CONTROLLING THE STATOR FLUX LINKAGES TO IMPROVE DYNAMIC BEHAVIOR OF GRID CONNECTED DFIG BASED WIND TURBINES UNDER LVRT CONDITIONS

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ABSTRACT

This paper proposes a comprehensive study of the LVRT of grid connected DFIG-based wind turbines. It provides a detailed investigation of the transient characteristics and the dynamic behavior of DFIGs during symmetrical and asymmetrical grid voltage sags. A detailed theoretical study supported by computer simulations is provided. A new rotor side control scheme for DFIG-based wind turbines to enhance its LVRT capability during severe grid voltage sags. The proposed control strategy focuses on mitigating the rotor-side voltage and current shock during abnormal grid conditions, without any additional cost or reliability issues.

Keywords: Wind Turbine, LVRT-Gird, DFIG

INTRODUCTION

In recent years, there has been a huge increase in global demand for energy as a result of not only industrial development, but also population growth. Consequently, the rise in consumption of traditional fossil fuels has led to many serious problems such as energy shortages, pollution, global warming, the shortfall of traditional fossil energy sources, and energy insecurity. These factors are driving the development of renewable energy technologies, which are considered an essential part of a well-balanced energy portfolio. Wind power is thought to be the most promising near-term alternative energy. As renewable energy sources grow in popularity, wind power is currently one of the fastest growing renewable sources of electrical energy. More than 54 GW of wind power was installed in 2016. With the increased presence of wind energy in the power system over the last decade, a serious concern about its influence on the dynamic behavior of the electric power network has arisen. Therefore, it becomes essential that grid-connected wind turbines behave similarly to conventional power plants and support the power network during normal and abnormal grid conditions. This has required many countries to develop specific grid codes for operation and grid integration of wind turbines. Among these grid codes, two main issues are of special concern for engineers in the area of power and energy, active and reactive power control in normal conditions and Low-Voltage Ride-Through (LVRT) capability during grid faults, or more succinctly, Fault Ride-Through (FRT) capability. In addition to the progress made in the creation of adequate grid codes for the proper utilization of wind energy, a significant improvement has been achieved in the design and implementation of robust energy conversion systems that efficiently transform wind energy. The Doubly-Fed Induction Generator (DFIG)-based wind turbine has become one of the most favorable choices in wind power generation. This is due to the prominent advantages that it has compared to the other energy conversion systems.

LITERATURE REVIEW

[2] "Comprehensive Analysis of the Dynamic Behavior of Grid-Connected DFIG-Based Wind Turbines under LVRT Conditions" Power generation and grid stability have become key issues in the last decade. The high penetration of large capacity wind generation into the electric power grid has led to serious concerns about their influence on the dynamic behavior of power systems. The Low-Voltage Ride-Through (LVRT) capability of wind turbines during grid faults is one of the core requirements to ensure stability in the power grid during transients. The doubly-fed induction generators (DFIGs) offer several advantages when utilized in wind turbines, but discussions about their LVRT capabilities are limited. This paper presents a comprehensive study of the LVRT of grid-connected DFIG-based wind turbines. It provides a detailed investigation of the transient characteristics and the dynamic behavior of DFIGs during symmetrical and asymmetrical grid voltage sags. A detailed theoretical study supported by computer simulations is provided.

[6] "Grid Connection Requirements and Solutions for DFIG Wind Turbines" As the number and size of wind farms continue to grow, many countries have established or are developing a set of specific requirements (i.e., grid codes) for operation and grid connection of wind farms. The objective of these grid codes is to ensure that wind farms do not adversely affect the power system operation with respect to security of supply, reliability and power quality. This paper reviews major grid code requirements for wind farms, and investigates various technologies developed by and solutions proposed by researchers and wind turbine manufactures in order to meet these requirements. In addition, some of the authors' work on these issues are discussed and demonstrated by simulation studies.

[8] "Overview of different wind generator systems and their comparisons" presents the LVRT characteristic, reviews the effect that voltage dips have on the operation of the different wind generator topologies and considers the technical requirements for its realization. System studies demonstrate its benefits while establishing a relationship between the shape of the characteristic and the strength of the interconnection. Results suggest that for stronger systems the profile may be excessive whereas for weak interconnections the demands placed upon the manufacturer are likely warranted.

[13] "Effect of low voltage ride through (LVRT) characteristic on voltage stability" The number of wind installations has grown worldwide at unprecedented rates in recent years. As well, the average size of the installations has increased due to the advent of larger capacity machine, variable speed technology, and an increasing number of off-shore sites. This raises the concern that widespread tripping of wind

generators following disturbances could lead to propagation of transient instabilities and could potentially cause local or system wide blackouts. This has provoked many utilities to adopt low voltage ride-through (LVRT) for wind turbines. The requirement places an added interconnection cost on the manufacturer and will influence the overall financing of the project.

