International Journal on Applications in Engineering and Technology
Volume 1: Issue 3: March 2015, pp 9-17. www.aetsjournal.com

# GRID INTEGRATION OF PERMANENT MAGNET SYNCHRONOUS GENERATOR WIND ENERGY USING MATRIX CONVERTER

[1]Mr.K.Jayaram,[2]Mr.M.Vadivel

[1,2]Department of Electrical and Electronics Engineering

1,2 SBM college of engineering and Technology Dindigul-624005,TamilNadu,India

***Abstract* - The Renewable energy sources, which have been expected to be a promising alternative energy source, can bring new challenges when it is connected to the power grid. However, the generated power from renewable energy source is always fluctuating due to environmental condition. In the same way Wind power injection into an electric grid affects the power quality due to the fluctuation nature of the wind and the comparatively new types of its generators. This paper introduces, on one hand, a Multilevel matrix converter system as an alternative to the conventional AC–AC converter configuration for the WECS and the optimized doubly-fed induction generator (DFIG), the Multilevel Matrix converter and the fly wheel energy storage system (FESS).**

***Keywords*—Power Quality, Wind Generating System(WGS), Two-level converter ,multi level converter, BESS, IEC standard.**

## I.INTRODUCTION

Recently, energy resource and environment problems have attracted much attention all over the world. The research on renewable energy resources without pollution pressure is very essential. Wind energy is such a kind of renewable energy resources [1~4]. With the development of power electronics, variable-speed generation mode which can realize maximum power point tracking (MPPT) [2~5] has became the mainstream. Due to the decreased cost of magnetic materials and improved performance of magnetic material characteristic, permanent magnet is used to replace the field winding of synchronous motor The application of permanent magnet synchronous generator for wind power generation has become a research hotspot .Usually, the power electronics devices applied in WECS (wind energy conversion system) include the converters based converter , known as –the green frequency converter has lots of advantages such as bidirectional energy flow, sinusoidal input and output current, as well as no large energy storage components It is an alternative which has a chance to replace active front-end converter in the near future. Especially, the matrix converter's derivative topology—two stage matrix converter which has almost the same function with conventional matrix converter and moreover has the possibility to simplify its topology according to its specific application, reduce its cost and improve its reliability [10].In the past decades, many attempts have been made to apply matrix converter to WECS. Ref [12] applied matrix converter to WECS based on doubly-fed induction generator. The matrix converter just replaced the active front-end converter without considering the special issues related with matrix converter. Ref [13] made full use of the function of frequency conversion of matrix converter, and much effort was paid to research on modulation strategy. Some other works [14] are almost similar to ref [12] without too much improvement.

## II. POWER CONVERTER TOPOLOGIES FOR WIND TURBINES

Basically two power converter topologies with full controllability of the generated voltage on the grid side are used currently in the wind turbine systems. These power converters are related with Type C and Type D wind turbine concepts.

### *A. Bidirectional back-to-back two-level power converter*

This topology is state-of-the-art especially in large DFIG based wind turbines [15]. The back-to-back PWM-VSI is a bi-directional power converter consisting of two conventional PWM-VSCs. The topology is shown in Fig. 1.

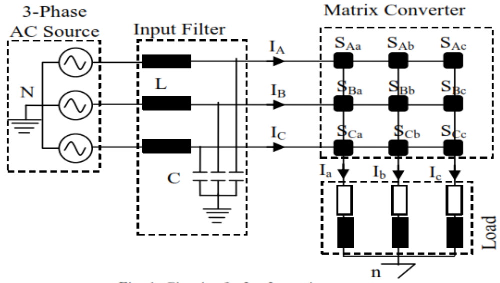



Fig. 1. Circuit of a 3 x 3 matrix converter

Each switch is characterized by a switching function, defined as follows and can connect or disconnect phase *K* of the input stage to phase *j* of the load.

$$S_{Kj}(t) = \begin{cases} 0 & \text{Switch, } S_{Kj} \text{ is open} \\ 1 & \text{Switch, } S_{Kj} \text{ is closed} \end{cases}$$
$$K = \{A, B, C\},\ j = \{a, b, c\}$$

