International Journal for Rapid Research in Engineering Technology & Applied Science
Vol VIII Issue VIII August 2022
ISSN Online :- (2455-4723)

A Review on PV- Doubly Fed Induction Generator Wind Turbine Technology

M.tech. Scholar Surendra Kumar Chourasiya, Professor. Vinay Pathak
Electrical & Electronics Engineering, Bhopal Institute of Technology, Bhopal (M.P.) (M.P) INDIA
surendrachourasiya01@gmail.com, *pathakvinay2000@gmail.com*

Abstract -Wind energy conversion system is becoming very popular now a days and the application of wound rotor induction machine is widely spread in wind energy generating stations because of its adaptability for variable speed wind turbines through which maximum possible extraction of wind energy is possible. Also among all the induction generator configurations for wind power systems the use of Doubly Fed Induction Generator (DFIG) configuration with back to back pulse width modulated voltage source converters (VSC) is one of the best topologies available and it is suitable for both grid connected systems as well as stand-alone systems. In this paper, a brief review of all the control strategies for both stator side converter and rotor side converter are discussed in stator flux oriented reference frame and results are compared on the basis of cost, efficiency , power consumption and harmonics

Keywords V2G and G2V three -phase inverter, MPPT, BSS, solar, DFIG

I INTRODUCTION

The rising demand for electricity and the scarcity of fossil fuel has intended to enhance the utilization of renewable energy sources for both economic and environmental benefits. WECS is regarded as a bulk supplier of electric power to power grids and wind power production is growing rapidly day by day. As indicated by the Global Wind Energy According to the orientation of wind turbines (WT), it is classified into two types i.e. horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). The HAWT with variable speed mode is the most convenient and commonly used WTs. The WT is able to extract more energy by adjusting the rotor speed. Such flexible wind speed operation also reduces drive train mechanical stress and smoothes output power. In a WECS after the WT the wind energy is converted to electrical energy through an optional gearbox and a generator attached with it. Doubly-fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) are predominant types of generator though other types of the generator have also been used. In today's competitive energy market the implementation of simple, reliable, efficient and cost-effective WECS is highly recognizable. But the nonlinear aerodynamic system, the mechanical complexity in the system, the presence of different kinds of faults make the operation of WECS more complicated. For the safety of WECS many efficient control strategies such as supervisory control for the startup and shut down of WT, blade pitch angle control, generator torque control, yaw control, internal generator control, power electronics devices control, pitch actuator control, fault-tolerant control etc. are implemented. Also, IEEE Standard 519–2014[2] requires that WECS must stand with the grid for a temporary overvoltage at the grid interconnection. Numerous research works are going on based on new control strategies for the improvement in the operation of WECS. Many researchers have contributed reviews with a focus on different aspects of the WECS. As the effect of WECS in large rating has a sizable impact on the grid, the grid-connected systems with WECS are the circle of research. Nevertheless, the study also diverges towards small rated WECS for standalone operation.[3] looks into variable-speed wind turbines, as the future trend in wind energy conversion, in contrast with the traditional fixed-speed wind turbines. Indirect-drive and direct-drive turbines are also contrasted for such a system.[4] presents a speed-sensor-less control of voltage and frequency for a stand- alone DFIG based on the root mean square (RMS) detection scheme. The reviews covering power electronics topologies are excluded.[5] brought out a comprehensive review of the four most popular maximum power point tracking (MPPT) control methods. Later on Kumar and Chatterjee[6] classified MPPT according to the power measurement i.e. direct or indirect power controller with a detailed assessment taking different parameters important during implementation. Tiwari and Babu focused on the structure of different pitch angle-based controllers from traditional to the modern approach. The stochastic nature of wind power specifically attracts power smoothing control. From the review of simulation results,[8] the kinetic energy of the inertia control method is a superior power smoothing approach above pitch control with FLS and DC link control by d axis current.[9] reviewed control schemes used in grid interfaced WECS for rotor side converter (RSC) and grid side converter (GSC) control. They brought a comparative presentation of rotor flux-oriented control (FOC) and direct torque control (DTC), voltage oriented control (VOC) and direct power control (DPC). Also, the performance of the VOC by different current controllers is presented. To protect the WECSs during the line fault condition and keep it connected to have low voltage ride through (LVRT), energy storage-based approaches are put side by side without an energy storage system.[10] They emphasize that the chopper circuit-based fault protection method is gaining interest due to the simplicity and low voltage ride through (LVRT) capability with reduced cost as no energy storage system is involved. This protects the DC link capacitor from the unwanted change in DC link voltage.[11] brought a review on posi- tion/speed sensor-less control strategies for direct-drive PMSG-based WECSs with a focus on observers for the unmeasured signal. Such control can improve the reliability of control for sensor faults and has significance in cost reduction.[12] reviewed on converter fault diag- nosis including both model-based and pattern-based methods and the challenges.[13] covered issues from feasibility to utilization including some insight into the adaptive and robust control applied to WECS.[14] summarized updates of numerous WT control techniques with their performance on research literature available up to 2016. Also, for internal fault, a review has been brought with more focus on model-based fault detection and control[15] but, further review of fault-tolerant control has been left out in the earlier review. However, there has been researching advancement beyond that.

