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Article

A Sensor-Less Based MPPT Scheme for DFIG Wind Conversion System

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Abstract: A notable facility for producing renewable and clean bulk power for utility grids are wind power turbines. Variable speed wind power generation now commonly uses double fed induction generators (DFIG) with partial size back-to-back converters. How to get power at maximum value with different wind speeds is the biggest issue with the wind energy system. Tracking involves a variety of techniques and understanding of mechanic sensors and system characteristics in order to attain the maximum output power. Prices will rise as a result of these techniques in order to improve the maximum power point tracking. This research suggests utilizing an MPPT control strategy that is based on a sensor-less scheme to harvest the highest power possible from wind turbines with DFIGs. In MATLAB/ SIMULINK, comprehensive models of various DFIG system configurations are completed.

Keywords: keyword: VSWT, DFIG, MPPT, sensor-less, wind turbines

1. Introduction

The utilisation of renewable forms of energy has been strongly influenced by the increasing demand for electric energy around the world. Wind energy appears to play a significant role in the near future among the unconventional renewable-based energy sources that have undergone extensive study. The capacity of the world's wind farms has grown significantly over the past 10 years, making it the renewable energy source with the quickest rate of development. In essence, there are numerous benefits to incorporating additional wind energy into electricity infrastructures. For instance, wind energy is a clean, renewable source that requires little maintenance [1]. By carefully controlling the shaft speed during variable-speed operation, the wind turbine can be run at Maximum Power Point Tracking (MPPT) over a large speed range.

Due to their abilities to regulate the exchange of active and reactive electricity within the network, DFIG-based wind turbines have long been regarded as the best solution for big capacity wind farms. Due to the DFIG's capacity to operate in variable speed modes, smooth operation and a power increase over other conventional generators can be accomplished. Because of its distinct qualities, including high efficiency, cheap cost, and flexible control, DFIG is growing in popularity among the various technologies used to construct wind producing systems [2]. The wound rotor induction generator that makes up the DFIG has its stator connected to the grid directly and its rotor connected via an electronic power converter. The rotor frequency and rotor speed are both managed by the power converter. Depending on the size of the frequency converter, this design enables a broad speed range of operation. The variable speed range usually revolves around the synchronous speed by around 30%. Power electronic converters can operate at varied speeds across a wide but constrained range because their rating is only 25–30% of generator capacity. In most cases, the rotor of a DFIG is connected via a B2B converter set, while the stator is connected directly to the grid. The two converters are connected using a shunt capacitor for dc purposes. In order to create the switching signals for converter switches, pulse width modulation (PWM) is used. For rotor and grid side converters, two control strategies are created. MPPT and reactive power regulation are goals of the rotor converter's control system. A path for rotor power to and from the grid with a unity power factor is provided by grid side converter control, whose tasks are to maintain the level of the dc bus voltage [3]. DFIG was often utilised to generate them in order to generate enormous amounts of electric power.

The output power of wind turbines varies depending on the operating conditions, and several control techniques are used to achieve MPPT [4]. Different control techniques are utilised to obtain MPPT in order to boost the effectiveness of WES. Numerous studies have been conducted with the goal of determining the wind energy's maximum output power. Generally speaking, MPPT approaches can be broadly divided into those that use sensors and those that don't. By observing the change in power, the scheme without sensors is utilised to track the MPPT. This technique can be broadly divided into two categories: perturbation and observation (P&O) methods and incremental conductance approaches [5]. The technique makes use of sensors to monitor the MPPT while adjusting torque and rotor speed. Tip Speed Ratio (TSR) Control is the name of this technique. Research has been done on a few control approaches to implement the MPPT control. Optimal torque, TSR, power signal feedback control, fuzzy logic control, and hill climb control are examples of patterns for these schemes [6-7].

In this article, complete models of DFIG-based grid-connected wind turbines are realised. The MATLAB/SIMULINK environment is used to simulate the dynamics of the system and control operations using a detailed model. The major goal of the project is to use a sensor-less approach to maximise the capacity of DFIG-based wind turbines operating at changing speeds. The structure of this essay is as follows. The system configuration comes first, followed by the wind energy conversion mechanism. Thirdly, the converter control system is discussed, and then the simulation results.

