Journal of Engineering and Computer Sciences
Qassim University, Vol. 7, No. 1, pp. 23-41 (January 2014/Safar 1435H)

Enhancing the Performance of Wind-Energy-Driven Double-Fed Induction Generators

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(Received 14/4/2014; Accepted for publication 30/5/2014)

ABSTRACT. The utilization of wind energy driven induction generators finds nowadays great interest. The present paper aimed at improving the performance of the induction generators at the different expected wind speeds employing control techniques from the rotor side. A set of two converters in the rotor circuit has been adjusted to inject a voltage such that the generator runs at the speed which allows the wind turbine to extract the maximum power from the wind, and at the same time to deliver the electrical power to the network at unity power factor. The double-fed induction generator has been modelled at steady-state conditions using frequency domain equivalent circuit. The performance characteristics of both double-fed induction generator (DFIG) and single-fed induction generator (SFIG) have been computed. The computed performance characteristics have revealed that the DFIG has superior performance characteristics as compared with the SFIG. The output active power of the generator has been clearly increased by double-feeding especially at wind speeds far from the base speed. Also, the DFIG nearly does not consume reactive power when compared with SFIG. Although the output power of the generator is clearly increased by doubly feeding it, the stator and rotor currents still within their rated values.

Keywords: Wind Energy, Double-fed Induction Generator, Optimization

1. Introduction

The utilization of wind energy is very important and finds nowadays great interest. This interest has become vital as all the experts have expected the rapid exhaust of the conventional energy resources. Therefore, generation of electrical energy from the renewable wind energy has found increasing applications.

Use of wind-turbines as prime movers has the problem of being of variable and unexpected velocities. As the frequency of the generated voltage of the synchronous generators is tied to the prime mover speed there is a need to other generator types or unconventional solutions. Use of induction generators may solve the problem of variable speed turbines [1-5].

Many researches concerning the analysis of the performance of grid-connected induction generator with solid state control has been performed. Abdel-halim et al [6-14] presented analysis of the performance of induction generators connected to the network via forced-commutated, naturally-commutated and chopping ac voltage controllers. Complete electrical performance characteristics (active power, power factor, harmonic contents, efficiency, e.t.c) have been included. Other authors [15-20] investigated the performance of the doubly-fed induction generators. Holdworth et al [17] have carried out a comparison between fixed-speed induction- generators (FSIG) and variable speed doubly-fed induction generators (DFIG). They showed that the FSIG during short circuits induces voltage sags at the terminal **busbars** which may lead eventually to voltage instability, while the DFIG improves the terminal bus voltage profiles thus increasing the stability margins. Fernandez et al [18] have developed a new way of aggregation of DFIGs under different incoming winds by an equivalent wind turbine to approximate the active and reactive powers of aggregated wind turbines. This technique could be particularly useful in modeling wind farms with high number of wind turbines by reducing the model order, and consequently the simulation time. De Almeida and Lopes [19] have described a control approach to provide a frequency regulation capability integrated into a DFIG active power control loop using the frequency deviation. Such an approach could contribute to increase the system robustness, reducing frequency changes following disturbances. Shaltout, *et. al.*, [20] proposed a simple control strategy of DFIG to facilitate harnessing maximum power extracted from the wind. This strategy is based on controlling the slip power, which is drawn from the rotor circuit and fed to the power grid through a rectifier-inverter set.

The present paper aims at improving the performance of the double-fed induction generators at the different expected wind speeds. A set of two three-phase controlled bridge converters is used in the rotor side to enable connecting the rotor-side to the grid. A control technique is employed to adjust the injected voltage in the rotor. It aims to maximize the extracted wind energy, to improve the performance characteristics of the induction generators, and to enhance the quality of the generated power. The converters in the rotor circuit will be adjusted to inject a voltage such that the generator runs at the speed which allows the wind turbine to extract the maximum power from the wind, and at the same time to deliver the electrical power to the network at unity power factor. The paper presents complete modelling of the double fed generator, computes the performance characteristics, and compares the characteristics with those of the single-fed induction generator.

2. System Description and Control Objectives

2.1 Induction Generator System

The system under study (Fig. 2.1) comprises a variable-speed double-output induction generator. The stator of the generator is directly connected to the grid. The generator slip-ring rotor is connected to the grid through a set of two controlled three-phase bridge converters. This bridge-converter set works either as rectifier-inverter set which rectifies the rotor-frequency slip-ring power and feeds it to the grid, or it works as inverter-rectifier set which rectifies the grid ac power and feeds it as slip-frequency power to the rotor.

