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# Enhancement of LVRT Capability of Grid Connected DFIG-Based Wind Energy Systems through Power Control Strategy

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***Abstract*— Due to its sensitivity to power system faults, initiation generating that is doubly fed (DFIG) Wind Turbine (WT) needs specialized power converter protection, specifically a crowbar. Crowbar safeguards must be installed on the wind turbines powered in order to preserve the lifespan of power electronics components. The rotor-side converter (RSC) is disabled. The rotor shorts out over the crowbar resistance when the crowbar is activated. The DFIG consequently functions to serve as a squirrel-cage induction generator (SCIG), when there are defects, tends to pull a significant amount of reactive power from the grid and might result in a supply voltage. In a DFIG-based depend fault-ride-through, crowbar, rotor-side, and grid-side converters are utilized (FRT) approach to improve transient response. By contrasting comparing the effectiveness of the mixed model of traditional proportional-integral and fuzzy logic controllers, the transient functioning of the system is specifically examined.**

***Keywords*— DFIG, Crowbar protection, Wind turbine, Transient stability**

## I. INTRODUCTION

Wind power has been increasing as a share of the world's total energy supply, and it is today one of the main energy sources. Thanks to its advantages of being plentiful, renewable, and ability of being broadly distributed without emitting greenhouse gases, wind power has persuaded many governments of the relevance of it as a new energy resource. based on the 2014 Global Wind Statistics Report, wind power capacity had quickly expanded to 336GW by mid-2014, accounting for close to 4% of the world's total energy consumption. 40% of the electricity used in Denmark in 2014 came from wind energy, and 114 763 MW of new wind farm installations were built in China, accounting for almost half of the total. Studies of its stability during faults and its performance during recovery have long been an important field of study because wind power generators helped build the energy edifice [1]. Eigenvalue research control systems for fault-ride-through, and mathematical models of DFIG [2] are only a few of the works that have been done on DFIG. The market has taken notice of the varying wind turbines using the double-fed induction generation due to its inexpensive installation costs, and superior ability to transmit energy at shifting wind velocity (DFIG). The concepts of the DFIG wind turbine have been the subject of numerous investigations [3–5]. This research then suggests robust control algorithms that combine the advantages of sliding mode theory and fuzzy logic. These controllers were created using the DFIG's dynamic model, which took into account how the voltage drop affected the stator flux. This strategy is shown to work better than other control design methods that assume are following this control method. A number of simulation scenarios are run on a 3 MW wind turbine system to show how well the suggested control strategies work when faced with voltage dips and parameter uncertainty. There is no rotor-side converter (RSC). The rotor shorts out over the crowbar's barrier when it is actuated. The DFIG therefore functions as a squirrel-cage induction generator (SCIG), which tends to pull a significant amount. The DFIG dynamic model, which considered how the voltage drop influenced the stator flux, was used to develop these controllers. It is demonstrated that this tactic outperforms previous control design techniques that rely on the supposition that the magnitude of the flow in the stator would be constant. The failure network specifications, which call for the generators of wind turbines to stay connected throughout voltage drops, are met by this control technique.

In addition to interactions between DFIG converter controllers, a low synchronized coupling, and the substitution of generating units, the extensive use of DFIG wind turbines in power system networks also has drawbacks. This can be

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detrimental to the dynamic properties of the power system, including frequency stability, power oscillation, transient stability, small-signal stability, and reliability of power.

## II. DFIG under Disturbances

A winding rotor induction tool with rotors circuit accessibility. The modelling of this machine has already been covered in the literature [6]. The Park's transformation model, which allows for the decoupled regulation of active and reactive power, converts three main characteristics into d-q elements

### *A. Crowbar with hysteresis Controller Effect*

The rotors current's transitory reactions in the standard DFIG under the crowbar protections, as well as the recommended best control strategy (LVRT and damping). Due to the power converter's low capacity, the voltage at the PCC dips at t0, and as soon as it does, The stator winding is more than the predetermined limit. The rotor power is permitted by the crowbar safety to quickly fall to the secure area. By the middle of 2014, it had quickly grown to 336GW, or about 4% of global energy consumption. Wind energy accounted for 40% of the electricity utilised in Denmark in 2014, and 114 763 MW of the world's new wind farm installations were constructed in China, making up about half of the total. Because wind power generators contributed to the construction of the energy edifice, studies of its stability during faults and its performance during recovery have long been an important subject of study. To shorten the crowbar's working duration, the LVRT and damping control schemes in [7-9] employ the improved hysteresis control method. The rotor current gradually decreases, as seen, until abruptly returning to normal functioning at t = 1:56 s. Since a crowbar operation with hysteresis control is obviously faster than one without it, the majority of the voltage dip is regulated by the DFIG with LVRT and dampening technique.