Control of the matrix converter must comply with the following basic two rules. Firstly, any two input terminals should never be connected to the same output line to prevent short-circuit, because the MC is fed by a voltage source. The other is that, an output phase must never be open-circuited, owing to the absence of a path for the inductive load current which leads to the over-voltages. The above two constraints can be expressed by (2).

$$\begin{aligned} m_{Aa}(t) + m_{Ba}(t) + m_{Ca}(t) = 1 \\ m_{Ab}(t) + m_{Bb}(t) + m_{Cb}(t) = 1 \\ m_{Ac}(t) + m_{Bc}(t) + m_{Cc}(t) = 1 \end{aligned}$$

In this paper, $V_{sK}$ are the source voltages, $i_{sK}$ are the source currents, $v_{jn}$ are the load voltages with respect to the neutral point n of the star connected load, and $i_j$ are the load currents. Also, other variables have been defined to be used as a basis of the modulation and control strategies: $v_{KN}$ are the MC input voltages, $i_K$ are the MC input currents, and $v_{jN}$ are the load voltages with respect to the neutral point *N* of the grid.

.

If $t_{Kj}$ is defined as the time during switch $S_{Kj}$ is on and $T_s$ the switching period, duty cycle of switch $S_{Kj}$ can be given as follows.

$$m_{Kj}(t) = \frac{t_{Kj}}{T_s}$$

So, modulation matrix can be given as in (4).

$$M(t) = \begin{bmatrix} m_{Aa}(t) & m_{Ba}(t) & m_{Ca}(t) \\ m_{Ab}(t) & m_{Bb}(t) & m_{Cb}(t) \\ m_{Ac}(t) & m_{Bc}(t) & m_{Cc}(t) \end{bmatrix}$$

Under ideal input voltage conditions, the three-phase sinusoidal input voltages of the MC will be as follows,

$$[v_{sK}(t)] = V_{sKm} \begin{bmatrix} \cos(\omega_i t) \\ \cos(\omega_i t + 2\pi/3) \\ \cos(\omega_i t + 4\pi/3) \end{bmatrix}$$

In accordance with this, each output phase voltages with respect to the neutral point N of the grid can be expressed by

$$[v_{jN}(t)] = [M(t)][v_{KN}(t)]$$

In the same way, the input currents are also shown by the

$$[i_K(t)] = [M(t)]^T [i_j(t)]$$

Where, $[M(t)]^T$ is the transpose matrix of $[M(t)]$.

The amplitude of the output voltage is limited to 50 percent of the input voltage in the initial approach of Venturini Modulation method. To obtain a maximum voltage transfer ratio, third harmonics of the input frequencies are added to the target output phase voltages and third harmonics of the output frequencies are subtracted from it as given in (8).

$$[v_{jN}(t)] = qV_{KNm} \begin{bmatrix} \cos(\omega_o t) - \frac{1}{6}\cos(3\omega_o t) + \frac{1}{2\sqrt{3}}\cos(3\omega_i t) \\ \cos(\omega_o t + \frac{2\pi}{3}) - \frac{1}{6}\cos(3\omega_o t) + \frac{1}{2\sqrt{3}}\cos(3\omega_i t) \\ \cos(\omega_o t + \frac{4\pi}{3}) - \frac{1}{6}\cos(3\omega_o t) + \frac{1}{2\sqrt{3}}\cos(3\omega_i t) \end{bmatrix}$$

Where, q is the voltage gain or voltage transfer ratio. By this way, a voltage transfer ratio of 0.866 which is maximum value can be obtained. The third-harmonic injection of the input and output frequencies into the target output voltages has no effect on the output line-to-line voltages [4, 6]. The target output voltage equals the average output voltage during each switching sequence.