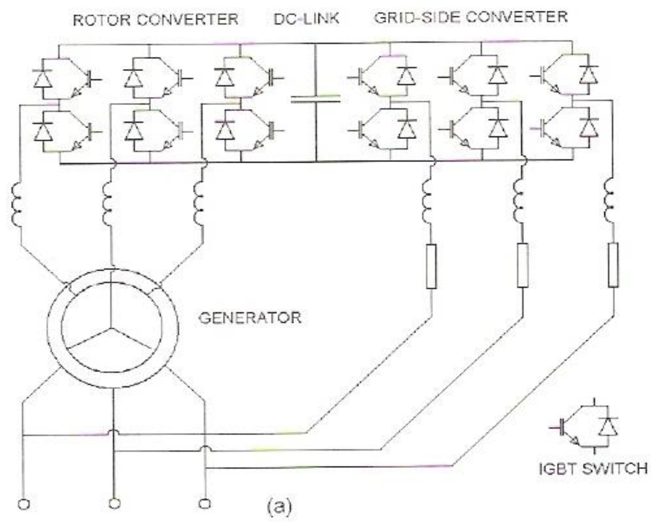

Fig. (2.1). Schematic diagram of the generator layout

2.2 Wind Energy and Wind Turbines

Wind turbines are mechanical devices specifically designed to convert part of the kinetic energy of the wind into useful mechanical energy. Several designs have been devised throughout the times. Most of them comprise a rotor that turns round propelled by lift or drag forces, which result from its interaction with the wind.

Depending on the position of the rotor axis, wind turbines are classified into vertical-axis and horizontal-axis ones (Fig. 2.2) [21].

Nowadays, almost all commercial wind turbines connected to grid have horizontal-axis two-bladed or three-bladed rotors. The rotor is located at the top of a tower where the winds have more energy and are less turbulent. The tower also holds up a nacelle. The gearbox and the generator are assembled inside. There is also a yaw mechanism that turns the rotor and nacelle. In normal operation, the rotor is yawed to face the wind in order to capture as much energy as possible. Although it may be very simple in low power applications, the yaw system is likely one of the more complicated devices in high power wind turbines. Finally, the power electronics are arranged at ground level.

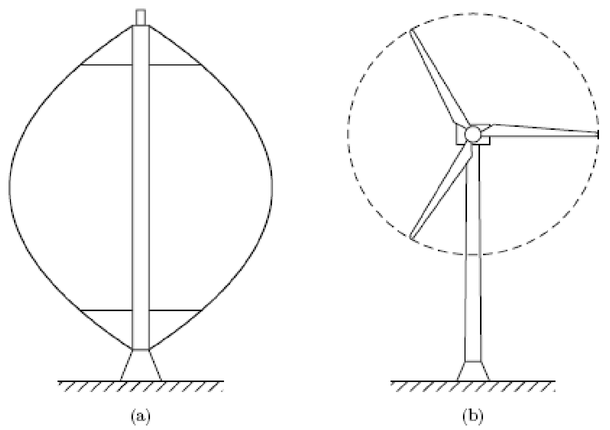

Fig. (2.2). (a) Vertical-axis and (b) horizontal-axis wind turbines

Commonly, thrust force, torque and power are expressed in terms of non-dimensional thrust (C_T), torque (C_Q) and power (C_P) coefficients as follows [22,23]

$$F_T = \frac{1}{2}\rho\pi R^2 C_T(\lambda,\beta)V^2, \tag{2.1}$$

$$T_r = \frac{1}{2}\rho\pi R^3 C_Q(\lambda,\beta)V^2, \tag{2.2}$$

$$P_r = C_P(\lambda,\beta)P_V = \frac{1}{2}\rho\pi R^2 C_P(\lambda,\beta)V^3, \tag{2.3}$$

$$C_Q = C_P/\lambda. \tag{2.4}$$

Note that the three coefficients are written in terms of the pitch angle and the so-called tip-speed-ratio λ defined as

$$\lambda = \frac{\Omega_r R}{V}. \tag{2.5}$$

This parameter is extremely important and, together with β in the case of variable-pitch rotors, determines the operating condition of a wind turbine. Hereafter, we use β to denote pitch angle deviations introduced by pitch actuators in the case of variable-pitch wind turbines. The torque and power coefficients are of special interest for control purposes.

Figure 2.3 [22,23] shows typical variations of C_Q and C_P with the tip-speed ratio and the pitch angle deviation. In the case of fixed-pitch wind turbines, C_Q and C_P vary only with λ, since β = 0 naturally. So, with some abuse of notation we will write C_Q (λ) and C_P (λ) to denote C_Q(λ, 0) and C_P (λ, 0), respectively. Figure 2.4 depicts typical coefficients C_Q (λ) and C_P (λ) of fixed pitch turbines in two-dimensional graphs.

