixon and Luis Morán, "Voltage Source Active Power Filter, Based on Multi-Stage Converter and Ultra capacitor DC-Link", IEEE Industrial Electronics Conference, IECON'2003, Roanoke, Virginia, USA, 2-6 November, 2003.

[3] Juan W. Dixon, Micah Ortúzar and Felipe Ríos, "Traction Drive System for Electric Vehicles, Using Multilevel Converters", The 19th International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium, Bexco, Busan, Korea. 19-23 October 2002.

[4] M. Khair Allah , Study of a new model and a new three-phase multilevel inverter topology has calculated switching, University of Versailles-Saint Quentin Yelines, 2008.

[5] Y. Sahali and M. K. Fellah "Selective Harmonic Eliminated Pulse-Width Modulation Technique (SHE PWM) applied to Three-level Inverter Converter", Rio de Janeiro, Brazil, 9-11 June 2003.

[6] H. Camblong, Electronic equipment for the effective integration of renewals in electricity networks, Lecturer and group leader of Ener-GEA-estia Lipsiprojet Aquitaine, 2007.

[7] K. Benmansour ,"Realization of a test bed for control and observation of multicultural converters approaches series hybrid", Thesis, University Cergy potoise, 2009.

[8] C. Gombert "Real-time simulation of power electronics devices dedicated to Electric Power Networks", Thesis Institute National Polytechnic of Grenoble, 2005.

[9] A. Taleb "By the strategy of elimination of harmonics of an asymmetric multilevel inverter cascade structure",,Acta Electrotechnics , vol. 49 ,N0 4, 2008.

[10]C. Fahrni , "Principle Power converters for multilevel integrated storage Application to particle accelerators", Federal college Polytechnic of Lausanne, PhD Science, May 2008.

[11]Peng. Li,"Formalism for the Supervision of Hybrid Systems Multi-Source Distributed Energy Generation: Application to Manage a Micro Network", PhD, Lille Central College, June, 2009.

[12]A. Muthuramalingam, M. Balaji and S. Himavathi "Selective Harmonic Elimination Modulation Method For Multilevel Inverters ", Pondicherry Engineering College Proceedings of India International Conference on Power Electronics 2006.