To achieve full control of the grid current, the DC- link voltage must be boosted to a level higher than the amplitude of the grid line-line voltage. The power flow of the grid side converter is controlled in order to keep the DC-link voltage constant, while the control of the generator side is set to suit the magnetization demand and the reference speed. The control of the back-to- back PWM-VSC in the doubly-fed induction generator based wind turbine is described in many articles. Some wind turbine manufacturers (e.g. Siemens Wind Power) have this topology for full - scale power converter wind turbines with squirrel-cage induction generator. The PWM-VSC is the most frequently used three- phase frequency converter. As a consequence of this, the knowledge available in the field is extensive and well established.Furthermore,manymanufacturers produce components especially designed for use in this type of converter (e.g., a transistor-pack comprising six bridge coupled transistors and anti paralleled diodes). Therefore, the component costs can be low compared to converters requiring components designed for a niche production. A technical advantage of the PWM-VSC is the capacitor decoupling between the grid inverter and the generator inverter. Besides affording some protection this decoupling offers separate control of the two inverters, allowing compensation of asymmetry both on the generator side and on the grid side, independently. The inclusion of a boost inductance in the DC-link circuit increases the component count, but a positive effect is that the boost inductance reduces the demands on the performance of the grid side harmonic filter, and offers some protection of the converter ag ainst abnormal conditions on the grid. However some disadvantages of the back-to- back PWM-VSI are reported in literature [3], [19] and [21]. In several papers concerning adjustable speed drives, the presence of theDC-link capacitor is mentioned as a drawback, since:

It is bulky and heavy; - it increases the costs and maybe of most importance; - it reduces the overall lifetime of the system.

Another important drawback of the back-to-back PWM-VSI is the switching losses. Every commutation in both the grid inverter and the generator inverter between the upper and lower DC-linkbranchisassociated with a hard switching and a natural commutation.

Since the back-to-back PWM-VSI consists of two inverters, the switching losses might be even more pronounced. The high switching speed to the grid may also require extra EMI-filters. To prevent high stresses on the generator insulation and to avoid bearing current problems [4] - [7] the voltage gradient may have to be limited by applying an output filter In order to achieve variable speed operation the wind turbines equipped with permanent magnet synchronous generator (PMSG) will require a boost DC-DC converter inserted in the DC-link as shown in Fig. 2 .

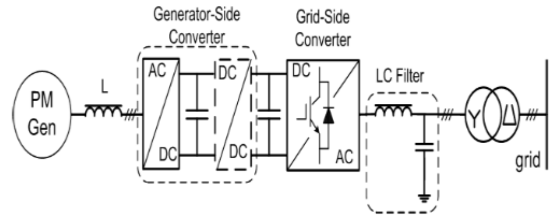



**Fig. 2. Permanent magnet synchronous generator based wind turbine with bidirectional power converter .**

### *B.Unidirectional power converter*

A wound rotor synchronous generator requires only a simple diode bridge rectifier for the generator side converter as shown in Fig. 3.

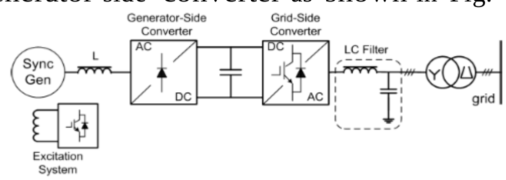



**Fig. 3. Variable speed wind turbine with synchronous generator and full-scale power converter.**

The diode rectifier is the most common used topology in power electronic applications. For a three-phase system it consists of six diodes.

The diode rectifier can only be used in one quadrant, it is simple and it is not possible to control it. It could be used in some applications with a DC-link. The variable speed operation of the wind turbine is achieved by using an extra powerconverter which feed the excitation winding. The grid side converter will offer a decoupled control of the active and reactive power delivered to the grid and also all the grid support features. These wind turbines can have a gearbox or they can be direct-driven .The same topology with an extra DC-DC conversion stage can be used for permanentmagnetsynchronous generators.