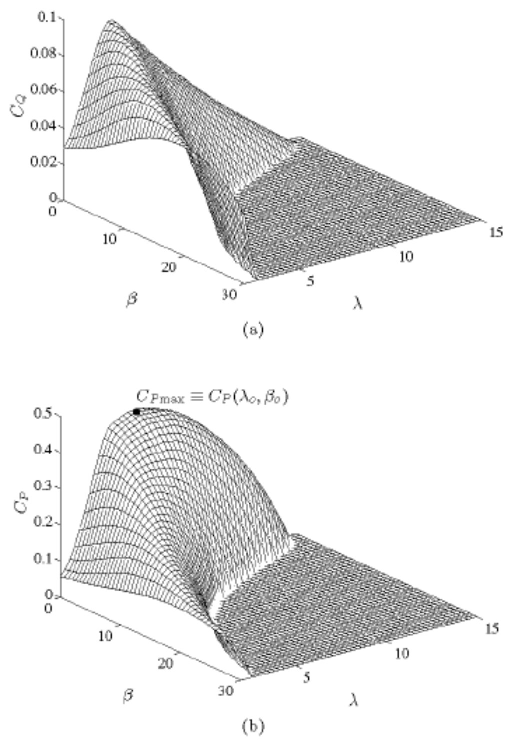

Fig. (2.3). Typical variations of C_Q and C_P for a variable-pitch wind turbine

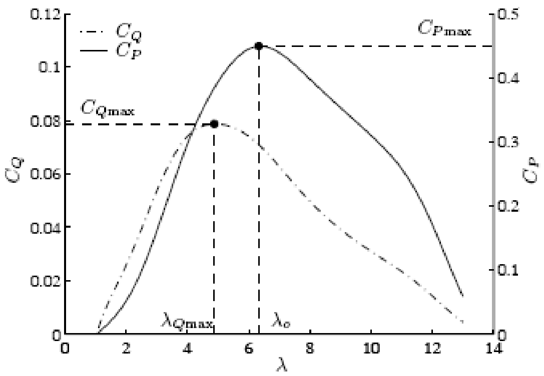

Fig. (2.4). Typical variations of (a) C_Q and (b) C_P for a fixed-pitch wind turbine

2.3. Control Strategy

The objective of the control strategy is to regulate the speed of the generator to force the turbine to operate as follows:

i. Limit the minimum speed of operation (region 1).

ii. Follow the curve of maximum power extraction from variable speed operation with partial load (region 2).

iii. Limit the maximum speed at partial load operation up to the rated generator power (region 3).

At the same time the power factor of the output current is maintained at unity power factor over the entire wind-speed range.

2.3.1 Regions 1 and 3: Minimum and Maximum Speed Control

The main objective is to maintain a constant speed of rotation of the turbine at its minimum value in region 1 and its nominal value in region 3.

Regarding wind energy extraction, maximization is not as high a priority as in region 2, where the speed of the turbine may evolve to maintain a specific speed corresponding to the maximum power coefficient; Cp_{max}. Here, the generator operates at constant speed.

2.3.2 Region 2: Maximum Power Tracking

In this operation region, the objective of the speed control is to follow the path of maximum power extraction. The wind turbine speed is regulated such that the power coefficient is kept at its maximum value at all wind speeds. Thus, the turbine will work at partial load following the maximum power extraction trajectory.

3. Steady-State Modelling

3.1 Electrical Side Modelling

Fig. 3.1 shows an approximate frequency domain circuit model of the 3-phase induction generator when doubly fed [5].

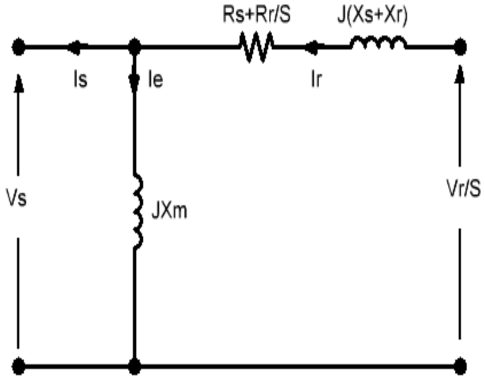

Fig. (3.1). Equivalent circuit of the DFIG

3.2 Mathematical Model

The equations which relate the generator output voltage; $\mathbf{V}_s$, and current; $\mathbf{I}_s$, to the injected voltage; $\mathbf{V}_r$, generator slip; S, and generator equivalent circuit parameters are as follows:

$$\mathbf{V}_s = \mathbf{V}_r/S - \mathbf{I}_r\,[(R_s + R_r/S) + j\,(X_s + X_r)] \quad (3.1)$$

$$\mathbf{I}_e = \mathbf{V}_s\ (-\,j\ 1/X_m) \quad (3.2)$$

$$\mathbf{I}_s = \mathbf{I}_r - \mathbf{I}_e \quad (3.3)$$

The mechanical input power; P_m, is calculated as follows:

$$P_m = (1\text{-}S)\ (-3\ I_r^2\ R_r/S + 3\ V_r/S\ I_r\ P.f_r) \quad (3.4)$$

The generator efficiency; η, is calculated as follows:

$$\eta = P_e/P_m \quad (3.5)$$

where P_e is the output electrical power, and is given by

$$P_e = 3\ V_s\ I_s\ P.f_s - 3\ V_r\ I_r\ P.f_r \quad (3.6)$$

In the previous equations the different phasors are denoted by

$$\mathbf{V}_s = V_s \angle \psi_s$$

$$\mathbf{I}_s = I_s \angle \varphi_s$$

$$\mathbf{V}_r = V_r \angle \psi_r$$

$$\mathbf{I}_r = I_r \angle \varphi_r$$

The stator and rotor power factors, $P.f_s$ and $P.f_r$ are given by

$$P.f_s = \cos(\psi_s - \varphi_s)$$

$$P.f_r = \cos(\psi_r - \varphi_r)$$

3.3- Analysis Methodology

The stator terminal rated voltage; $\mathbf{V}_s$, is taken as a reference. At a certain wind speed, the slip and the input mechanical power are determined according to the mode of operation [5]. At this specific slip, the approximate equivalent circuit (Fig. 3.2) is used to solve for the injected voltage; $\mathbf{V}_r$, as a magnitude and phase angle such that the input mechanical power is that corresponding to the maximum power extracted from the wind, and at the same time the output current; $\mathbf{I}_s$, is forced to have a unity power-factor. This is done by trial and error as follows:

i- $\mathbf{I}_r$ is chosen such that $\mathbf{I}_s$ is in phase with $\mathbf{V}_s$ (the reactive component of $\mathbf{I}_r$ is equal to $\mathbf{I}_e$, while the active component is not defined)

ii- Equation 3.1 is used to calculate $\mathbf{V}_r$,

iii- Equation 3.3 is used to check whether the input mechanical power is as required or not. If not go back to (i).

iv- The iteration continues till a solution is reached.