## III. Methodology

### *A. Crowbar protection and DFIG behaviour during grid disturbances*

A Matlab model of a wind power plant (WPP)-DFIG with crowbar protection against disturbances was created to demonstrate and assess the failure technique as outlined. A simulations analysis is offered to evaluate the proposed control strategy and show its reliability and effectiveness during voltage instability. The simulation's features for the DFIG and turbine models are based on a 3 MW wind generator. The outcomes are contrasted with those of traditional vector control.

## IV. Simulation Results

Numerous studies investigating the impacts of network disturbances on DFIGs have been published [10]. Taking Park's model into consideration, the pertinent stator and rotors fluxes (_s and _r, correspondingly), as well as outputs (u s and u r), are provided as in (i):

$$\Psi_s = L_s i_s + L_m i_r$$
$$\Psi_r = L_r i_r + L_m i_s$$
$$u_s = R_s i_s + \frac{d\Psi_s}{dt}$$
$$u_r = R_r i_r + \frac{d\Psi_r}{dt} - j\omega_m \Psi_r \qquad \text{(i)}$$

In this equation, L m stands for the capacitance, _m for the angular velocity about the rotor, I s and I r for the stator and rotor currents, L S and L r for the stator and rotor inductors, and R s and R r for the rotor and stator resistance values, correspondingly. One of the most crucial variables to be examined is the rotor voltage, or u r, which is produced by the rotor flux and may be computed by adjusting (ii) and (iii) as follows:

$$\Psi_r = \frac{L_m}{L_s}\Psi_s - \sigma L_r i_r \qquad \text{(ii)}$$

$$\sigma = 1 - \frac{(L_m)^2}{L_s L_r} \qquad \text{(iii)}$$

The crowbar triggers the capacitor's dc voltage, the capacitor's dc link voltage begins to charge once the RSC begins actively controlling the reactive power. When the problem has been cleared (Figure 1). It is important to take note of the voltage change at the generator terminals (Figure 2) with a large quantity of reactive power. When the rotors present surpasses the allowed value, the voltage support of GSC and RSC coordinate their management to increase the PCC voltages at fault clearance [11].

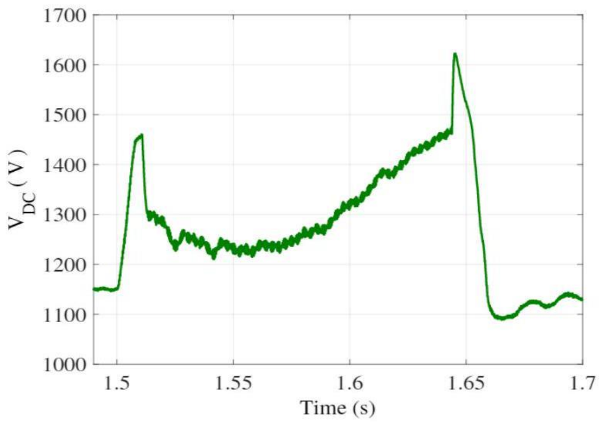


Figure 1: DC voltage of DFIG with LVRT scheme.

It is feasible to derive the rotor voltage as indicated below by substituting _r into (iv).

$$u_r = \frac{L_m}{L_s}\left(\frac{d}{dt} - j\omega_m\right)\Psi_s + \left(R_r + \sigma L_r\left(\frac{d}{dt} - j\omega_m\right)\right)i_r \qquad \text{(iv)}$$

The stator flux, which creates the open circuit rotor voltage u r0, is the first component of the equation above. Setting i r will allow to get its expression=0 in (v),

$$u_{r0} = \frac{L_m}{L_s}\left(\frac{d}{dt} - j\omega_m\right)\Psi_s \qquad \text{(v)}$$

Due to the minimal reactance, temporary reactance, and typically constrained blunder of DFIG, the second element in

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(vi) is smaller than u r0 in ordinary process. The rotary energy produced by the stator flux can therefore be represented as follows shown in [vi].

$$u_{r0} = j\omega_r \frac{L_m}{L_s}\Psi_s = \frac{L_m}{L_s}\frac{\omega_r}{\omega_s} U_s e^{j\omega_s t} \quad \text{(vi)}$$

where the relative rotor and stator angular speeds, are _r and _s. The rotor voltage U r0's size during typical operation comes

$$U_{r0} = \frac{L_m}{L_s}\frac{\omega_r}{\omega_s} U_s = \frac{L_m}{L_s} s U_s \quad \text{(vii)}$$

where

$$\omega_r = \omega_s - \omega_m$$

and s denotes the slip:

$$s = \frac{\omega_s - \omega_m}{\omega_s}$$

The amplitude of the stator voltage and slip, along with the operational circumstances, define the rotors voltage. the rotor flux-induced open circuit rotor voltage at the time of the fault is represented as follows:

$$u_{r0} = -\frac{L_m}{L_s}\left(j\omega_m + \frac{1}{T_s}\right)\frac{U_s}{j\omega_s} e^{j\omega_s t_0} e^{-t/T_s} \quad \text{(viii)}$$