2. System Configuration

Wind energy conversion systems use the rotor blades of wind turbines to convert the kinetic energy of the wind to mechanical energy. The generator then changes the mechanical energy into electrical energy, which is delivered into the grid via power electronic converters. The system under investigation, shown in Fig. 1,

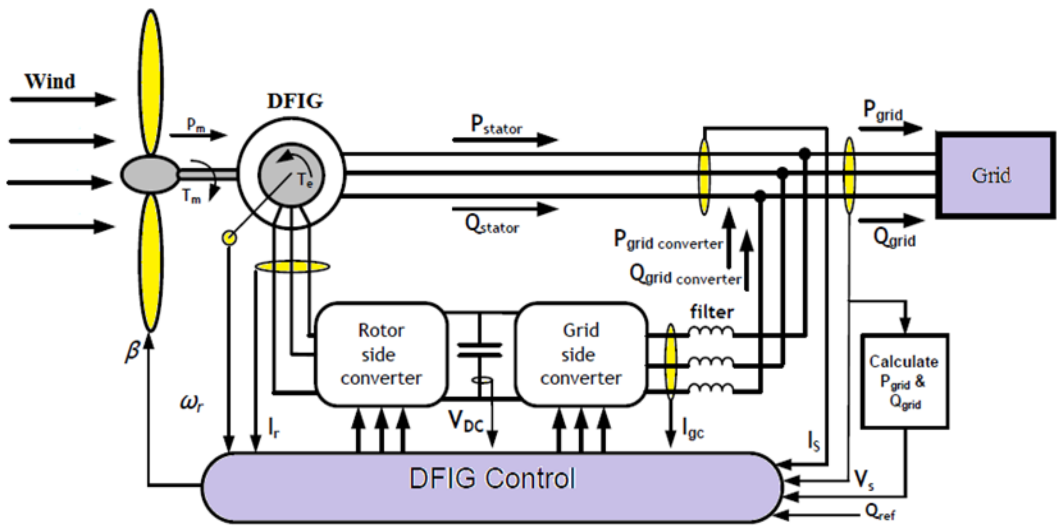


Figure 1. DFIG-based wind turbine setup.

3. System Description

3.1. Wind Turbine Model

It is commonly known that the aerodynamic rotor converts available wind power through the wind turbine at the shaft into mechanical power.

The mechanical power available increases as the cube of the wind speed, according to [8]:

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

The tip-speed ratio, on the other hand, is described as [9]:

$$\lambda = \frac{\omega_r R}{V} \tag{2}$$

The mechanical input torque, T_m, is given as follows:

$$T_m = \frac{p_m}{\omega_r} \tag{3}$$

The block diagram, which describes the mechanical model of WTS, is shown in Fig. 2. On the other hand.

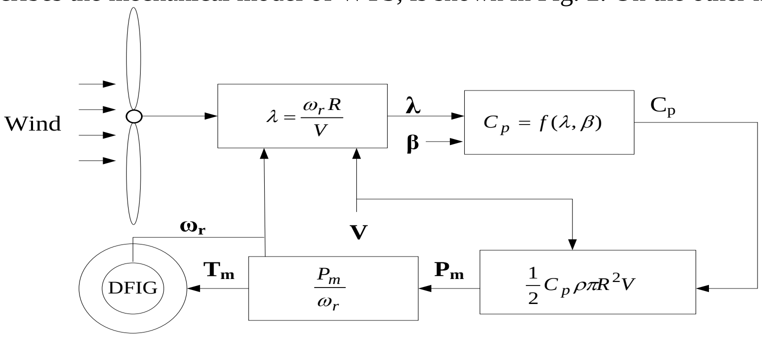


Figure 2. System configuration of wind turbine.

Fig. 3 depicts a typical Cp-characteristic for various values of the pitch angle. Assumed maximum value of Cp is $C_{p\text{-max}} = 0.48$. This result is obtained for both $\beta = 0$ degree and $\lambda = 8.1$.