II RELATED WORK

Sobhy S. Dessouky et al. (2018) most important challenge in wind energy is maximising the quantity of power generated at any given wind speed. Several ways of mechanical sensor and system characteristic knowledge are necessary to monitor the maximum output power point. These tactics will increase prices in the actual world in order to increase maximum power point tracking. Using DFIGs and the MPPT control scheme, this paper proposes a way for obtaining the maximum power from a wind turbine based on perturb and observer approaches. A thorough model of DFIG system configurations is created using Matlab/Simulink. The simulation results demonstrate that the system operates effectively and that the suggested control mechanism increases wind power integration into the grid

Essam. H. Abdou et al. (2018) wind speed estimate (WSE) is used in the paper to extract the greatest power from a 1.5 MW DFIG-based wind energy conversion system (WECS). The wind speed is estimated using the rotor speed. The optimal shaft speed is chosen based on wind speed. An MPC system is also used to monitor rotor speed and estimate its optimal value in response to variations in wind speed. The simulation results revealed that the recommended MPPT technique may generate the optimal rotor speed for maximising output power

Xinglong Wang et al. (2017) Wind farms based on DFIG (Double-Fed Induction Generator) must be explored in high-altitude mountainous locations to improve the validity and accuracy of wind farm integrated power system dynamic analysis in hilly regions. The properties of wind farms in high-altitude mountainous locations can be explored first. Second, a short review of the simplified wind farm modelling technique is in order. In the third stage, a complex wind farm modelling approach based on PSS/E and a user-defined model is offered, together with temporal and geographical wind speed distributions. A case study comparing a complete model and a simple model was conducted on a Guizhou wind farm to assess the applicability of the three comparisons: variation of wind speed distribution, cut-in wind speed, and cut-out wind speed. The ideas and conclusions will be useful in studying the dynamic features of high-density wind power integrated power systems in mountainous areas

Preeti Sonkar et al. (2017) power sector has showed an interest in renewable energy sources in order to meet the ever-increasing demand for power. Wind energy is the fastest-growing renewable energy source, necessitating the usage of wind turbines to manage the frequency of the grid. Wind turbines are used for grid frequency adjustment utilising inertial control and droop control techniques. This article investigates the frequency response of a DFIG-based wind turbine for the ARMA wind speed model. The study also investigates the impact of increasing wind power potential on the frequency response of wind power plants running without frequency control as well as with both inertial and droop controllers. The droop parameter has also been modelled for various amounts of wind power penetration. This study is unique in that it examines the impacts of increasing wind power potential without and with frequency control techniques, as well as adjusting droop parameters in their totality. The current situations have been simulated using MATLAB/SIMULINK. The results of the simulation suggest that wind turbines with inertial control and droop control can have a favourable impact on the environment

Xie Hua et al. (2018) system's frequency management need is increasing as a result of the increased penetration of wind power. Wind turbine control technique research is critical for primary frequency regulation. An inertia and droop control strategy for DFIG wind power is suggested based on the design of this study. To implement the control approach, a DFIG wind turbine model is created using RTDS. The wind turbine's simultaneous frequency tracking and efficient primary frequency regulation are proved by simulation results produced utilising the aforementioned control approach