3.4 Single-Fed Induction Generator Modelling

The normally run induction generator with its stator terminals connected to the supply, and its rotor is short-circuited may be referred to as single-fed induction generator (SFIG). This generator is modelled at steady-state by the usual equivalent circuit of induction machine [5] keeping in mind that the slip is negative (Fig. 3.2).

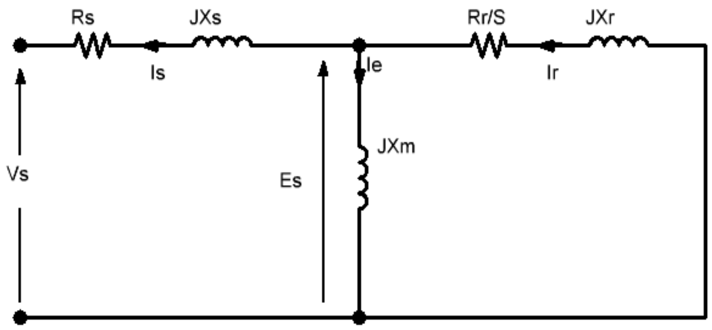

Fig. (3.2). Equivalent circuit of the SFIG.

The output current, active power, reactive power at a specified slip; S, and terminal voltage, V_s can be determined as usual for the ac circuit analysis using the equivalent circuit.

4. Results

The mathematical model given in Section 3 has been applied to an induction generator having the parameters given in Tables 4.1 and 4.2 and coupled to a wind turbine having the parameters given in Table 4.3 [24]. The generator performance characteristics have been determined over the 3 operation regions.

Table (4.1). Main Characteristics of the Generator

Nominal stator active power	2.0 MW
Nominal torque	12732 Nm
Stator voltage	690 V
Stator current	1760 A
Rotor current	1807 A
Nominal speed	1500 rpm
Speed range	900–2000 rpm
Pole pairs	2

Table (4.2). Equivalent Model of the Generator

Magnetizing inductance Lm	2.5 mH
Rotor leakage inductance L_r	0.087 mH
Stator leakage inductance L_s	0.087 mH
Rotor resistance R_r	0.026 ohm
Stator resistance R_s	0.029 ohm

Table (4.3). Turbine Parameters

Type	Horizontal-axis turbine
Radius	42 m
Nominal wind speed	12.5 m/s
Variable speed ratio (minimum–maximum turbine speed)	9–18 rpm
Optimum tip speed ratio	7.2
Maximum power coefficient C_{p_max}	0.44

The DFIG performance characteristics are shown in Fig. 4.1-4.6. To evaluate the performance characteristics of the DFIG, it will be helpful to compare it with the SFIG. The SFIG performance characteristics are determined using the following procedure:

i- The generator is assumed to run near its synchronous speed (1500 rpm) at the base wind speed 6.5 m/s, while the tip-speed ratio; λ, at this condition gives the maximum C_p value of the turbine (0.455).

ii- At other value of the wind speed, keeping in mind that the generator still runs very near to its nominal synchronous speed, the tip-speed ratio is determined.

iii- Using the characteristic of the wind-turbine (Fig. 2.4), C_p is determined, and consequently the mechanical power and torque are determined (Eqns. 2.2 and 2.3)

iv- At this torque the slip, then output current, active power, reactive power and power factor are determined using the equivalent circuit shown in Fig. 3.2.

Following the previous procedure, the extracted power and torque at different wind speeds in case of SFIG are given in Table. 4.4.

Table (4.4). Extracted power and torque

Mechanical torque, Nm	Mechanical power, watts	C_p	λ	Wind-speed, m/s
1017	159659	0.29	10.2	4
1778	279300	0.35	9.1	4.5
2671	419400	0.39	8.19	5
5208	817626	0.44	6.825	6
6109	959217	0.45	6.55	6.25
6969	1094250	0.455	6.3	6.5
7506	1178450	0.44	6.1	6.75
8084	1269208	0.43	5.85	7
11221	1761758	0.4	5.11	8

The performance characteristics of the SFIG are shown in Figs. 4.7 - 4.12. Comparing the performance characteristics of the DFIG with the SFIG reveals the following:

- The output active power of the generator is clearly increased by double-feeding especially at wind speeds far from the base speed. For example, at wind speed of 4 m/s, the total output active power is about 0.27 MW for DFIG while it is about 0.16 MW for SFIG which means an increase of about 68%. At wind speed of 8 m/s, the total output active power is about 2.55 MW while it is about 1.73 for SFIG which means an increase of about 47% (Figs. 4.4 and 4.8)

- The DFIG nearly does not consume reactive power when compared with SFIG. The DFIG consumes from the rotor side a maximum reactive power of about 0.0025 MVAR at low speed. No reactive power is required at the base wind speed (6.5 m/s). At wind speeds higher than the base wind speed, the DFIG delivers reactive power which reaches about 0.0027 MVAR at wind speed of about 8 m/s. On the other hand, the SFIG consumes reactive power ranges from 0.6 MVAR at wind speed of 4 m/s up to 0.98 MVAR at wind speed of 8 m/s (Figs. 4.5 and 4.9).