From (1), the wind generator must run at a specific speed that corresponds to WS in order to track the MPP displayed in Fig. 4. This is necessary to extract the maximum amount of power at the available wind speed. Maximizing power extraction at low to medium wind speeds is the goal of operating in the MPPT mode. This is achieved by adhering to the wind power coefficient's maximum value (C_{p_max}), as seen in Fig. 4.

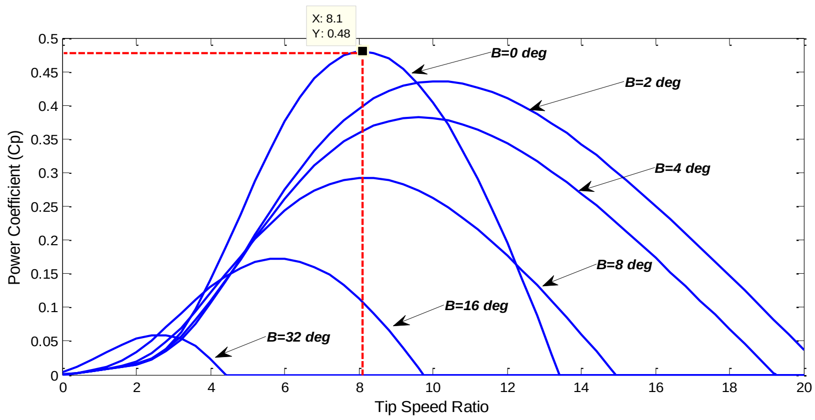


Figure 3. Cp -λ characteristics, for various values of the β.

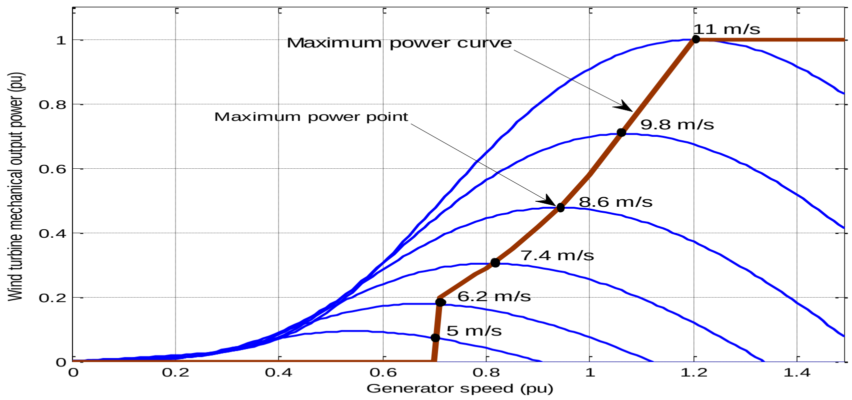


Figure 4. Wind turbine characteristics.

3.2. DFIG Modeling

The most popular type of electrical motor, with a wide range of ratings and configurations, is the asynchronous machine. It is frequently utilized in wind generation systems because of its speed flexibility. Fig. 5 depicts the d-q equivalent circuit schematic of a DFIG. Has the electrical equations for the DFIG based on the analogous circuit.are found in [10-11].

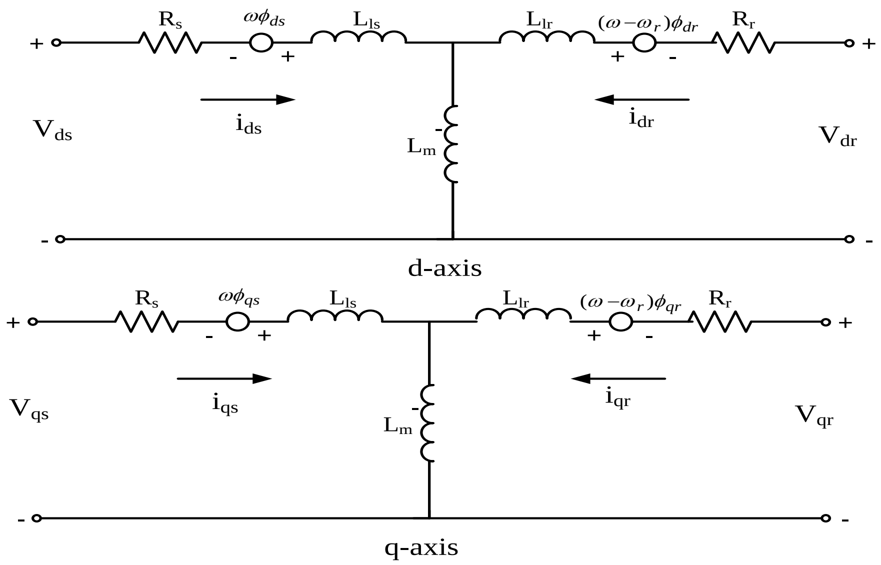


Figure 5. d-q equivalent circuit of DFIG.