.**Md Aktarujjaman et al. (2020)** Inverter-interfaced renewable energy sources are likely to replace fossil fuel-powered classic synchronous generators from the existing power system in the next years. Wind turbines based on doubly fed induction generators are predicted to be among these renewable energy sources (DFIG). This will have a significant influence on grid dynamics due to the absence of system inertia and the intermittent nature of wind generation. This paper demonstrated how DFIG-based wind turbines may effect grid voltage and frequency by integrating into the grid using PSS/E professional simulation software. The simulation investigations are carried out using a power grid network model that integrates hydro, gas, and wind generation, and they are carried out under various voltage and frequency contingencies or disturbances. In the simulation trials, DFIG-based variable-speed wind turbines from the world's major manufacturers were used. The system frequency, as well as the impacts of various flaws on the system voltage, are extensively evaluated as a consequence of this inquiry and analysis. Furthermore, this study investigates the grid code requirements for DFIG-based wind turbines in electrical systems with a high penetration of DFIG-based turbines. According to a careful analysis of simulation studies, DFIG-based wind turbines can contribute to system frequency and voltage control under various contingencies or network breakdowns.

Anjali V. Deshpande et al. (2019) Renewable energy sources are gaining pace and beginning to make a substantial contribution to the global energy mix as a result of increased power demand and the constraints imposed by traditional energy sources. Wind power plants are currently being created all over the world to supplement the regular grid due to technological improvements. As a result, wind power's contribution to the power system is growing at a quicker rate, making it vital to understand how wind power influences the system's features. Wind power generators such as SCIG, DFIG, and SG are examples. Because of its benefits such as maximum power tracking, variable speed operation, and separate management of active and reactive power, DFIG is the most commonly used technology. This paper describes DFIG and its simplified model, which may be used to evaluate wind-integrated power systems. According to this article, a double-fed induction generator (DFIG) may be utilized efficiently for variable-speed wind power generation

Jin Ma et al. (2018) the usage of precise models is the only way to ensure the authenticity of a simulation. Modeling of doubly fed induction generation (DFIG) for study of power system stability has attracted researchers' interest in recent years due to its extensive application in wind power production. Wind turbine manufacturers have constructed models that are not only difficult to grasp, but also proprietary and adapted solely to their own models. A variety of generic models that have been simplified are available. Among these, the current-source based model is the most often used for analysing the stability of power systems. Until recently, the model's validation has been based on limited real-world data or chosen simulated scenarios. As a result, due to a lack of systematic and theoretical evaluation of its validity, it is probable that the current-source based model may be improperly utilised in real engineering practises. This paper investigates the validity of the current-source model in the presence of both symmetrical and asymmetrical faults. Our practise of modelling and analysing an actual wind farm in North China confirms the validity of this work on the current-source based DFIG model

Subinay Vajpayee et al. (2020) discusses the use of a PLL control technique in a doubly fed induction generator to improve the management of imbalance grid voltage in real time grid synchronisation. DFIG is an abbreviation for double fed induction generator (DFIG). The impact of uneven voltage on traditional PLLs based on dq conversion is demonstrated in this work. All of the modelling and simulation were done in PSCAD. Even though the grid voltage is balanced, the unbalanced positive sequence component significantly improves PLL stability. Because it is rapid and stable, the proposed technique may be employed in DFIG's wind power system even when the main grid is down, making it perfect for usage in wind turbines. As a result, the system was built to deal with both ordinary and unusual circumstances. The addition of a PLL considerably improved the system's stability

III PV-DFIG

In its topology, the solar PV array is connected at the DC link of DFIG based WECS through a boost converter and a

DC-DC converter. However, it increases the switching losses and cost, because of additional DC-DC converter along with grid side converter. In [15], the authors have demonstrated the wind-solar PV system with BES in standalone mode. In its configuration, the solar PV array is connected at the DC link of wind turbine driven DFIG through a boost converter. However, the current through BES is not controlled, because it is directly connected at the DC link. Further, the microgrids based on DG, wind and solar sources have been developed and reported in the literature [16]-[18]. In [16], the authors have discussed the capacity planning of BES for a microgrid based on wind, solar and diesel sources that are located in island. However, optimal fuel operation of DG has not been discussed. In [17], the authors have demonstrated a wind-diesel microgrid for fuel efficient zone with BES. However, the BES current is not controlled due to its direct connection at the DC link. Moreover, the chances of getting away from fuel efficient zone is more due to connection of only one RE source. Venkatraman et al. [18] have presented a wind-solar-diesel microgrid with BES for certain remote area. However, the optimal operation of DG has been ignored while developing the source and load controllers. In any microgrid, the BES plays vital role during the mismatch of generation and demand. Moreover, it helps in extraction of maximum power both from wind and solar, especially when the generation is more than the demand. There are many maximum power point tracking (MPPT) techniques discussed in the literature, both for wind and solar to extract maximum power corresponding to particular wind speed and insolation, respectively [12],