– Although the output power of the generator is clearly increased by doubly feeding it, the stator and rotor currents still within their rated values (Fig. 4.6 and 4.10)

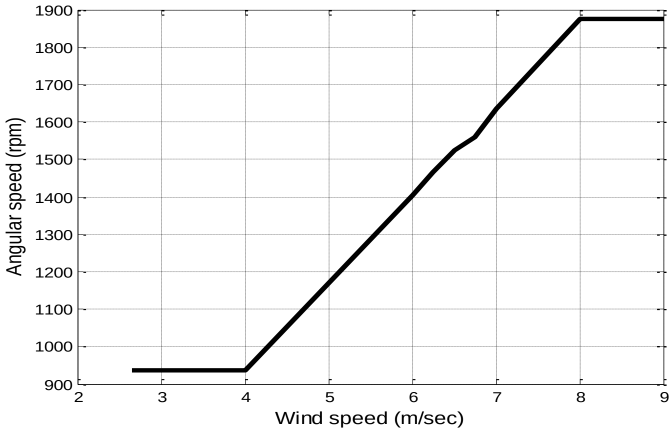

Fig. (4.1). DFIG speed versus wind speed for the 3-operation regions

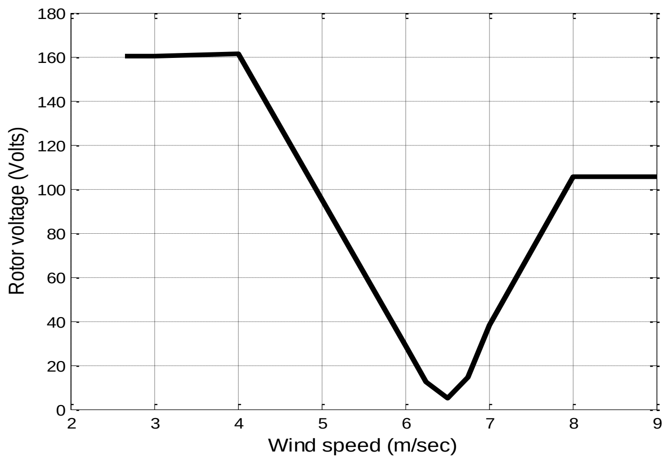

Fig. (4.2). Magnitude of the DFIG rotor voltage versus the wind speed

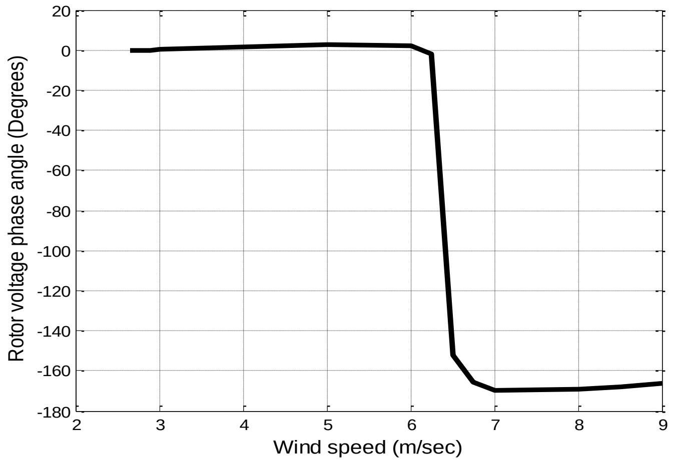

Fig. (4.3). Phase-angle of the DFIG rotor voltage versus the wind speed

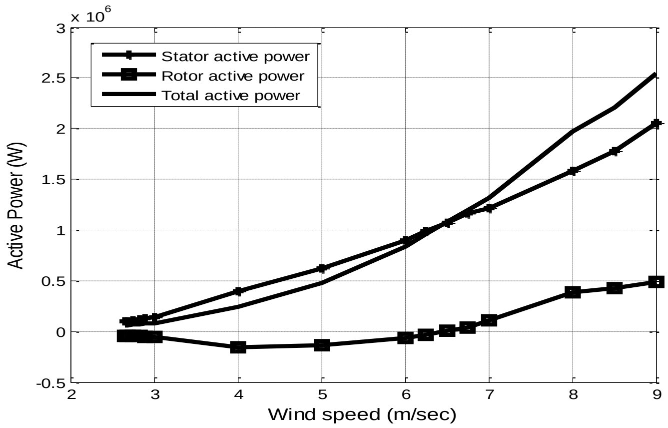

Fig. (4.4). DFIG stator, rotor and total active output power versus the wind speed