4. Sensor-Less MPPT Scheme

Figure 6 depicts the schematic diagram of a sensor-less WES. In this method, the link between the MPP of the turbine and the generator rotor speed is established using lookup tables. The MPP curves of the wind turbines must be understood in order to use the PSF control technique to track the MPP. Additionally, the power curves must be determined through simulation on a single wind turbine or from the wind turbine's data sheet [12]. In this method, reference power is produced either by using a maximum power curve that has been recorded or by applying the mechanical power equation for a wind turbine, where the input is rotor speed. This approach is generally easy, quick, and effective. However, because it is not directly monitor wind speed, it is less efficient than TSR control method because wind changes do not reflect instantly and strongly on the reference signal.

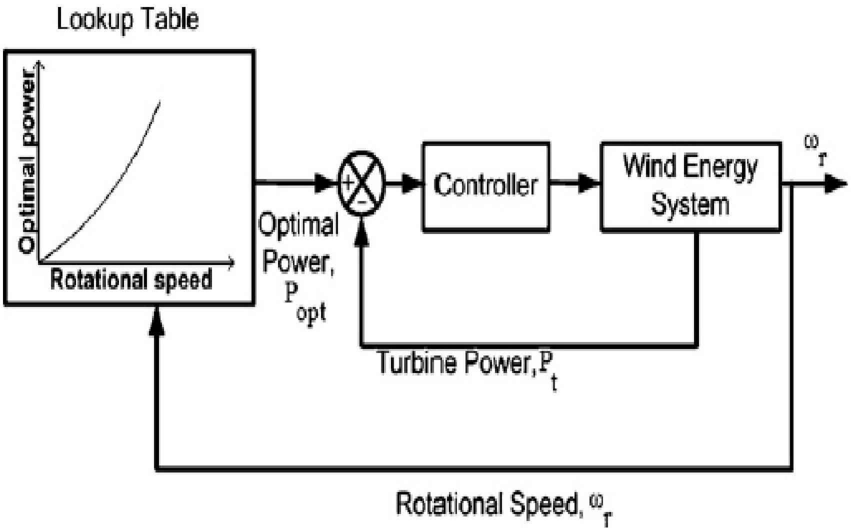


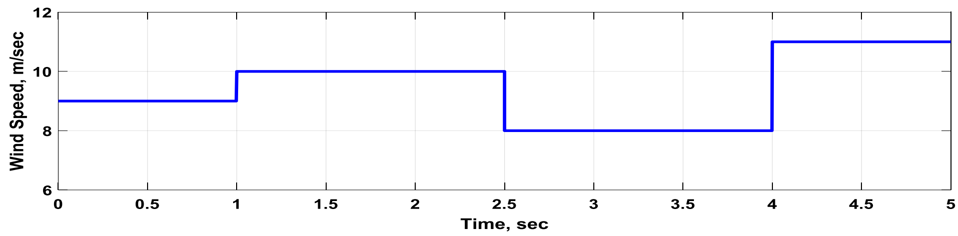
Figure 6. The schematic block of a WTS with the Sensor-Less control strategy.

