VOLTAGE RESTORATION CAPABILITY ENHANCEMENT OF PARALLEL DFIG UNITS

Ashwani Kumar Mishra[1], Shashank Rai[2], Pradyumn Chaturvedi[3]

Email:ashwanimishra9117@gmail.com[1], engineer.shashank.rai@gmail.com[2], *pradyumn.c@eee.vnit.ac.in[3]*

[1]M.Tech Scholar, Department of Electrical and Electronics Engineering, Technocrats Institute ofTechnology, Bhopal, India

[2]M.Tech Scholar, Department of Electrical and Electronics Engineering, Technocrats Institute ofTechnology, Bhopal, India

[3]Associate professor, Department of Electrical & Electronics Engineering, National Institute of Technology,Nagpur, India

ABSTRACT:

In this paper application of grid connected Double Fed Induction Generator (DFIG) with and without rotor control is presented. DFIG is a variable speed wind turbine system this means it will generate constant output even under the condition of variable wind speed. In this work performance analysis and harmonic mitigation of two parallel DFIG grid connected system is presented. To obtain the constant output and to reduce the harmonics rotor side converter as well as grid side converter is connected. The converter is designed using voltage source inverter. The inverter control is designed using proportional integral controller. A comparative analysis for load voltage THD is presented using with and without converter.

KEYWORDS: *Double Fed Induction Generator (DFIG), Low Voltage Ride Through (LVRT),Point of Common Coupling (PCC), Voltage source converters (VSC), Voltage Unbalance Factor (VUF), Total Harmonic Distortion (THD).*

1. INTRODUCTION

WPGS has integrated into power system utility to cope up continual load demand with low carbon emission presenting green technology [1]. The WPGS is of fluctuating nature which may the operating conditions of other conventional generating power system. The P and Q are the two main parameters affected due sudden load demand following a fault; wind gust and/or voltage unbalance conditions [2]. In recent past, novel topologies were adopted to make smooth coordination of P and Q transfer pertaining to continuously changing wind speed patterns without affecting other generating units operating parallel by enhancing Low Voltage Ride Through (LVRT) capabilities. DFIG is one such variable speed wind turbine which employs independent rotor side converter which can control the rotor independently [3].

Coordinate control of DFIG units in parallel with network integration is a conflicting process because synchronization of different units is itself complicated with network integration. Therefore, to increase profitability, the network must adaptively control the voltage unbalance factor (VUF) at the PCC; A balance can be made between the performance of the DFIG task and the quality of the PCC control.

In this paper, a PI controller-based converter is designed to support the grid-connected operation of parallel DFIG units. The proposed controller controls the gate parameter as well as the rotor parameter simultaneously. As a result of which the flow of real and reactive power at PCC becomes smooth. The controller integrates the unit with grid and regulates the voltage at PCC also it reduces the harmonics of the system the proposed controller has been tested for constant wind speed as well as variable wind speed operation [4].

This research aims to study various scenario of operation of parallel units of DFIG when connected to a poor grid. The state of the DFIG is that it is designed to operate at various speeds whose output is kept constant by a controller which is the design feature of DFIG. In this work to test operation of parallel units of DFIG two units are considered. The two units are connected at grid bus and at PCC voltage is controlled.

2. DOUIBLY FED INDUCTION GENERATOR (DFIG)

Doubly Fed Induction Generator, as the name suggests got two winding; magnetic field winding and armature winding which are separately connected to external equipments. The working principle is same as all the rotating machines has. Fig-1 shows the constructional feature of DFIG.

AC generator and DFIG have similar structural characteristics, but DFIG is different in that it can operate at variable speed which is why it is as durable as a wind power generation system at high speed. degree of change. DFIG is a combination of four system technologies aerodynamic, mechanical, electromagnetic and electronic.

Due to DFIG's ability to operate under varying wind speed conditions, its application as a wind power generation system is increasing day by day. The principle of operation of the DFIG is as an induction generator with a multiphase winding rotor and a brushed multiphase slip ring assembly to access the rotor windings. As mentioned earlier, the DFIG is powered from two ends, one end of the generator is connected to the mains and the other is to two reverse voltage power converters VSC [6].The VSC is designed using three phase 2 level universal bridge with three arms as shown in figure 1. Both the inverters are linked with Dc link capacitor to stop circulation of leakage current and proper matching of inverters. At both the ends of converter filters are connected. Generator has two windings; one winding is directly connected to the output, and produces 3-phase AC power at the desired grid frequency [7]. The other winding (traditionally called the field, but here both windings can be outputs) is connected to a variable frequency three-phase AC supply. This power input is frequency and phase adjusted to compensate for changes in turbine speed [8].