## III. MATRIX CONVERTER

The increasing share of wind in power generation will change considerably the dynamic behavior of the power system , and may lead to a reduction of power system frequency regulation capabilities . In addition, network operators have to ensure that consumer power quality is not compromised . Hence, new technical challenges emerge due to the increased wind power penetration, dynamic stability and power quality,implying research of more realistic physical models forwind energy conversion systems (WECSs) . Power-electronic converters have been developed for integrating wind power with the electric grid.The use of power-electronic converters allowfor variable-speed operation of the wind turbine, and enhanced power extraction. Invariable- speed operation, a control method designed to extract maximum power from the wind turbine and provide constant gridvoltage and frequency is required [12].Variable-speed WECSs offer the following advantages: mechanical stress is reduced, torque oscillations are not transmitted to the grid, and below rated wind speed the rotor speed is controlled to achieve maximum aerodynamic efficiency.The variable-speed WECSs are implemented with either Z-source matrix converter is an ac-ac converter that can directly convert an ac power supply voltage into an ac voltage of variable amplitude and frequency without a large energy storage element.In 1980,Venturini and Alesi na presented the first algorithm capable of synthesizing output sinusoidal reference voltages from a balancedthree-phase voltage source connected to the converter input terminals. Recent research on matrix converters has focused mainly on modulation schemes and on ac drive applications. The first study of a single-phase matrix converter was performed by Zuckerberger on a frequency step-up and fundamental voltage step-down converter. The research in [6] - [8] focused on step-up/step down frequency operation with a safe-commutation strategy. Applications of single-phase matrix converters have been described for induction motor drives, radio – frequency induction heating, audio power amplification, and compensation voltage sags and swells [9] - [11]. It has been reported that the use of safe-commutation switches with pulse width modulation (PWM) control can significantly improve the performance of ac-ac converters [12]. However, in the conventional single-phase matrix converter topology, the ac output voltage can not exceed the ac input voltage. Furthermore, it is not possible to turn both bidirectional switches of a single-phase leg on at the same time; otherwise, the current spikes generated by this action will destroy the switches. These limitations can be overcome by using Z-source topology [13]. Research on Z-source converters has focused mainly on dc-ac inverters and ac-ac converters. Recently, the work on Z-source dc-ac inverters has focused on modeling and control, the PWM strategy, applications, and other Z-network topologies. The Z-source ac-ac converters focus on single-phase topologies and three-phase topologies [6]and[13].

In applications where only voltage regulation is needed, the family of single-phase Z-source ac-ac converters proposed has a number of merits, such as providing a larger range of output voltages with the buck–boost mode, reducing inrush, and harmonic current. However, no one has designed a converter based on a Z-source structure and a matrix converter topology that can provide ac-ac power conversion with both a variable output voltage and a step -changed frequency.

## IV. PROPOSED TOPOLOGY

In this paper, Integrated Matrix convertor Topology. The matrix converter is capable of a direct conversion of the generator variable AC frequency into the grid constant AC frequency. Thus, it is an AC-AC converter. A technology review of matrix converters can be seen in ref. [20]. Two distinct advantages arise from this topology, the converter requires no bulky energy storage or DC-link, and control is performed on just one converter [12]. Also, the converter is smaller, lighter and more reliable than conventionalconverters. Because of these characteristics matrix converters are a good alternative for the variable-speed operation of WECSs [21]. One of the major drawbacks of a matrix converter is that eighteen total switches are required, causing an increase in converter cost. Also, industrial wide use of matrix converter is still limited due to certain undesirable characteristics: sensitivity to distortion ininput powersupply due to the lack of reactive component in the power circuit; and sensitivity to the rapidly fluctuating input voltage frequency when used in WECSs [22].

Multilevelconverters are AC-DC-AC converters, well suited for medium and high-power applications [23] 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 efficiencies when compared with the conventional two-level topology [24,25]. A survey of topologies, controls, and applications for multilevel inverters can be seen in ref. [26].

Multilevel converters are, however, limited by the following drawbacks: voltage unbalances, high component count, and increased control complexity [24]. A critical issue in three - level converters is the design of the DC –link capacitors. Thus, special attention should be paid to the unbalance in the voltage of the capacitors for the three- level converters, which may produce a malfunction of the control. One possible design of the DC-link is given in ref.

[25].Reference[26] proposes a control methodology that achieves the regulation of torsional dynamics and the DC-link capacitor voltage without involving the grid-side converter controls, eliminating the influence of those dynamics on the grid.

Several papers have been issued on matrix, two-level or multilevel power converters, bu t mainly using simplified models to describe the WECS or the control strategies themselves. However, the increased wind power penetration, as nowadaysoccurs for instance in Portugal, requires new models and system operation tools.

As a new contribution to earlier studies, a more realistic modeling of WECS with different power converter topologies is presented in this study, combined with a complex control strategy, and comprehensive performance simulation studies are carried out in order to adequately assert the system performance.