IV DFIG WIND TURBINE

Figure **1** shows the structure of the DFIG wind turbine and control system. The DFIG principally consists of a back-to-back grid-side converter (GSC) and a rotor-side converter (RSC). The stator windings are interfaced with the power grid, while the rotor windings are connected to the power grid by RSC and GSC. The decoupling of the rotor from the power grid has the merit that the power capacity of the converters is 30% of that of the wind turbine **3**. Consequently, the cost of converters and the harmonic filter is significantly reduced. In addition, the smaller converter size not only results in lower power loss but also leads to higher efficiency. In particular, the salient feature of a DFIG wind turbine is the controllability of the active and reactive power outputs (P_{DFIG}, Q_{DFIG}, respectively). Based on the vector control technique both P_{DFIG} and Q_{DFIG} can be independently controlled by the control system in Fig. 1. This control system is composed of the speed controller, the voltage controller, and the pitch angle controller. Here, the main control objective of a DFIG is amelioration of power system oscillations. The study result in indicates that the control in the RSC gives a much higher damping effect on the oscillation mode than that in the GSC. Therefore, the RSC is appropriate for power oscillation dampinghe quadrature-axis current of the RSC (i_{qr}) can be used to control the active power output by the speed controller, while the direct-axis current of the RSC (i_{dr}) can be employed to control the reactive power output by the voltage controller. With the ability of reactive power output control of the DFIG, reactive power compensation is not required as in a fixed-speed wind turbine. This ability not only supports the DFIG terminal voltage during the steady state and grid faults but also eliminates the installation cost of reactive power compensating devices.

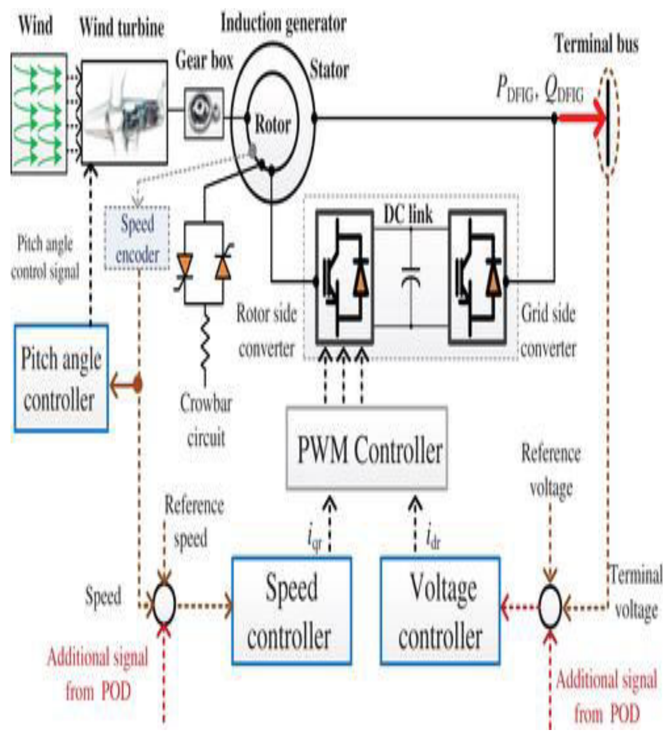

Fig 1 DFIG wind turbine

The crowbar circuit, which consists of antiparallel thyristors and a resistor, is connected to the rotor circuit, as shown in Fig. **1**. The objective of the crowbar circuit is to limit the high current in the rotor circuit and to provide a bypass for it. The protection of the rotor circuit is effected without disconnecting the converter from the rotor or from the power grid during and after a fault. As a result, the fault (low-voltage) ride-through capability of the DFIG wind turbine is improved. The resistance should be low enough to mitigate the overvoltage across the converter terminal. On the contrary, it should be sufficiently high so that the high current in the rotor can be limited.