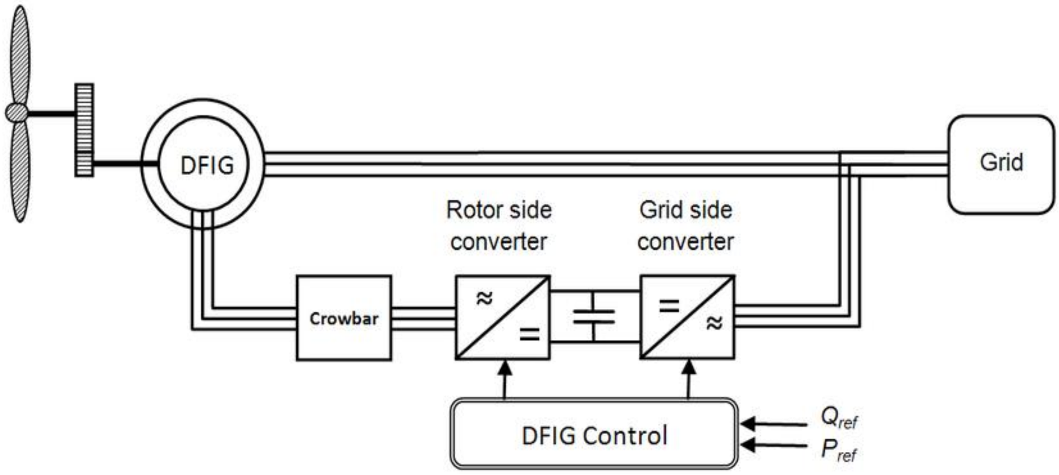

Fig. 1 **Schematic of a DFIG connected to a wind turbine.**

3. PROPOSED WORK

In this paper a weak grid is connected to parallel DFIG units. A grid side controller (GSC) is developed to compensate the voltage unbalance at PCC for autonomous operation of multiple DFIG units. In this paper two DFIG units are considered for parallel operation. The performance analysis for both constant speed and variable speed for the parallel DFIG units are studied under following cases;

Case 1(Figure 2); In this case electrical distance between the DFIG and the PCC is considered negligible hence the PCC voltage is replaced with the DFIG stator voltage. Rotor side converter (RSC) regulates the average stator active and reactive power outputs, and the GSC is controlled to keep the dc-link voltage stable. Unbalanced PCC voltage can be caused for various reasons, i.e., unbalanced local loads, unbalanced transmission line impedance, fault in any part of the system and so on [17].

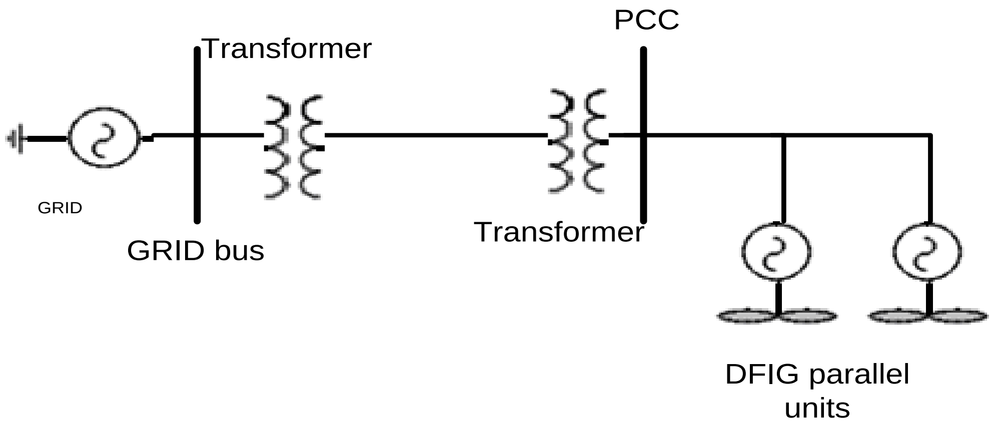

Fig. 2 Single line diagram of grid connected DFIG

Case 2 (Figure 3); In this case electrical distance between the DFIG and the PCC is considered. One transformer is connected between grid and 30 km line and another is connected between line and DFIG. The voltage of PCC is not same as DFIG stator voltage and any deviation in PCC voltage may affect the DFIG performance and vice versa. Hence a controller is customized which can control the VUF at both the ends.