CONVENTIONAL SYSTEM

The DC bus voltage and torque waveforms are regulated within limits. The DC bus voltage oscillation is less than 100 volts, which falls within the safe operation area. The torque waveform doesn't have offset and its oscillation is damped out gradually. The conventional control has active power flow from the turbine to the rotor side on DC magnetic field, which serves to explain the torque offset in Fig. 1.1. However, with the proposed control method, the rotor DC voltage and current are perpendicular to one another, which do not introduce any active power to the rotor side.

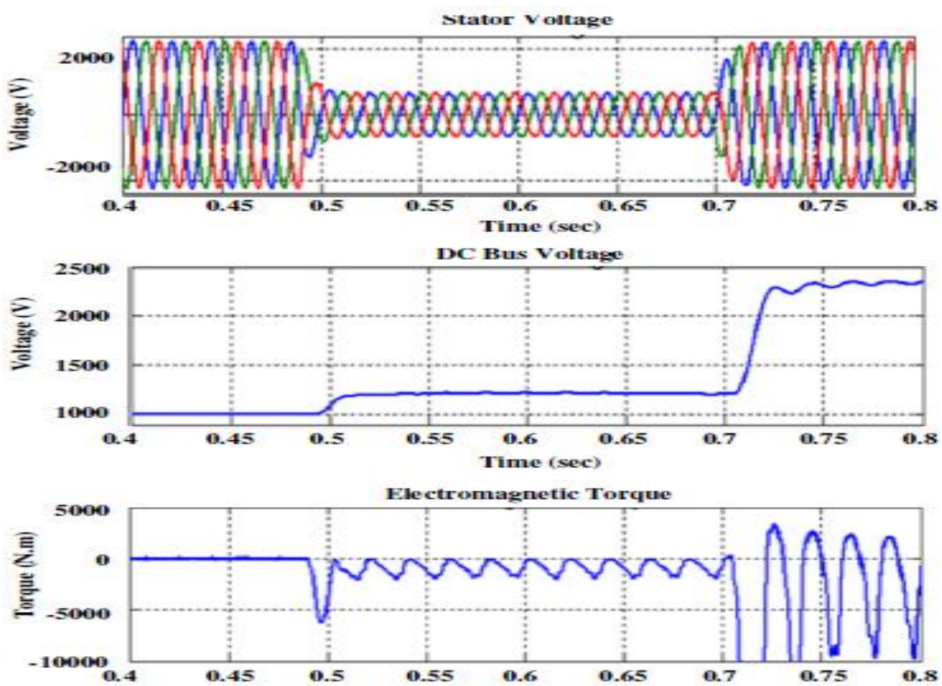


Fig 1.1 DFIG DC bus voltage and torque during fault with the conventional vector control strategy.

PROPOSED SYSTEM

This proposes a LVRT of grid-connected DFIGs. It gives a detailed investigation of the dynamic behavior of DFIG-based wind turbines during different types of grid voltage sags. The analysis explicate that the main reason for the dynamic response of the DFIG to a grid voltage transient is the DC (natural) stator flux linkage component, which is a transient component that is fixed to the stator. It appears as the magnetic field as continuous and maintain no discontinuity in the state variables of the generator. The DC stator flux linkage component induces oscillations of rotor voltages in the rotor circuit. Depending on the severity of the sag the voltage induced by natural flux can be much higher than the rotor rated voltage.