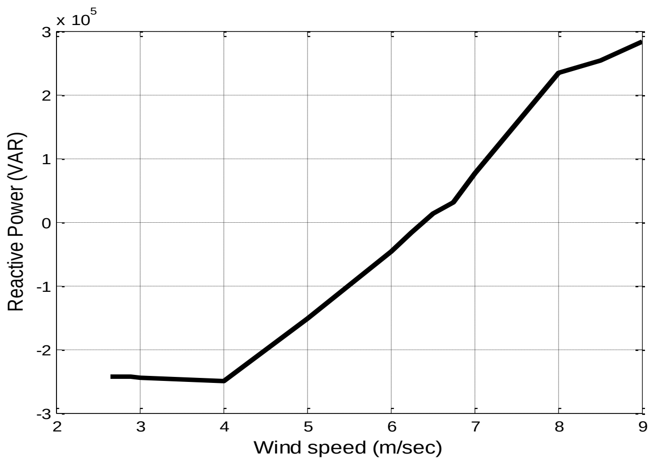

Fig. (4.5). DFIG rotor reactive power versus the wind speed

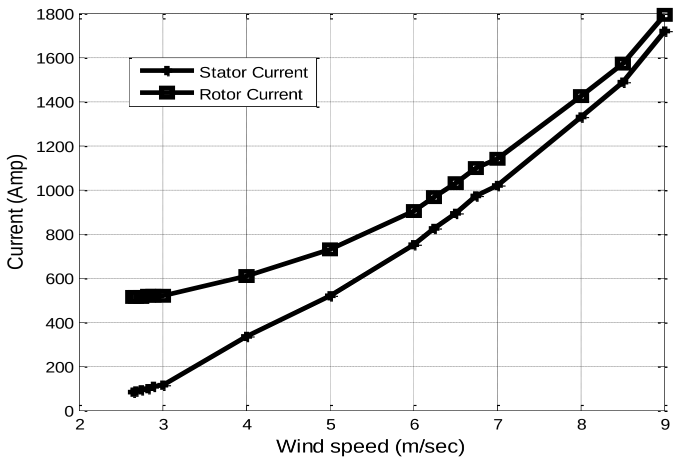

Fig. (4.6). DFIG stator and rotor currents versus the wind speed

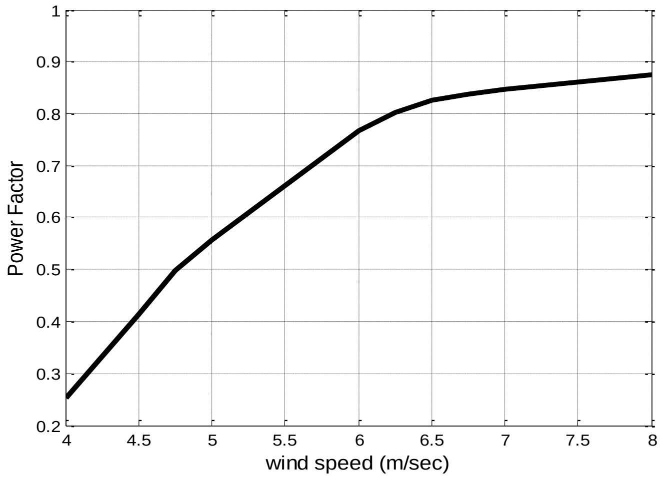

Fig. (4.7). SFIG power factor versus the wind speed

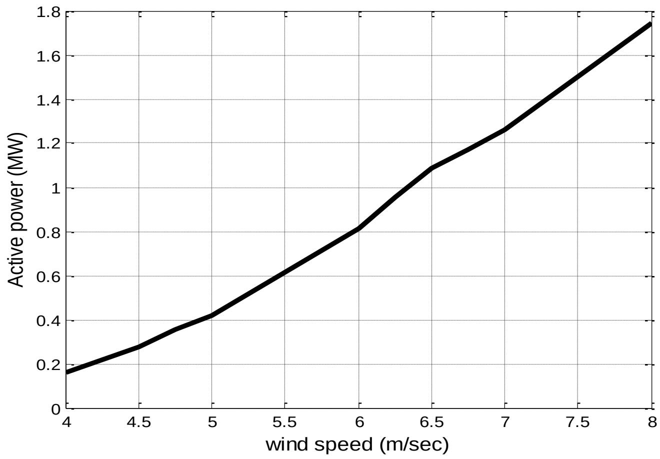

Fig. (4.8). SFIG active output power versus the wind speed

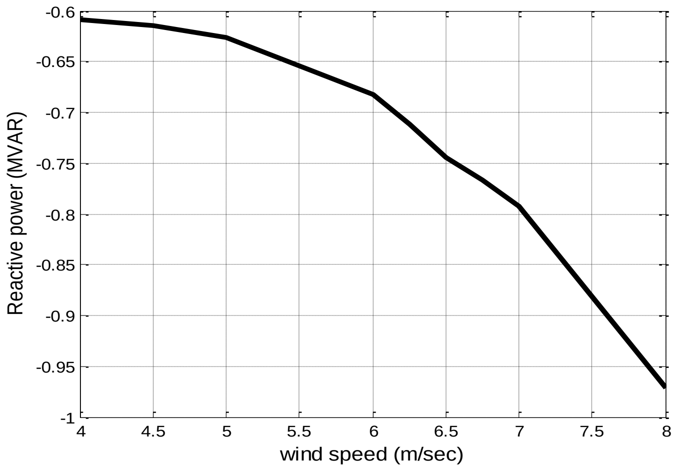

Fig. (4.9). SFIG reactive output power versus the wind speed

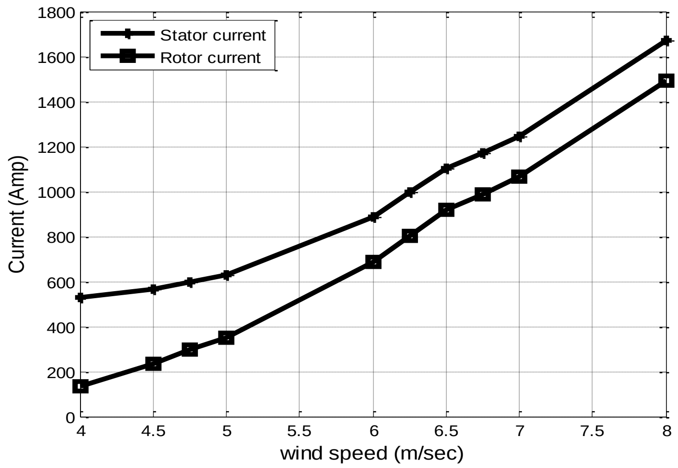

Fig. (4.10). SFIG stator and rotor currents versus the wind speed

5. Conclusion

The present paper aimed at improving the performance of the induction generators at the different expected wind speeds employing control techniques from the rotor side. The paper aimed to maximize the benefit of the wind energy, to improve the performance characteristics of the wind-driven induction generators, and to enhance the quality of the generated power. The inverter in the rotor circuit has been adjusted to inject a voltage such that the generator runs at the speed which allows the wind turbine to extract the maximum power from the wind, and at the same time to deliver the electrical power to the network at unity power factor.

The computed performance characteristics of both the double fed induction generator (DFIG) and the single-fed induction generator (SFIG) has revealed that the control of the induction generator through injecting voltage in its rotor circuit enhances the performance of the generator as compared with the SFIG. The output active power of the generator is clearly increased by double-feeding especially at wind speeds far from the base speed. Also, The DFIG nearly does not consume reactive power when compared with SFIG. The DFIG consumes from the rotor side a very low reactive power at low wind speeds, while no reactive power is required at the base wind speed. At wind speeds higher than the base wind speed, the DFIG delivers reactive power. On the other hand, the SFIG consumes noticeable reactive power. Although the output power of the generator is clearly increased by doubly feeding it, the stator and rotor currents still within their rated values.

6. References