5. Simulation Results of Performance Converter Control of DFIG-Based WTS

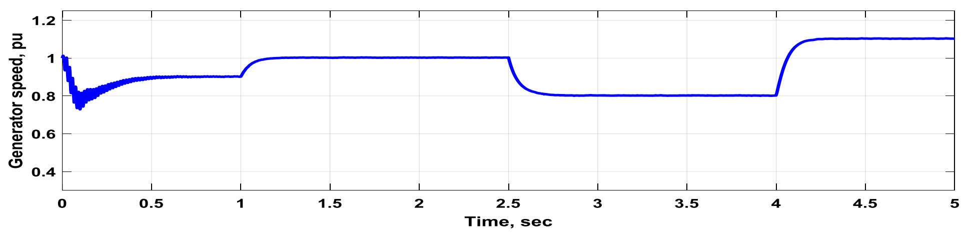
Two case studies that take into account various fluctuations in WS have been done in order to assess the effectiveness of the control schemes that have been devised for DFIG-based wind turbines. The appendix contains a definition of the system's parameter.

5.1. Case (1) Step Change in WSP

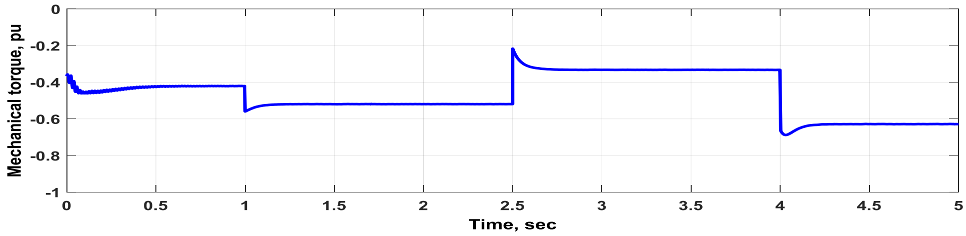
With a mean WS of 10 m/s and a time span of 5 sec, it is believed that the WS profile ranges up and down as a step function. Figures 7(b) and 7(c) show the change in rotational speed and mechanical torque over time. The system's responses were shown in the following Figures. The generator's rotational speed is depicted in Fig. 7(b), with the exception of rapid changes brought on by the existence of rotor inertia, which follows the same WS profile. As seen in Fig. 7(c), as WS rises, mechanical input torque rises as well, and the torque becomes negative to produce power.



(a)



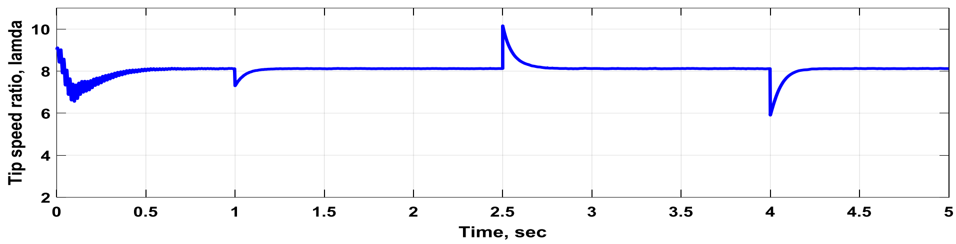
(b)



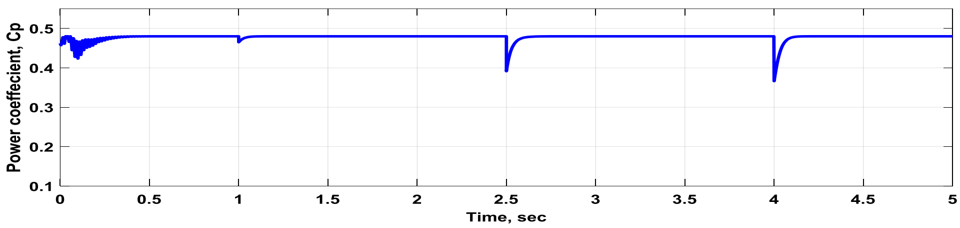
(c)

Figure 7. Simulation results of WECS under RSC case (1): (a) WS variation in m/s, (b) generator speed (pu), and (c) Mechanical torque (pu).

In order to maintain tip speed ratio at the ideal level and guarantee the highest possible value of the power coefficient Cp, the controller modifies the rotational speed in response to variations in WS. As a result, as shown in Figs. 8(a) and 8(b), the MPPT is accomplished. These numbers clearly show that Cp and are kept at their target values over the simulation duration. The abrupt change in the wind speed profile causes mild spikes to be visible at 1 second, 2.5 seconds, and 4 seconds.