The size of this fixed-length voltage space vector, which is attached to the rotor, decreases exponentially until it is zero. But in relation to the rotor, this energy spins counterclockwise with an angular frequency of ωm

$$u_{r0}{}^{r} = -\frac{L_m}{L_s}\left(j\omega_m + \frac{1}{T_s}\right)\frac{U_s}{j\omega_s} e^{j\omega_s t_0} e^{j\omega_m t} e^{-t/T_s} \quad \text{(ix)}$$

The magnitude of u r0 r reaches its maximum at the breakdown instant. Due to its low value (T s=12.5 s for the DFIG under examination), the phrase 1/T s in (x) is ignored.

$$U_{r0}(t_0) = \frac{L_m}{L_s}\frac{\omega_m}{\omega_s} U_s = \frac{L_m}{L_s}(1-s)U_s \quad \text{(x)}$$

Therefore, when a situation exists, the voltage magnitude at the rotor is very close to the strength at the stator. If the DFIG is operating normally, at amazingly speed, the voltage magnitude at the rotor may be a little greater Table 1 lists the characteristics of the DFIG and network [13].

Table 1: Grid Connected Wind Turbine Parameters.

| Parameters | Value | Unit |
|---|---|---|
| Rated power | 3 | MW |
| Rated speed | 12 | m/s |
| Cut in wind speed | 5 | m/s |
| Cut out wind speed | 19 | m/s |
| Rated Voltage | 690 | V |
| Frequency | 50 | Hz |
| $R_s$ | 0.016 | pu |
| $R_r$ | 0.00549 | pu |
| $L_{ls}$ | 0.18 | pu |
| $L_{lr}$ | 0.16 | pu |
| $L_m$ | 2.9 | pu |

Power converter regulation is crucial for optimal DFIG output behaviour both in normal operation and when there is a problem. Reference [14–16] has already described the DFIG control and its successful operation in common grid configurations. But in contrast to the current work. Because of this, the failure though ability of this machine was not covered in those papers. In specifically, we contrast the performance of DFIG wind generators with and without LVRT and damping system in this paper. Moreover, a sophisticated cascaded hybrid fuzzy-PI is used to regulate the LVRT method. For a 3 MW WPP, MATLAB/Simulink was used to evaluate how well the proposed monitoring system performed. Figure 2 shows the simulation configuration for the network. At the point of common link, the DFIG is directly connected to two parallel 33 kV power lines 10 km in length (PCC) [17 ,18].

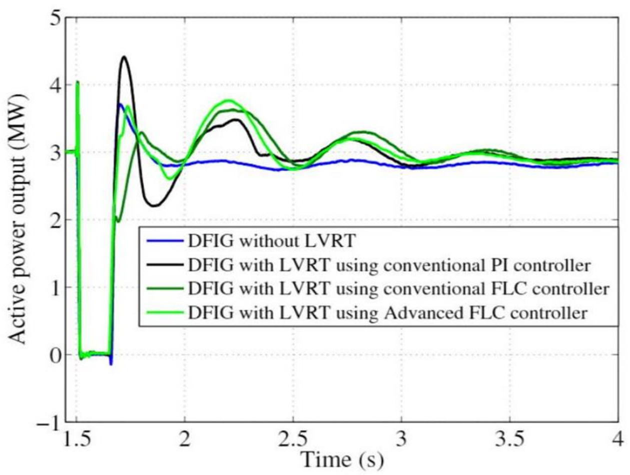


Figure 2: The voltage U at DFIG-based wind power plant terminal.

## V. CONCLUSION

This study's goal was to create a reliable voltages grid connected control strategy for Method for spatial wind turbines in order to improve LVRT performance by utilising the Dfig - based wind systems' suitable control properties. The goal of this control strategy is for RSC and GSC to cooperate in order to control voltage. As long as the crowbar is not in the way, the RSC controls reactive power by default. Therefore, this integrated architecture may be a good solution to enhance the LVRT abilities of the DFIG wind farms by making use of the control flexibility of the DFIG wind turbine system. The effective control capabilities of the DFIG wind system were used to increase the fault-ride-through capability. The study after that provides reliable control algorithms that combine the benefits of fuzzy logic and sliding mode theory. The dynamic model of the DFIG, which considered how the voltage drop influenced the stator flux, was used to develop these controllers. It has been

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established that this approach performs better than other strategies that make assumptions.

## REFERENCES

[1] L. Yang, Z. Xu, J. Østergaard, Z. Y. Dong, K. P. Wong, and X. Ma,"Oscillatory stability and eigenvalue sensitivity analysis of a DFIG windturbine system," IEEE Transactions on Energy Conversion, vol. 26,no. 1, pp. 328–339, 2011.