[1] Singh, Bhim “Induction Generators-A prospective”, *Electrical Machines and Power Systems*, Vol. 23, (1995), pp. 163-177.

[2] Subbiah, V. and Geetha, K “Certain Investigations on a Grid Connected Induction Generator with Voltage Control”, *Proc. of the IEEE International Conference on Power Electronics, Drives and Energy Systems*, New Delhi, India. Jan. (1996), pp. 439-444.

[3] McNerney, G, Richardson, R.D., and Holly, W. "The effect of power electronic converter on power fluctuation and harmonic distortion in a WECS", *American society of mechanical engineers, Solar Energy Division*, Vol. 9, (1990), pp. 237-241.

[4] Babu, S.S., Mariappan, G.J., and Palanichamy, S., “A Novel Grid Interface for Wind-Driven Grid-Connected Induction Generators”, *Proc. of IEEE/IAS International Conference on Industrial Automation and Control*, Hyderabad, India, Jan., (1995), pp. 373-376.

[5] Akhmatov, V., "*Induction Generators for Wind Power*", Multi-Science Publishing Co. Ltd., Essex, United Kingdom, 2005.

[6] Abdel-halim, M.A., “Solid-state control of a grid connected induction generator”, *Electric Power Components and Systems Journal*, Vol. 29, No. 2, (2001), pp. 163-178.

[7] Almarshoud, A.F., Abdel-halim, M.A., and Alolah, A.I. “Control of Grid Connected Induction Generator Using Naturally Commutated AC Voltage Controller”, *Proc. of IEEE Canadian Conference on Electrical and*

Computer Engineering (CCECE), Toronto, Canada, May (2001), pp. 839-843.

[8] Almarshoud, A.F., Alolah, A.I., and Abdel-halim, M.A., “Performance of Grid Connected Induction Generator under Naturally Commutated AC Voltage Controller”, *Electric Power Components and Systems*, Vol.32 (7), (2004), pp. 691-700.

[9] Almarshoud, A.F., Alolah, A.I., and Abdel-halim, M.A., “Analysis and Operation of Non-Isolated Three-Phase Induction Generator Controlled by Symmetrical Angle Technique”, *Proc. of IEE International Conference on Computational Aspects and Their Applications in Electrical Engineering*, Jordan, March (2004).

[10] Almarshoud, A.F., Alolah, A.I., and Abdel-halim, M.A., “Analysis and Operation of Non-Isolated Three-Phase Induction Generator Controlled by a Transistorized ac Converter”, *Proc. of the IEEE Aegean Conference on Electrical Machines and Power Electronics (ACEMP)*, Istanbul, Turkey, May (2004).