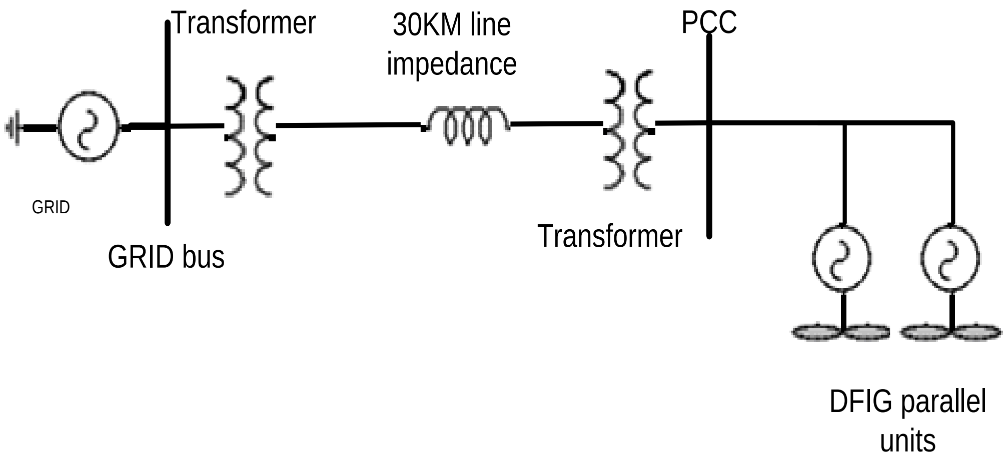

Fig. 3 Single line diagram of grid connected DFIG considering electrical distances

In both the above mentioned cases the system performance is analyzed with and without grid side and rotor side converter and results shows that the designed converter controls the voltage unbalance smoothly. The converter is customized using abc-dq transform, PLL, PI controller and active filtering element. The sinusoidal input is fed to abc-dq transform where three phase sinusoidal signal is converted into equivalent and two phase signal which simplifies the control design. The phase lock loop synchronizes the controlled voltage signal with the grid. The PI control generates the equivalent gain function so that triggering of the universal bridge can be controlled. The harmonic or distortion can be filter out using active filter. Here inductance and capacitance of suitable rating is connected. The result for the cases mentioned is discussed in next section.

4. SIMULATION RESULTS

In this chapter results for two operating conditions are presented to test the proficiency of the proposed work considering electrical distance from the grid;

1. Simulation results for Parallel operation of DFIG units without PI controller.
2. Simulation results for Parallel operation of DFIG units with PI controller.

In this research both RSC and GSC is controlled by controlling triggering of three phase universal bridge converter. This is done by applying sinusoidal PWM technique. One of the important elements of this research work is phase lock loop (PLL). PLL is a controller used to synchronize set of variable at different frequencies with the reference three-phase sinusoidal signals. Automatic Gain Control enables the input (phase error) of the PLL regulator to scale according to the input signals magnitude. The simulation model of the parallel DFIG unit with grid connected operation without controller is shown in figure 4 and the simulation model of the system with controller is shown in figure 5. The design parameters for the model is shown in table 1.