This paper is organized the integrated modeling of the WECS with different power converter topologies: matrix, two-level and multilevel. The next Section presents the control strategy: pulse width modulation (PWM) by space vector modulation (SVM) associated with sliding mode is used for controlling the converters, and power factor control is introduced Research on Z-source converters has focused mainly on dc-ac inverters and ac-ac converters. Recently, the work on Z-source dc-ac inverters has focused on modeling and control, the PWM strategy, applications, and other Z-network topologies. The Z-source ac-ac converters focus on single-phase topologies and three-phase topologies [6]and[13].

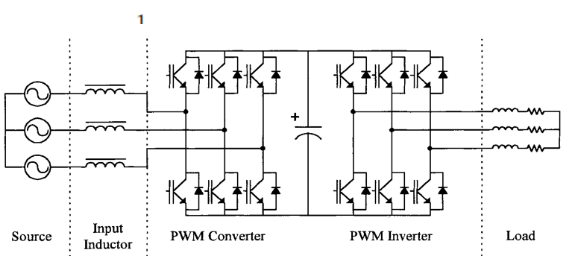



Fig5. The simulated WECS with Conventional AC-AC converter.

$$\lambda_{opt} = 7.057 \quad (5)$$

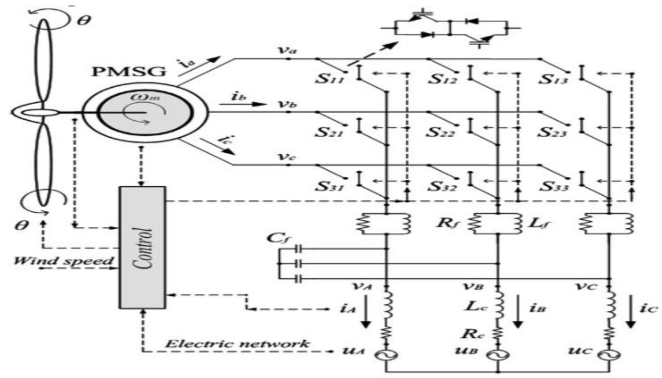



Fig 6. The simulated WECS with matrix converter.

The mechanical power of the wind turbine is given by:

$$P_t = \frac{1}{2}\rho A u^3 c_p$$

Pt is the mechanical power of the wind turbine, r is the air density, A is the area covered by the rotor blades, u is the wind speed upstream of the rotor, and cp is the power coefficient.

The power coefficient cp is a function of the pitch angle q of rotor blades and of the tip speed ratio l, which is the ratio between blade tip speed and wind speed upstream of the rotor. The computation of the power coefficient requires the use of blade element theory and the knowledge of blade geometry. These complex issues are normally empirically considered. In this paper, the numerical approximation developed is followed, where the power coefficient is given by:

$$c_p = 0.73\left(\frac{151}{\lambda_i} - 0.58\,\theta - 0.002\,\theta^{2.14} - 13.2\right) e^{-18.4/\lambda_i}$$

$$\lambda_i = \frac{1}{\dfrac{1}{(\lambda - 0.02\,\theta)} - \dfrac{0.003}{(\theta^3 + 1)}}$$

The mechanical power is given by substituting (2) and (3) into (1). From (2), the global maximum for the power coefficient is at null pitch angle, and it is equal to:

$$c_{p_{max}} = 0.4412$$

corresponding to an optimal tip speed ratio at null pitch angle, given by:

$$\lambda_{opt} = 7.057$$

A blade active pitch angle controller must be included in a variable-speed WECS [18], employing pitch control when reducing the angle of attack: increasing the blade pitch angle reduces the capture of wind energy.

***A -Two-level converter***

The two-level converter is an AC-DC-AC converter, with six unidirectional commanded IGBTs $S_{ik}$ used as a rectifier, and with the same number of unidirectional commanded IGBTs used as an inverter. The rectifier is connected between the PMSG and a capacitor bank. The inverter is connected between this capacitor bank and a first order filter, which in turn is connected to an electric network. The groups of two IGBTs linked to the same phase constitute a leg k of the converter. A three-phase active symmetrical circuit in series models the electric network.The configuration of the simulated WECS with two-level converter is shown in Fig. 7.For the two-level converter modeling it is assumed that: (1) the IGBTs are ideal and unidirectional, and they will never be subject to inverse voltages, being this situation