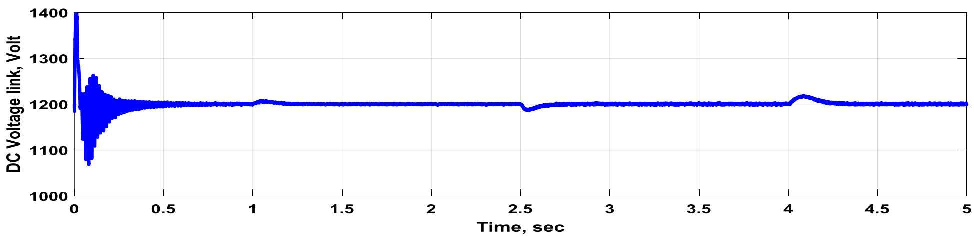
(a)



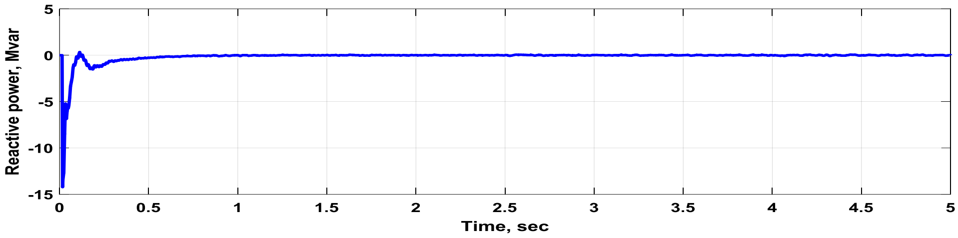
(b)

Figure 8. Turbine output (a) change of TSR, and (b) Cp**.**

Figure 9 shows the dc link voltage variation, active power, and reactive power to demonstrate the viability of the GSC. The real dc voltage remains nearly constant over the course of the whole research window, as shown in Fig. 9(a), since the controller provides a strong agreement between actual and reference values of the dc link voltage. The reactive power fed to the grid in Fig. 9(b) is roughly zero, indicating that the generator is operating at a unity p.f.



(a)

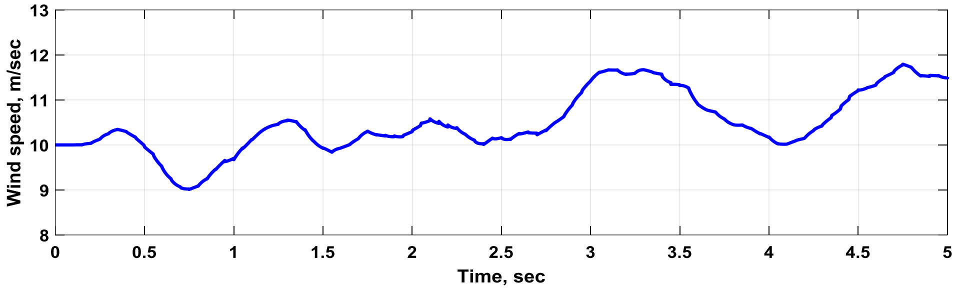


(b)

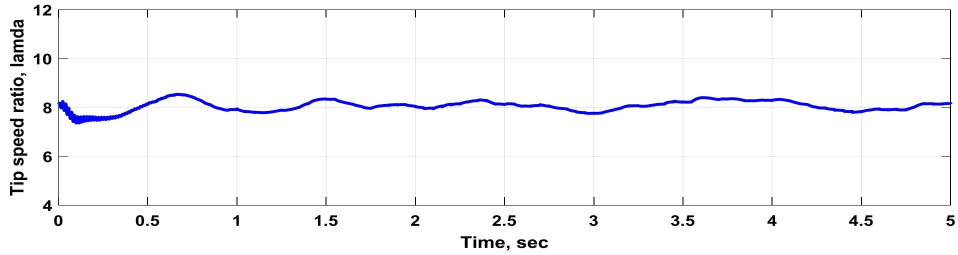
Figure 9. (a) DC- link voltage (volt), and (b) Reactive power (MVar).