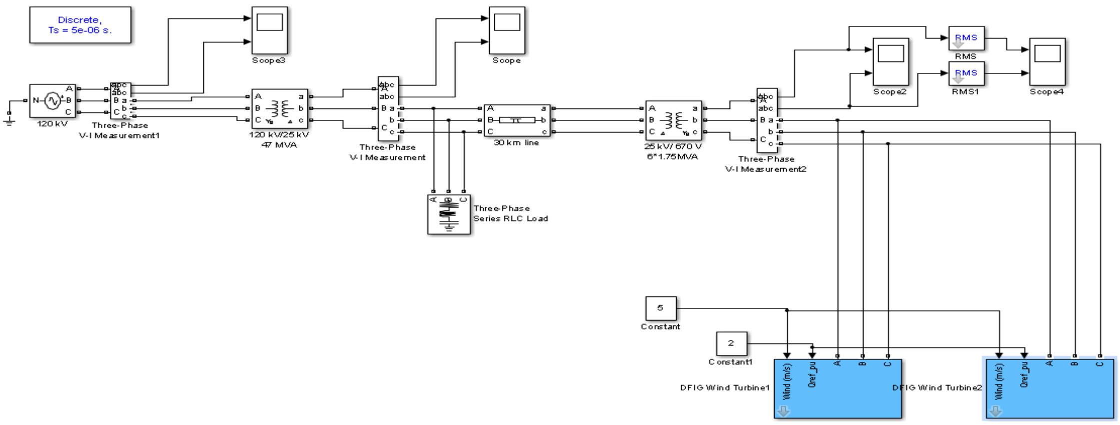

Fig. 4Simulation model without controller

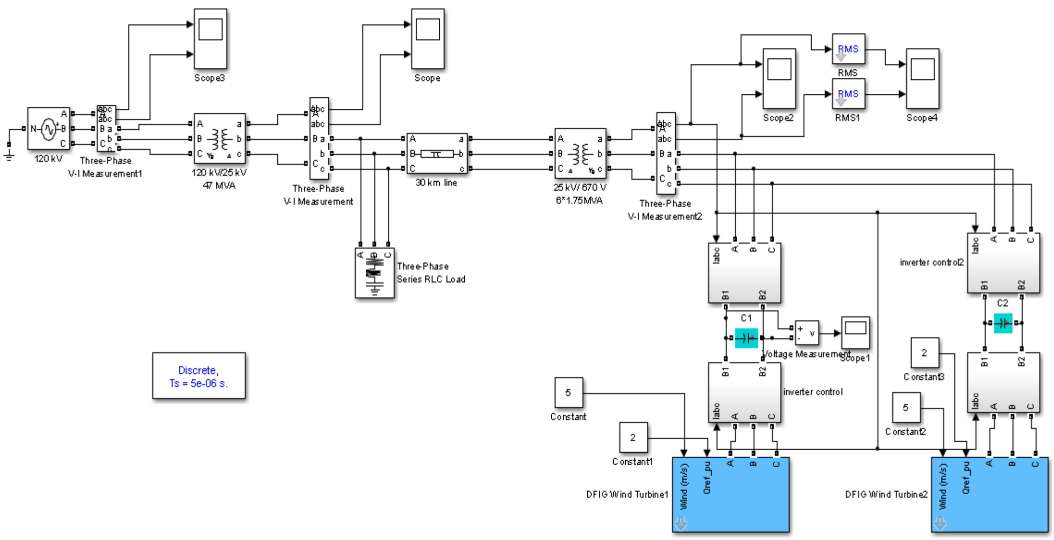

Fig. 5 Simulation model with the proposed controller installed

Table 1.Design parameters

DFIG unit parameter selection		Grid unit parameter selection	
PARAMETER	RATINGS	PARAMETER	RATINGS
DFIG rating each	1.5 MW	Grid voltage	120KV
Stator voltage	570 V	Transformer	6*1.75MVA
Frequency	50Hz	Line resistance	0.11 ohm
Lf	4.41mH	Line inductance	1.05mH
Cf	0.5e-6	Kp	0.04
DC-link capacitance	900e-6	Ki	500

Simulation results for the grid connected parallel DFIG units at the point of common coupling without controller for the voltage and current is shown in figure 6. The THD of the PCC voltage at this condition is shown in figure 7.

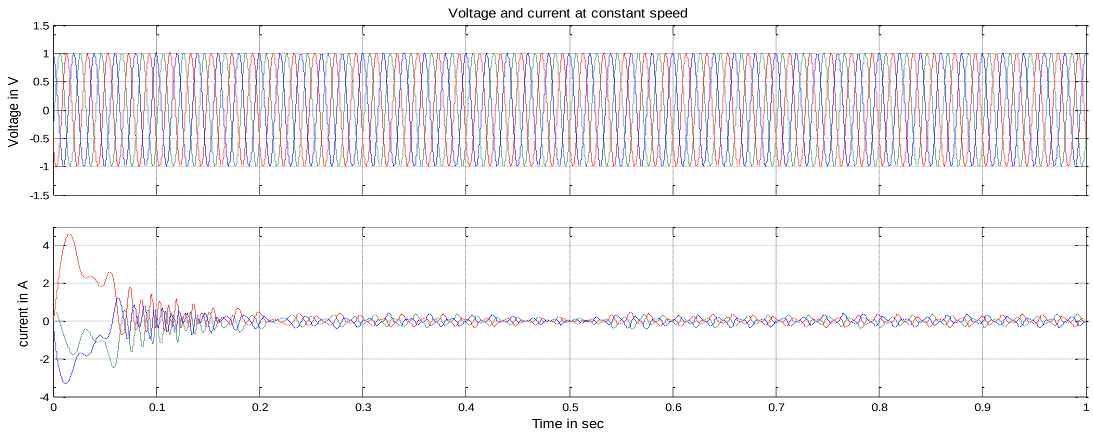

Fig. 6 Voltage and current at PCC for Parallel operation of DFIG units without PI controller