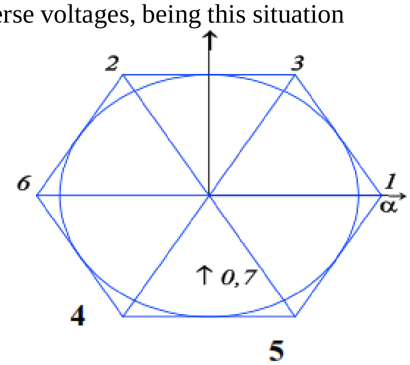



**Fig. 9. Output voltage vectors for the two-level converter.**

For the two-level converter modeling it is assumed that: (1) the IGBTs are ideal and unidirectional, and they will never be subject to inverse voltages, being this situation guaranteed by the arrangement of connection in anti-parallel diodes; (2) the diodes are ideal: in conduction it is null the voltage between its terminals, and in blockade it is null the current that passes through it; (3) the voltage in the exit of the rectifier should always be $v_{dc} > 0$; (4) each leg k of the converter should always have one IGBT on a conduction state. For the switching function of each IGBT, the switching variable $\gamma_k$ is used to identify the state of the IGBT i in the leg k of the converter. The index i with i=1,2; identifies the IGBT. The index k with k=1; 2; 3 identifies a leg for the rectifier and k=f4; 5; 6 identifies the inverter one. The two conditions [11] for the switching variable of each leg k are given by:

$$\gamma_k = \begin{cases} 1, & (S_{1k} = 1 \text{ and } S_{2k} = 0) \\ 0, & (S_{1k} = 0 \text{ and } S_{2k} = 1) \end{cases} \quad k \in \{1, \ldots, 6\}$$

The topological restriction for the leg k is given by:

$$\sum_{i=1}^{2} S_{ik} = 1 \quad k \in \{1, \ldots, 6\}$$

$$\sum_{i=1}^{2} S_{ik} = 1 \quad k \in \{1, \ldots, 6\}$$

Hence, each switching variable depends on the conduction and blockade states of the IGBTs. The phase currents injected in the electric network are modeled by the state equation:

$$\frac{di_k}{dt} = \frac{1}{(L_c + L_f)}(u_{sk} - R_c i_k - u_k) \quad k = \{4, 5, 6\}$$

The Capacitor voltage $V_{dc}$ is given by

$$\frac{dv_{dc}}{dt} = \frac{1}{C}\left( \sum_{k=1}^{3} \gamma_k i_k - \sum_{k=4}^{6} \gamma_k i_k \right)$$

Hence Two level converter is modeled

## V. SIMULATION RESULTS

Controllers used in the converters are PI controllers. PWM by SVM associated with sliding mode control is used for controlling the converters. The sliding mode control strategy presents attractive features such as robustness to parametric uncertainties of the turbine and the generator as well as to electric grid disturbances .Sliding mode control is particularly interesting in systems with variable structure,such as switching power converters, guaranteeing the choice of the most appropriate space vectors. The aim is to let the system slide along a prede - changing the system structure. The choice of the wind turbines is dependent on the prospective site where the wind turbine is located. The prospective site is an important issue that should be considered for the success of the implementation. The wind speed highly influences the mechanical power acquired by a WECS. Even a small variation in the absolute value of the wind speed may result in a significant change on the mechanical power, due to the cubic relationship between velocity and power. Hence, the behavior of the wind at a prospective site should be properly analyzed and understood. Realizing the nature of wind is important for an appropriate design, which allows adequate tuning with the wind characteristics expected at this prospective site .The identification of the wind variability at a site is often achieved by grouping the data, using a frequency distribution probability function, usually a Weibull or a Rayleigh distribution. Suppose a variable-speed horizontal axis WECS is installed, with three blades, upwind at a site with the wind data given by the frequency distribution shown in Fig. 8.The average wind speed is vm ¼ 8:2 m=s for the distribution given in Fig. 8. The wind turbine will be in operation most of the time for wind speeds ranging between 5 m/s and 10 m/s. The rotor speed varies smoothly during the accumulation of kinetic energy in the rotor [12]. When rated wind turbine speed is reached, if a sudden wind gust appears the rotor speed is allowed to increase until 10%. This is due to the fact that the pitch control response is not instantaneous. Hence, it cannot respond in due time to sudden wind gusts.The stored kinetic energy can be employed to further smooth fluctuations in the available wind power . The wind turbine has rated wind speed of 13 m/s, maintaining energy conversion for wind speeds until 25 m/s. The wind turbine works with tip speeds between 25.65 m/s, for the cut-in wind speed of 2.5 m/s, and 81.04 m/s, between the wind speed of 16 m/s and the cut-out wind speed of 25 m/s.