[11] Abdel-halim, M.A. and Almarshoud, A.F., “AC Chopper Controlled Grid-Connected Induction Generator”, *Qassim University Scientific Journal-Engineering and Computer Sciences,* Vol. 1, No. 1, (2008).

[12] Abdel-halim, M.A. and Almarshoud, A.F., "Voltage Firing Control Of Grid Connected Induction Generator", *Qassim University Scientific Journal-Engineering and Computer Sciences*, Vol. 2, No. 1, (2009).

[13] Abdel-halim, M.A. and Almarshoud, A.F., "Voltage Extinction-Angle Control Of Grid-Connected Induction Generator", *Qassim University Scientific Journal- Engineering and Computer Sciences*, Vol. 3, No. 1, (2010).

[14] Abdel-halim, M.A. and Almarshoud, A.F., “The Electro-mechanical Performance Characteristics of Network-Connected Induction Generators through Different AC Voltage Controllers, *Qassim University Scientific Journal- Engineering and Computer Sciences*, Vol. 4, No. 1, (2011).

[15] Carlos, R., “Current Control in the Grid Connection of the Double-Output Induction Generator Linked to a Variable Speed Wind Turbine”, *Industrial Electronics Conference (IECON)*, Vol. 2, (2002), pp. 979-984.

[16] Ruben, P., “A Cage Induction Generator using Back to Back PMW Converters for Variable Speed Grid Connected Wind Energy System”, *Industrial Electronics Conference (IECON)*, Vol.2, (2001), pp. 1376-1381.

[17] L. Holdsworth, X. G. Wu, J. B. Ekanayake, and N. Jenkins, “Comparison of Fixed Speed and Doubly-Fed Induction Wind Turbines during Power System Disturbances”, *IEE Proceedings Generation, Transmission, and Distribution*, Vol. 150, No. 3, May (2003), pp. 343-352.

[18] Fernandez, L.M., Garcia, Jurado, F., and Saenz, J.R., “Aggregation of Doubly Fed Induction Generators Wind Turbines Under Different Incoming Wind Speed”, *Proceedings of St. Petersburg Power Tech Conference*, St. Petersburg, Russia, June (2005), pp. 27-30.

[19] Almeidam, R.G. de and Lopes, J.A.P., “Primary Frequency Control Participation Provided by Doubly Fed Induction Wind Generators”, *Proceedings of the Power System Computation Conference (PSCC)*, Liege, Belgium, August (2005), pp. 22-26.

[20] Shaltout, A.A. and El-Ramahi, A.F., "Maximum Power Tracking for a Wind Driven Induction Generator Connected to a Utility Network", *Applied Energy*, Vol. 52, (1995), pp. 243-253.

[21] Ackermann, T. and S¨oder, L., "An overview of wind energy-status," Renewable and Sustainable Energy Reviews, Vol. 6 (1-2), (2002), pp. 67–127.

[22] Bossanyi, E., "The design of closed loop controllers for wind turbines," *Wind Energy*, Vol. 3 (3), (2000), pp. 149–163.

[23] Leithead, W. and Connor, B., "Control of variable speed wind turbines: design task," *International Journal of Control*, Vol. 73 (13), (2000), pp. 1189-1212.

[24] Boldea, I. and Nasar, A., "*The Induction Machine Handbook*", CRC Press, (2006).

تحسين آداء مولدات الحث ذات التغذية المزدوجة والمحرحة بطاقة الرياح

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(قدم للنشر في ٢٠١٤/٤/١٤م ؛ وقبل للنشر في ٢٠١٤/٥/٣٠م)

ملخص البحث. توقع الخبراء النفاذ السريع لمصادر الطاقة التقليدية خلال السنوات القادمة، ولهذا فإن استخدام طاقة الرياح أصبح يجد العديد من التطبيقات والاهتمام هذه الأيام. ولقد كان من أهداف المشروع البحثي الحالي تحسين أداء مولدات الحث المدارة بطاقة الرياح عند السرعات المختلفة للرياح، وذلك بالربط المزدوج للمولد من جهة العضو الثابت والعضو الدوار، حيث يستخدم مبدلات الكترونيات القوى في العضو الدوار لحقن جهد مناسب من خلاله يتم التحكم في سرعة المولد وبالتالي التوربينة عند سرعات الرياح المختلفة، بحيث يتم استخلاص أعلى طاقة ميكانيكية من الرياح، وأيضا ضبط التيار الخارج من العضو الثابت بحيث يكون له نفس طور الجهد.

ولقد تم وضع نموذج لمولد الحث ذي الارتباط المزدوج حيث تم تمثيله في وضع الاستقرار بدائرة مكافئة، ومنها استنتج النموذج الرياضي. وبالاعتماد على النموذج الرياضي تم تطوير برنامج حاسوب لحساب خواص الأداء للمولد ذي الارتباط المزدوج، ومن ثم مقارنته بخواص الأداء للمولد المرتبط بالشبكة من جهة العضو الثابت فقط. إن مقارنة الخواص تؤكد التحسن الكبير في أداء المولد ذي الارتباط المزدوج حيث أن القدرة الفعالة المتولدة قد زادت

المتوسطة السائدة، وكذلك

مقارنة بالمولد أحادي الر

تيارات العضوين الدوار و