A- Frequency Stability: frequency stability is the ability of a power system to maintain a steady frequency following a severe system upset resulting in a significant imbalance between generation and load. It relies on the ability to maintain/restore equilibrium between generation and load. Instability takes place in the form of sustained frequency swings, leading to tripping of generating units and/or loads. The proliferation of DFIG wind turbines in power systems aggravates system frequency instability because of some reasons, as described below.

1. When the integration of DFIG wind turbines into power systems increases, the large output power fluctuations result in severe system frequency variation. This makes the frequency relays, which are installed at wind farms, disconnect wind farms from power systems. This not only exacerbates frequency and/or voltage stability but also excites power oscillations2. Owing to the decoupling between the power grid and the DFIG rotor by the back-to-back converters, the grid frequency variation cannot be detected by the DFIG rotor. As a result, the massive installation of DFIG wind parks drastically diminishes the apparent system inertia. This not only escalates the rate of system frequency change but also worsens the nadir of frequency drop under the loss of generators. This also implies that the time interval for the spinning reserve to compensate the power imbalance shortens. This influence is manifest in small power systems, isolated microgrid/weak grids and isolated island grids such as in Ireland and the UK

B- Transient Stability: As clarified in Ref. 12, transient stability is concerned with the ability of the power system to maintain synchronism when subjected to a severe disturbance such as a short-circuit. It depends on the initial operating point of the system and the severity of the disturbance. Instability is normally in the form of aperiodic angular separation due to inadequate synchronizing torque.

Since the inertia of the DFIG rotor is decoupled from the power grid, and the high installation of DFIG wind turbines replaces the conventional synchronous generators, not only the effective system inertia is degraded but also the synchronizing torque is deteriorated. These bring about an increase of the aggregated angular acceleration or deceleration of synchronous generators after system faults occur. These scenarios directly endanger the system's transient stability performance.

The impact of reduced inertia of the power grids with large DFIG wind farms on the level of transient stability margin reduction was studied in previous works. Time-domain nonlinear simulation for any initial operating conditions and applied faults is used to calculate the transient stability index in order to determine the transient stability margin of the power system with DFIG wind farms The study result signifies both the detrimental and beneficial impacts of increased DFIG installation on the transient stability. In , a new transient stability index using sensitivity analysis is evaluated by time simulation. The result shows that suitable location of DFIG wind turbines augments the power system transient stability margin. When DFIG wind turbines are situated at some other locations, the stability margin becomes worse.

However, transient stability analysis by time simulation still has some disadvantages such as the trial runs of increasing fault interval, the lack of stability degree data, the indemonstrable post-fault trajectories, etc. To tackle these problems, the energy function method is adopted.he energy function based on the potential energy boundary surface method is used to analyze the influence of reduced inertia on the system transient stability. With the direct computation of the critical energy and the critical fault clearing time, study result reveals that the reduced effective system inertia due to DFIG wind turbines causes a degradation of the system's critical clearing time and transient stability margin. Besides, the required additional inertia under the inertial reduction by other machines can be estimated by the proposed technique for contributing the inertial support from DFIG wind turbines. In Ref. **22**, study result using the transient energy margin evaluation advocates that when the voltage sag, fault clearing time, and wind power penetration are higher than certain thresholds, the DFIG wind farms have an adverse impact on the transient stability.

On the other hand, there have been studies that apply the DFIG wind turbine to augment power system transient stability. The DFIG converter controller can be divided into fixed and adaptive structures. For the fixed structure controller of a DFIG, an RSC controller is modified so that the input torque reference of a DFIG is modulated using a feedback of the frequency of the DFIG terminal bushereby, the output active power of a DFIG is modified during the post-fault condition. This changes the electrical power of adjacent synchronous generators and enlarges the transient stability margin.

C- Small-Signal Stability: As mentioned in Ref. 12, small-signal stability is concerned with the ability of the power system to maintain synchronism under small disturbances. It hinges on the initial operating point of the system. Instability can be of two forms: (i) increase in rotor angle through a nonoscillatory disturbance due to lack of synchronizing torque, or (ii) rotor oscillations of increasing amplitude due to lack of sufficient damping torque. The small-signal stability problem is associated with the local plant mode oscillation with a frequency of about 1.0–2.0 Hz and inter-area mode oscillation with a frequency of about 0.2–0.8 Hz.