Hence, the power coefficient is designed as a function of the wind speed, as shown in Fig. 11.

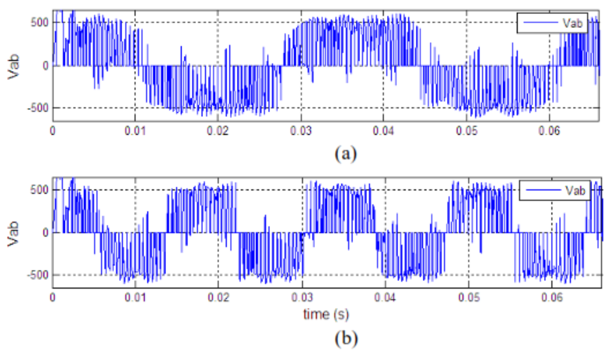
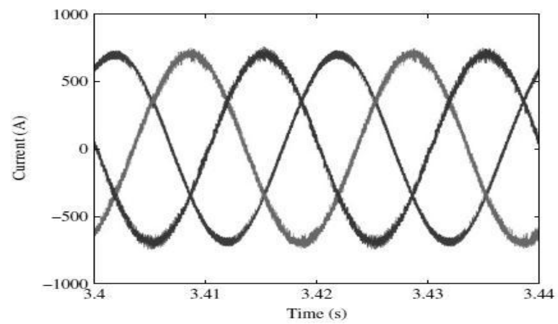



Fig. 5. Output line-to-line voltage: (a) in 30 Hz (b) in 60 Hz



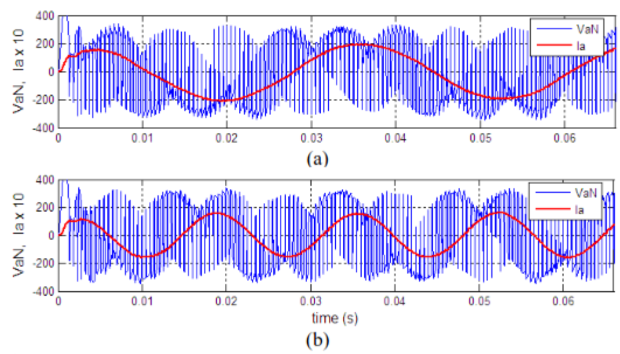




Fig. 6. Output phase voltage with respect to star point of source and output current: (a) in 30 Hz (b) in 60 Hz

The power coefficient increases until 8 m/s, and between 8 m/s and 10 m/s the power coefficient is constant at the maximum power coefficient.

At wind speeds greater than 10 m/s the power coefficient is decreased and at wind speeds greater than 13 m/s the power is maintained at its rated value.The mathematical models for the WECS with the matrix, two- level and multilevel power converter topologies were implemented in Matlab/Simulink. The WECS simulated in this case study has a rated electric power of 900 kW. A wind speed upstream of the rotor given by a ramp increase is considered in the simulation, taking 2.5 s between the speeds of 4.5 m/s and 25 m/s. Also, a time horizon of 3.5 s is considered. The switching frequency for the IGBTs is 5 kHz. Fig. 12 shows blades pitch angle variation with the wind speed. Thus, the pitch angle varies with the wind speed, between 13 m/s and 25 m/s, in order to avoid over-rated power excursion of the WECS. But, between 16 m/s and 25 m/s the pitch angle varies in order not only to avoid over-rated powerexcursion, but also to maintain the tip speed at 81.04 m/s.