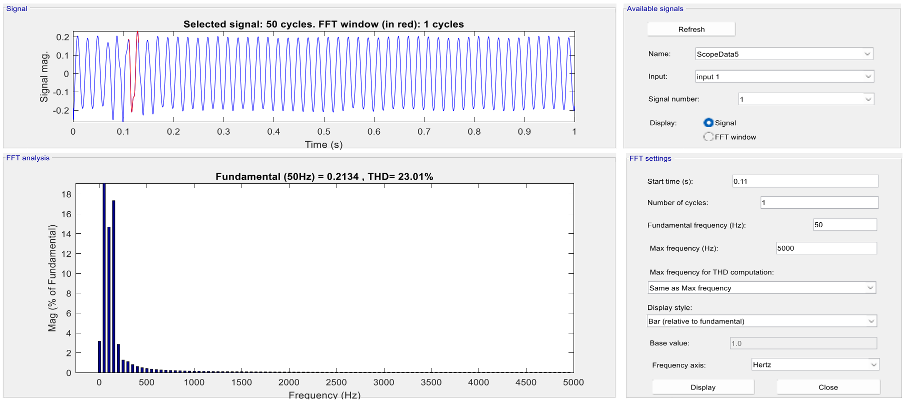

Fig. 7 THD of voltage at PCC for Parallel operation of DFIG units without PI controller at constant speed

Simulation results for the grid connected parallel DFIG units at the point of common coupling with the proposed controller for the voltage and current is shown in figure 8. The THD of the PCC voltage at this condition is shown in figure 9.

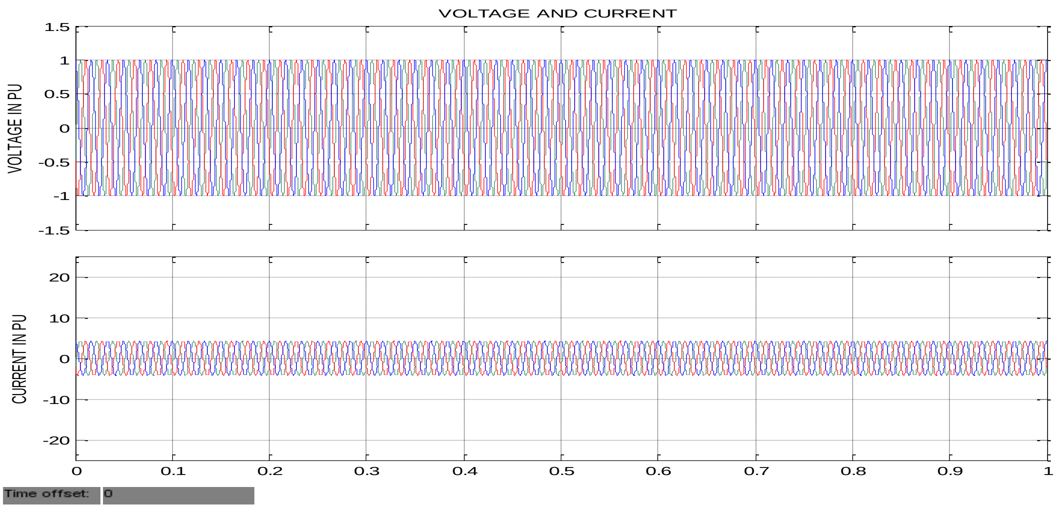

Fig. 8 Voltage and current at PCC for Parallel operation of DFIG units with PI controller at variable speed.