Since the DFIGs are asynchronous machines and decoupled from the power grid by converters, they do not initiate new oscillation modes. However, they can influence the damping of oscillation modes by the following four mechanisms On the other hand, recent events in Minnesota and Hebei province

D-Ancillary Services from DFIG Wind Turbine: With increasing integration of DFIG wind turbines into power grids, DFIG wind turbines can be expected to become active and reactive power service providers. With sophisticated wind forecasting methods nowadays as well as the power smoothing techniques, DFIG wind turbines can be treated as a dispatchable power source by power utilities. Accordingly, it is possible for DFIG wind turbines to contribute ancillary services such as frequency control, voltage control, power oscillation damping, etc. to power systems. In addition, various national grid codes require DFIG wind turbines to offer ancillary services . In the following, we review previous works on frequency control, voltage control, and power oscillation damping from DFIG wind turbines.

E- Frequency Control: The frequency control support by DFIG wind farms can be categorized into two groups: inertial control and power reserve control . The former temporarily releases the kinetic energy stored in the DFIG rotor to lessen the frequency nadir at the initial stage of a disturbance, while the latter injects the reserved power in a wind turbine to supply insufficient power persistently. Although the latter has a better control effect than the former, to take part in the primary frequency control, the deloaded operation of DFIG wind turbines is required. In other words, DFIG wind turbines are operated below the maximum power point tracking (MPPT) curve. This causes an inevitable loss of wind energy. Studies on the frequency control support by DFIG wind turbines with power reserve control can be found in Here, the survey of the inertial control in previous studies is carried out.

F-Conventional Inertial Control of DFIG Wind Turbine: To avoid the adverse impact of the ROCOF loop, replaces the ROCOF loop in the conventional inertial control with the maximum ROCOF loop to retain the maximum ROCOF and get rid of the negative influence after the frequency rebound. This scheme not only releases more kinetic energy both before and after the frequency rebound but also raises the frequency nadir more than the conventional inertial control.

G-Voltage Control: Under low-speed operation, the active power output of a DFIG wind turbine is much lower than its rated power. It is possible that a DFIG wind turbine can inject the reactive power to a power grid for enhancing the voltage profile during steady and transient states.

V CONCLUSION

In this paper, various methods for analyzing DFIG wind turbines impact on power system dynamic performance, such as frequency stability, transient stability, small-signal stability, and voltage stability, have been reviewed. Advanced control techniques of the DFIG for grid service supports, i.e. frequency control, voltage control, and power oscillation damping, have been described. The results and future trend can be summarized as follows.

The replacement of synchronous generators by DFIG wind turbines not only reduces the effective system inertia but also aggravates the synchronizing torques. This mainly affects the power system's dynamic performances. Nevertheless, the controllable output power of DFIG wind turbines with appropriate control can be utilized to ameliorate the power grid dynamics.

Regarding the impact on frequency stability, DFIG wind farms not merely worsen the frequency nadir but also expedite the ROCOF. To alleviate both problems, the hidden inertia of DFIGs can be extracted by inertial control. The key point of this control is how to adapt the controller gains so that more kinetic energy stored in the DFIG rotor can be released. Improved inertial control methods that can inject more kinetic energy and guarantee stable operation are significantly required.

VI REFERENCE

1. **Global wind Energy Council. Global wind** report annual market update 2015. Global Wind Energy Council, 2015
2. REN21. Renewables 2016 global status report, 2016
3. Muller S, Deicke M, De Doncker RW. Doubly fed

induction generator systems for wind turbines. IEEE Industry Applications Magazine 2002; 8(3): 26– 33.