5.2. Case (2) Random Change in WSP

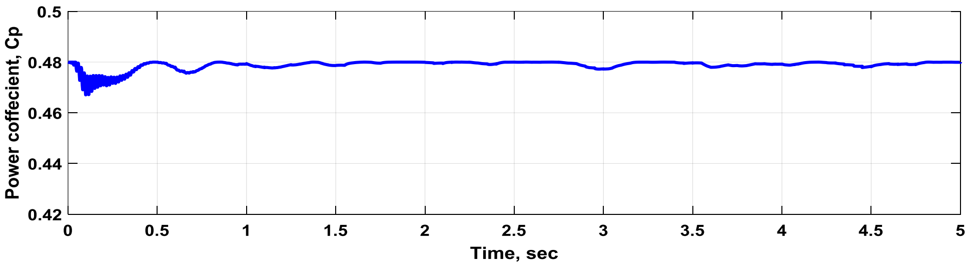
In instance 2, the WS profile depicted in Figure 10(a), which fluctuates randomly, has an average WS of 10 m/s and a turbulence intensity of 12%. According to the equivalent wind speed model offered in the WT blockset, MATLAB/SIMULINK [13], wind speed time series are provided. The λ and Cp are shown in Fig. 10(b) and (c), respectively. These Figures make it clear that $\lambda\text{-}_{opt}$ and C_{p_max} are nearly constant for the duration of the simulation.



(a)



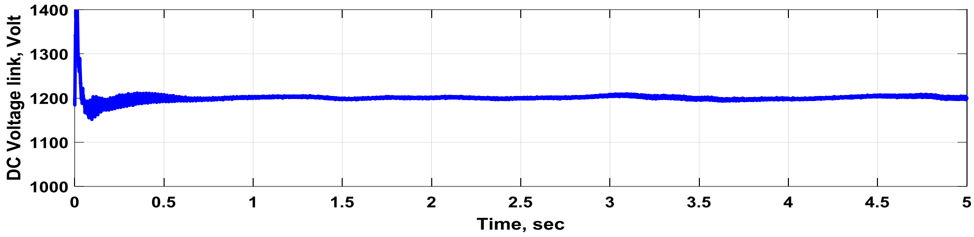
(d)



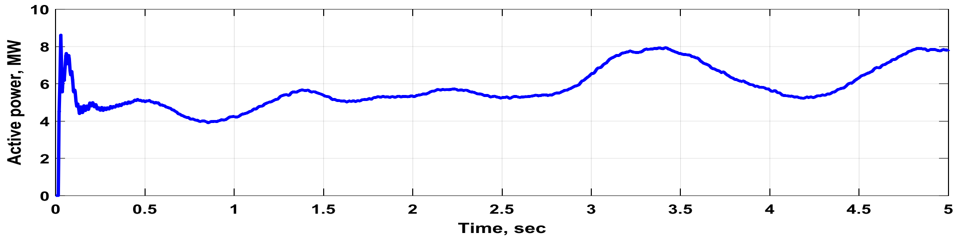
(c)

Figure 10. Simulation results of WECS under RSC, case (2), (a) WS variation in m/s, (b) λ, and (c) Cp.

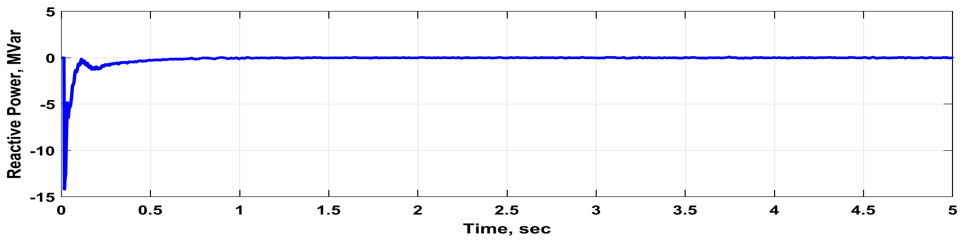
The performance of the GSC controller under a random change in the WS profile is exposed in Fig. 11. The dc link voltage is fixed during the entire period, as presented in Fig. 11(a). Figure 11(b) depicts the active power fed to the grid, whereas Figure 11(c) depicts the reactive power fed to the grid.