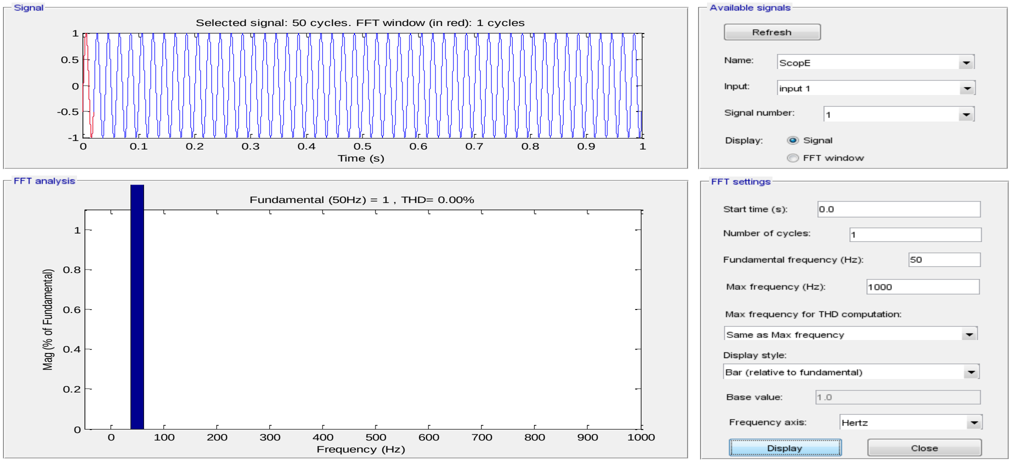

Fig. 9 Voltage THD at PCC for Parallel operation of DFIG units with PI controller at variable speed

From the results it can be seen that without rotor side control, PCC voltage is reduced a lot and does not match the rated value of the grid. Also, the THD of the PCC voltage is 23 %, which is very high. When the rotor as well as grid converter is connected in the DFIG unit, it maintains the constant rated voltage at PCC as well as THD is very low having 0.1%. hence the proposed converter is capable of maintaining power quality at rated value.

5. CONCLUSION

A flexible compensation strategy for parallel DFIGs is presented when connected to grid for voltage restoration capability enhancement. In this work a PI control designed to control DFIG units as well as grid profile which could continuously control voltage at PCC. Thus, the flexible tradeoff between the balanced output current and the balanced PCC voltage could be achieved.

The system has been studied for various operating conditions considering electrical distances of transmission line and ignoring the same. The RSC and GSCs as per there capability automatically compensate the PCC voltage and stator voltage of the DFIG units capacity without real-time communication. The theoretical analysis and the simulation have shown the effectiveness and good control performance of the proposed strategy.

REFERENCES

[1] Nian, H., & Pang, B. (2018). Stability and power quality enhancement strategy for DFIG system connected to harmonic grid with parallel compensation. IEEE Transactions on Energy Conversion, 34(2), 1010-1022.

[2] Okedu, K. E. (2016). Enhancing DFIG wind turbine during three-phase fault using parallel interleaved converters and dynamic resistor. IET Renewable Power Generation, 10(8), 1211-1219.

[3] Naidu, R. P. K., & Meikandasivam, S. (2020). Power quality enhancement in a grid-connected hybrid system with coordinated PQ theory & fractional order PID controller in DPFC. Sustainable Energy, Grids and Networks, 21, 100317.

[4] Bui, V. T., Hoang, T. T., Duong, T. L., & Truong, D. N. (2019, July). Dynamic voltage stability enhancement of a grid-connected wind power system by ANFIS controlled static var compensator. In 2019 International Conference on System Science and Engineering (ICSSE) (pp. 174-177). IEEE.

[5] Dyanamina, G., & Kumar, A. (2016, November). Performance improvement of grid connected DFIG fed by three level diode clamped MLI using vector control. In 2016 IEEE Region 10 Conference (TENCON) (pp. 560-565). IEEE.

[6] Rashid, G., & Ali, M. H. (2017). Fault ride through capability improvement of DFIG based wind farm by fuzzy logic controlled parallel resonance fault current limiter. Electric Power Systems Research, 146, 1-8.

[7] Islam, M. R., Huda, M. N., Hasan, J., Sadi, M. A. H., AbuHussein, A., Roy, T. K., & Mahmud, M. A. (2020). Fault ride through capability improvement of DFIG based wind farm using nonlinear controller based bridge-type flux coupling non-superconducting fault current limiter. Energies, 13(7), 1696.

[8] Jerin, A. R. A., Kaliannan, P., & Subramaniam, U. (2017). Improved fault ride through capability of DFIG based wind turbines using synchronous reference frame control based dynamic voltage restorer. ISA transactions, 70, 465-474.