BLOCK DIAGRAM

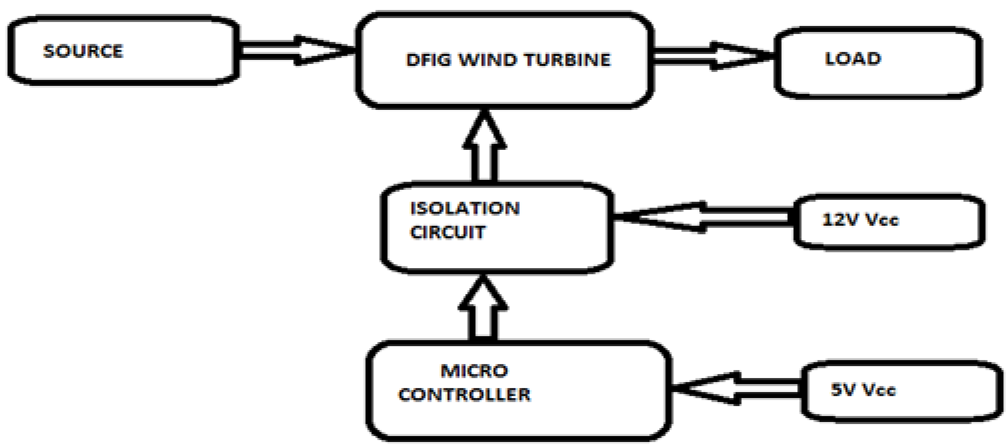


Fig 1.2 Block Diagram

CIRCUIT DIAGRAM

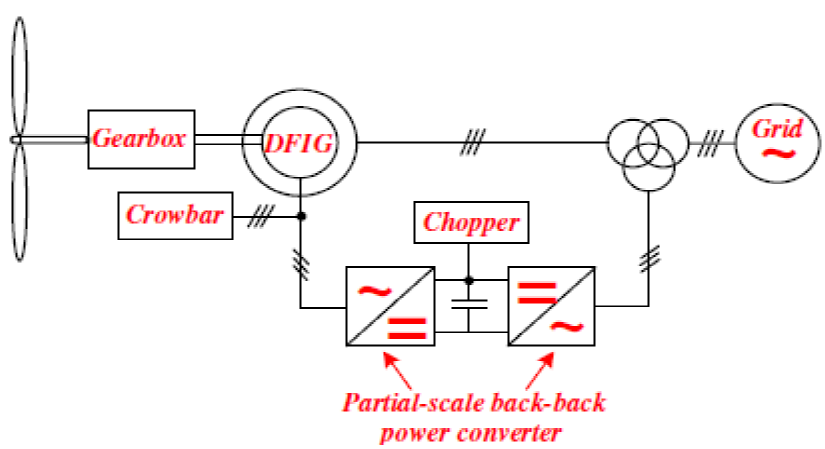


Fig 1.3 circuit diagram

CONTROL STRATEGY

The main objective of the control strategy is to accelerate the decay of the DC component of the stator flux linkage. The changing rate of the stator DC flux linkage is associated with the stator resistance, transmission line stray resistance and the DC component of the stator winding current. Therefore, there are two ways to control the stator DC flux linkage:

- Changing the resistance of the stator winding.
- Applying active control to the DC component of the stator winding current.

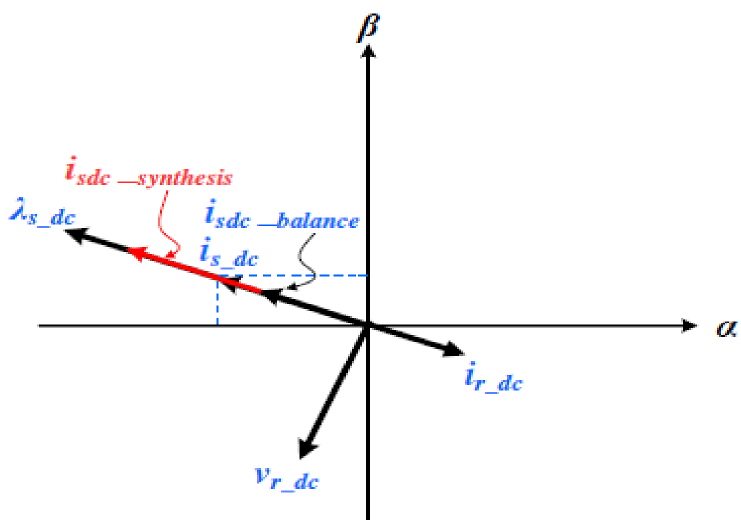


Fig 1.4 Proposed rotor current control

The normal current control in slip frequency and the active current control in rotor speed frequency for forced decay of stator DC flux together. the controlled current vector diagram for forced decay of stator DC flux. Fig 1.4 Illustrates Accelerate and eliminate the stator DC flux component means to maximize the stator DC current. Here we attempt to maximize the DC damping effect by aligning the rotor current in rotor frequency to the opposite direction of the stator DC flux. In this manner, the rotor current will increase the stator current and speed up the DC flux decay for the stator.

The proposed and conventional control strategies are also compared in terms of DC bus voltage and rotor electromagnetic torque. Fig. 1.1 shows those waveforms with a conventional control strategy and Fig. 1.5 shows the novel proposed control strategy. In Fig. 1.5, the DC bus is overcharged during fault and is far beyond the maximum voltage limit. The torque waveform with oscillation superimposed has a constant offset, as shown in Fig. 1.1. Torque offset is generated by the DC magnetic field and the oscillation is due to AC and DC magnetic field interaction.