4. Tazil M, Kumar V, Bansal RC, Kong S, Dong ZY, Freitas W, Mathur HD. Three-phase doubly fed induction generators: an overview. IET Electric Power Applications 2010; 4(2): 75– 89.
5. Abad G, Lopez J, Rodriguez M, Marroyo L, Iwanski G. Doubly Fed Induction Machine: Modeling and Control for Wind Energy Generation. Wiley; 2011, 625 pp.
6. Zin AABM, Mahmoud Pesaran HA, Khairuddin AB, Jahanshaloo L, Shariati O. An overview on doubly fed induction generators' controls and contributions to wind base electricity generation. Renewable and Sustainable Energy Reviews 2013; 27: 692– 708.
7. Jadhav HT, Roy R. A comprehensive review on the grid integration of doubly fed induction generator. International Journal of Electrical Power and Energy Systems 2013; 49: 8– 18.
8. Milano F. Power System Modelling and Scripting. Springer; 2010.
9. Rahim AHMA, Habiballah IO. DFIG rotor voltage control for system dynamic performance enhancement. Electric Power Systems Research 2011; 81(2): 503– 509.
10. 10Pathak AK, Sharma MP, Bundele M. A critical review of voltage and reactive power management of wind farms. Renewable and Sustainable Energy Reviews 2015; 51: 460– 471.
11. Morren J, de Haan SWH. Ridethrough of wind turbines with doubly-fed induction generator during a voltage dip. IEEE Transactions on Energy Conversion 2005; 20(2): 435– 441.
12. Kundur P, Paserba J, Ajjarapu V, Andersson G, Bose A, Canizares C, Hatziargyriou N, Hill D, Stankovic A, Taylor C, Custem TV, Vittal V. Definition and classification of power system stability. IEEE Transactions on Power Systems 2004; 19(2): 1387– 1401.
13. Causebrook A, Atkinson DJ, Jack AG. Fault ride-through of large wind farms using series dynamic braking resistors. IEEE Transactions on Power Systems 2007; 22(3): 966– 975.
14. kanayake J, Jenkins N. Comparison of the response of doubly fed and fixed-speed induction generator wind turbines to changes in network frequency. IEEE Transactions on Energy Conversions 2004; 19(4): 800– 802.
15. Ekanayake J, Jenkins N, Strbac G. Frequency response from wind turbines. Wind Engineering 2008; 32(6): 573– 586.
16. Xie Hua, Xu Hongyuan, Li Na, “Control strategy of DFIG wind turbine in primary frequency regulation” 2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA) Year: 2018 | Conference Paper | Publisher: IEEE DOI: 10.1109/ICIEA.2018.8397992
17. Md Aktarujjaman, M. E. Haque, S. Saha, M. Negnevitsky “Impact of DFIG Based Wind Generation on Grid Voltage and Frequency Support” 2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM) Year: 2020 | Conference Paper | Publisher: IEEE DOI: 10.1109/SPEEDAM48782.2020.9161867
18. Anjali V. Deshpande, V. A. Kulkarni Simplified Model of DFIG in Wind Integrated Power System 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC) Year: 2019 | Conference Paper | Publisher: IEEE DOI: 10.1109/ICCMC.2019.8819670
19. Jin Ma, Dawei Zhao, Liangzhong Yao, Minhui Qian, Koji Yamashita, Lingzhi Zhu Analysis on application of a current-source based DFIG wind generator model CSEE Journal of Power and Energy Systems Year: 2018 | Volume: 4, Issue: 3 | Journal Article | Publisher: CSEE DOI: 10.17775/CSEEJPES.2018.00060
20. Subinay Vajpayee, Nihar Ranjan Panda, Prasanajit Behera, Sarat Chandra Swain “Implementation of PLL algorithm in DFIG based wind turbine connected to utility grid 2020 Second International Conference on Inventive Research in Computing Applications” (ICIRCA) Year: 2020 | Conference Paper | Publisher: IEEE DOI: 10.1109/ICIRCA48905.2020.9182961
21. Kamal Ouezgan, Badre Bossoufi, Mohammed Najib Bargach, “DTC Control of DFIG-Generators for Wind Turbines: FPGA Implementation” International Renewable and Sustainable Energy Conference (IRSEC) Year: 2017 | Conference Paper | Publisher: IEEE DOI: 10.1109/IRSEC.2017.8477300
22. Panneer Selvam Manickam, Prakasam Periasamy Tracking the Maximum Wind Power Point using Neuro-Fuzzy Control with DFIG-BESS for Wind Energy System 2018Conference on Emerging Devices and Smart Systems (ICEDSS) Year: 2018 | Conference Paper | Publisher: IEEE DOI: 10.1109/ICEDSS.2018.8544358