(a)



(b)



(c)

Figure 11. Simulation results of WECS under GSC: (a) dc link voltage, (b) active power, and (c) reactive power**.**

6. Conclusions

In the Matlab/Simulink environment, this work gives thorough modelling of a grid-connected DFIG wind turbine together with the control strategies of the interface converters. The RSC and GSC converters in this setup are built with two different control methods. The MPPT scheme is based on the sensor-less methodology; as a result, the sensor-less approach increases system stability by removing schemes involving mechanical sensors and lowers system costs. The resilience and viability of the DFIG suggested schemes are demonstrated by the simulation results. The designed control system of DFIG provides the MPPT scheme, which is based on the sensor-less technique, under various wind speed situations. This control strategy can also be utilized to deliver an electrical network with a unity P.F (i.e. Q ≈0). The results of the simulation show good tracking capabilities, and the system's reaction is judged to be satisfactory under various operating situations.

7. References

[1] T. Ackermann, "Wind power in power systems," book, John Willey and Sons, 2005.

[2] M. Sleiman, B. Kedjar, A. Hamadi, K. Al-Haddad, and H. Y. Kanaan, "Modeling, control and simulation of DFIG for maximum power point tracking," in Control Conference (ASCC), 2013 9th Asian, 2013, pp. 1-6.

[3] W. S. E. Abdellatif, A. M. Hamada, and S. A. M. Abdelwahab, “Wind speed estimation MPPT technique of DFIG-based wind turbines theoretical and experimental investigation,” Electrical Engineering, March 2021.
[4] S.M.R. Kazmi, H. Goto, H.-J. Guo and O.Ichinokura, “ A novel algorithm for fast and efficient speed-sensorless maximum power point tracking in wind energy conversion system,” IEEE Transactions on Industrial Electron, vol. 58, pp. 29–36, 2011.
[5] S. S. Dessouky, W. S. E. Abdellatif, S. A. M. Abdelwahab, and M. A. Ali," Maximum Power Point Tracking Achieved of DFIG-Based Wind Turbines Using Perturb and Observant Method", 2018 Twentieth International Middle East Power Systems Conference (MEPCON), Cairo University, Egypt, 2018.
[6] A. Naba and A. Nadhir, "Power Curve Based-Fuzzy Wind Speed Estimation in Wind Energy Conversion Systems," Journal of advanced computational intelligence and intelligent informatics, vol. 22, pp. 76- 87, 2018.
[7] A. Naba, "Sensorless wind energy conversion system using fuzzy wind speed estimator," in Instrumentation, Control and Automation (ICA), 2016 International Conference on, 2016, pp. 166-170.
[8] W.S.E. Abdellatif , A. H. K. Alaboudy,and A. M. Azmy, “Evaluation of voltage flicker emissions of variable speed DFIG-based wind turbines", 3rd International Conference on Energy Systems and Technologies , Cairo, Egypt, 16 – 19 Feb. 2015.
[9] A. A. Salem, N. A. Nouraldin, A. M. Azmy, and W. S. E. Abdellatif, “Fuzzy logic-based MPPT technique for PMSG wind generation system,” International Journal of Renewable Energy Research, vol.9, no.4, December, 2019.
[10] H. Sang Ko, G. Yoon, N. H. Kyung and W. P. Hong “Modeling and control of DFIG-based variable-speed wind-turbine” *Electric Power Systems Research*, no. 78, pp. 1841–1849, 2008.
[11] A. H. K. Alaboudy, A. M. Azmy, and W.S.E. Abdellatif, “Controller performance of variable speed wind driven doubly-fed induction generator,” IEEESaudi Arabia Smart Grid (SASG) , 7-9 Dec. 2015.
[12] A. A. Salem, N. A. N. Aldin, A. M. Azmy, and W. S. E. Abdellatif, “Implementation and Validation of an Adaptive Fuzzy Logic Controller for MPPT of PMSG-Based Wind Turbines,” IEEE Access, vol. 9, pp. 165690–165707, 2021, doi: 10.1109/ACCESS.2021.3134947.
[13] F .Iov, A. D. Hansen, P. Sorensen, and F.Blaabjerg. "Wind turbine blackest in Matlab/Simulink," Research Project, Institute of Energy Technology, Alborg University, Mar. 2004.