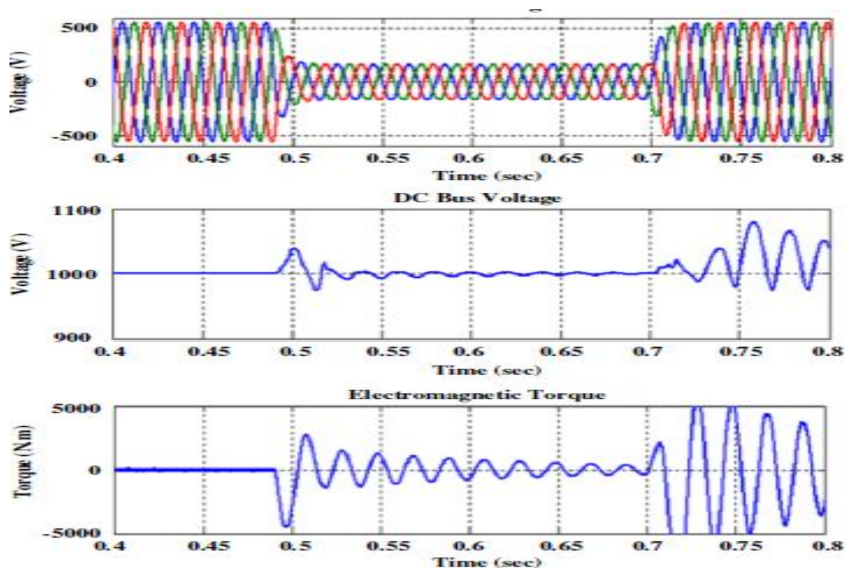
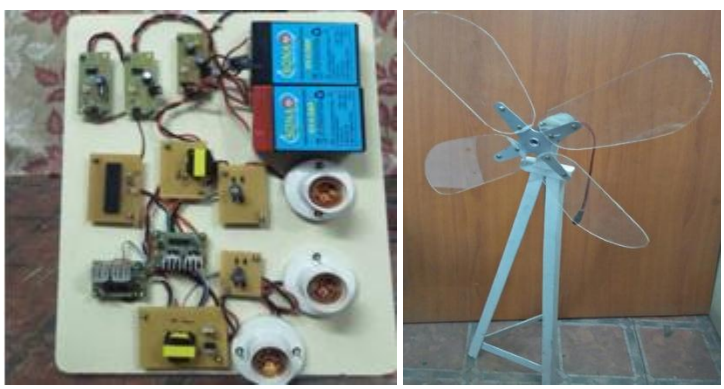


Fig 1.5 DFIG DC bus voltage and torque during fault with the proposed

Control strategy

OUTPUT RESULT



	SIMULATION RESULT	HARDWARE RESULT
WIND GENERATE OUTPUT	12V	12V
GEAR BOX	1:20	1:300
INPUT VOLTAGE	12V	12V
INPUT AMPS	25amps	4.5amps
OUTPUT VOLTAGE	500V	230V
OUTPUT PHASE	3 PHASE	3 PHASE

ADVANTAGES

- Good low voltage raid through capabilities
- Better fault raid through capabilities

CONCLUSION

It provides a detailed investigation of the dynamic behavior of DFIG-based wind turbines during different types of grid voltage sags. The analysis shows that the main reason behind the dynamic response of the DFIG to a grid voltage transient is the DC (natural) stator flux linkage component, which is a transient component that is fixed to the stator. It appears as the magnetic field and is continuous and there is no discontinuity in the state variables of the generator. The DC stator flux linkage component induces high oscillatory rotor voltages in the rotor circuit. Depending on the severity of the sag, the voltage induced by natural flux can be much higher than the rotor rated voltage. Therefore, this will result in the saturation of the rotor converter. In regards to the recurring grid faults, the analysis shows that the voltage recovery of the first grid fault also introduces the stator natural flux. If this stator natural flux still exists when the subsequent grid fault occurs, the stator natural flux produced by the voltage recovery and by the next voltage sag may be superposed. This may cause the DFIG to fail to ride through the recurring faults, even with the assistance of the rotor side crowbar. As a result, the FRT strategies designed for single grid faults do not provide the best solution for the FRT of the DFIGs under recurring grid faults. This paper also presents a detailed description of the most cited and commonly used LVRT solutions for DFIG-based wind turbines by improving the RSC control strategies (active methods). It describes the basic operation principle, as well as advantages and disadvantages of each proposed solution. Finally, a new rotor-side control scheme to enhance the LVRT capability of DFIGs-based wind turbines during severe grid voltage sags is proposed. The control strategy is directed at mitigating the rotor-side voltage and current shock during abnormal grid conditions, without any additional cost or reliability issues.

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