The mechanical power of the wind turbine Pt , the electric power of the generator Pg, and the difference between these two powers,The next figures show simulation results for the WECS with the two-level converter. The capacitor voltage $v_{dc}$ is shown in Fig. 1

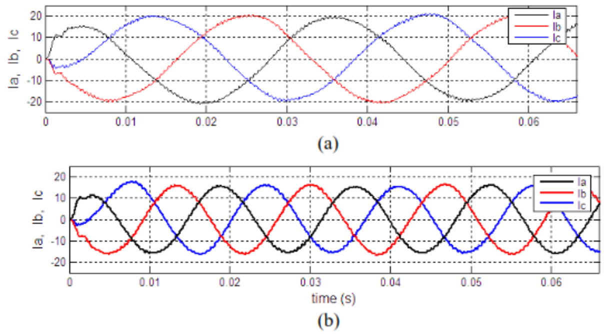



Fig. 8. Three phase output current: (a) in 30 Hz (b) in 60 Hz

The instantaneous three-phase currents injected in the grid are shown in Fig. 14.

The next figures show simulation results for the WECS with the multilevel converter. The capacitor voltage $v_{dc}$ is the sum of the voltages $v_{C1}$ and $v_{C2}$, respectively at the capacitor banks $C_1$ and $C_2$. These voltages are shown in Fig. 15.The instantaneous three-phase currents injected in the grid . Fig. 15 shows that the capacitors voltages $v_{C1}$ and $v_{C2}$ are nearly equal, and approximately half of the $v_{dc}$ voltage, which is of the utmost importance for the multilevel converter since an unbalance may result in a malfunction on the control. Also, it is important to notice that the voltages across the IGBTs of the two Level converter

## VI. .Conclusion

A contribution to improvement of the performances for wind energy conversions systems of Integrated multilevel converter has been presented in this paper. The first part is dedicated to the analysis, modeling and simulation of the considered system.. The control strategy is based on PWM by SVM associated with sliding mode control, and power factor control is introduced at the output of the power converters. Although more complex, this control strategy is justified for more realistic results.The two-mass model for the rotor is relevant in oscillatory studies for the prediction of the WECS behavior. Simulation results have shown that the best performance of the WECS, regarding power quality, is achieved with the use of multilevel converters.

## REFERENCES

[1] A New Variable-Speed Wind Energy Conversion System Using Permanent-Magnet Synchronous Generator and Z-Source Inverter Seyed Mohammad Dehghan, Student Member, IEEE, Mustafa Mohamadian, Member, IEEE, and Ali Yazdian Varjani, Member, IEEE

[2] N. Yamamura, M. Ishida, and T. Hori, ―A simple wind power generating system with permanent magnet type synchronous generator,‖ in Proc.IEEE Int. Conf. Power Electron. Drive Syst., 1999, vol. 2, pp. 849–854.

[3] T. Tafticht, K. Agbossou, A. Cheriti, and M. L. Doumbia, ―Output power maximization of a permanent magnet synchronous generator based standalone wind turbine,‖ in Proc. IEEE ISIE 2006, Montreal, QC, Canada,pp. 2412–2416.

[4] A. M. Knight and G. E. Peters, ―Simple wind energy controller for an expanded operating range,‖ IEEE Trans. Energy Convers., vol. 20, no. 2,pp. 459–466, Jun. 2005.

**[5]** permanent magnet generators applied to variable-speed wind-energy systems connected to the grid,‖ IEEE Trans. Energy Convers., vol. 21, no. 1, pp. 130–135, Mar. 2006.

[6] M. G. B. Venturini and A. Alesina, ―Solid state power conversion: A Fourier analysis approach to generalized transformer synthesis,‖ *IEEE Trans. Circuits Syst.*, vol. CAS-28, pp. 319–330, Apr. 1981.

[7] D. G. Holmes, ―The general relationship between regular-sampled pulse width modulation and space vector modulation for hard switched converters,‖ in *Conf. Rec. 1992 IEEE-IAS Annu. Meeting*, pp. 1002–1009.

[8] L. Huber and D. Borojevic, ―Space vector modulated three-phase to three-phase matrix converter with input power factor correction,‖ *IEEE Trans. Ind. Applicat.*, vol. 31, pp. 1234–1246, Nov./Dec. 1995.

[9] H. W. van der Broek, H. C. Skudelny, and G. V. Stanke, ―Analysis and realization of PWM based on voltage space vectors,‖ *IEEE Trans. Ind.Applicat.*, vol. 24, pp. 142–150, Jan./Feb. 1988.

[10] Melício R, Mendes VMF, Catalão JPS. Modeling and simulation of a wind energy system: matrix versus

***u***
***l***
***t***
***i***
***l***
***e***