[2] Y. Mishra, S. Mishra, F. Li, Z. Y. Dong, and R. C. Bansal, "Small-signalstability analysis of a DFIG-based wind power system under differentmodes of operation," IEEE Transactions on Energy Conversion, vol. 24,no. 4, pp. 972–982, 2009.

[3] F. Wu, X.-P. Zhang, K. Godfrey, and P. Ju, "Small signal stabilityanalysis and optimal control of a wind turbine with doubly fed inductiongenerator," IET Generation, Transmission and Distribution, vol. 1, no. 5,pp. 751–760, 2007.

[4] M. Yamamoto and O. Motoyoshi, "Active and reactive power controlfor doubly-fed wound rotor induction generator," IEEE Transactions onPower Electronics, vol. 6, no. 4, pp. 624–629, 1991.

[5] F. Wu, X.-P. Zhang, P. Ju, and M. J. Sterling, "Decentralized nonlinearcontrol of wind turbine with doubly fed induction generator," IEEE Transactions on Power Systems, vol. 23, no. 2, pp. 613–621, 2008.

[6] Sava, G.N.; Costinas, S.; Golovanov, N.; Leva, S.; Duong, M.Q. Comparison of active crowbar protection schemes for DFIGs wind turbines. In Proceedings of the 2014 16th International Conference on Harmonics and Quality of Power (ICHQP), Bucharest, Romania, 25-28 May 2014; pp. 669-673.

[7] Kasem, A.H.; El-Saadany, E.F.; El-Tamaly, H.; Wahab, M. An improved fault ride-through strategy for doubly fed induction generator-based wind turbines. IET Renew. Power Gener. 2008, 2, 201-214.

[8] Duong, M. Q., Leva, S., Mussetta, M., & Le, K. H. (2018). A comparative study on controllers for improving transient stability of DFIG wind turbines during large disturbances. Energies, 11(3), 480.

[9] Duong, M. Q., Nguyen, H. H., Le, K. H., Phan, T. V., & Mussetta, M. (2016, November). Simulation and performance analysis of a new LVRT and damping control scheme for DFIG wind turbines. In 2016 IEEE International Conference on Sustainable Energy Technologies (ICSET) (pp. 288-293). IEEE.

[10] Xie, D., Xu, Z., Yang, L., Østergaard, J., Xue, Y., & Wong, K. P. (2013). A comprehensive LVRT control strategy for DFIG wind turbines with enhanced reactive power support. IEEE transactions on power systems, 28(3), 3302-3310.

[11] Ardjoun, S. A. E. M., Denai, M., & Abid, M. (2019). A robust power control strategy to enhance LVRT capability of grid-connected DFIG-based wind energy systems. Wind Energy, 22(6), 834-847.

[12] Yang, L., Xu, Z., Ostergaard, J., Dong, Z. Y., & Wong, K. P. (2011). Advanced control strategy of DFIG wind turbines for power system fault ride through. IEEE Transactions on power systems, 27(2), 713-722.

[13] Lohde R, Jensen S, Knop A, Fuchs FW. Analysis of three phase grid failure and Doubly Fed Induction Generator ride-through using crowbars. Proceedings of the 12th European Conference on Power Electronics and Applications (EPE 2007), Aalborg, Denmark, September 2007. Xiang, D.; Ran, L.; Tavner, P.J.; Yang, S. Control of a doubly fed induction generator in a wind turbine during grid fault ride-through. IEEE Trans. Energy Convers. 2006, 21, 652-662.

[14] Abad, G.; Rodriguez, M.; Poza, J.; Canales, J. Direct torque control for doubly fed induction machine-based wind turbines under voltage dips and without crowbar protection. IEEE Trans. Energy Convers. 2010, 25,586-588

[15] Yu, L.; Chen, G.C.; Cao, D.P.; Wu, G.X. Low voltage ride-through control of doubly fed induction generator during symmetric voltage sag. Electr. Mach. Control 2010, 14, 1-6.

[16] Pena, R.; Clare, J.; Asher, G. Doubly fed induction generator using back-to-back PWM converters and its application to variable-speed wind-energy generation. IEE Proc. Electr. Power Appl. 1996, 143, 231-241.

[17] Ngamroo, I. (2017). Review of DFIG wind turbine impact on power system dynamic performances. IEEJ Transactions on electrical and electronic engineering, 12(3), 301-311.

[18] Hansen, A. D., Michalke, G., Sørensen, P., Lund, T., & Iov, F. (2007). Co-ordinated voltage control of DFIG wind turbines in uninterrupted operation during grid faults. Wind Energy: An International Journal for Progress and Applications in Wind Power Conversion Technology, 10(1), 51-68.