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Low Voltage Ride-Through Protection Techniques For DFIG Wind Generation

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Abstract: Due to the rapid increase of penetration level of wind generation connected directly to the bulk power system grid, a new grid codes have been issued that require Low-Voltage Ride Through (LVRT) capability for wind turbines so they can remain online and support the electric grid post fault events instead of instantaneous tripping. This capability will increase the stability of the network and reduce generation shortage after the fault clearance. Each utility has its own grid codes for this LVRT. There are many types of wind generators, and currently the Doubly Fed Induction Generator (DFIG) is the most popular type among the leading wind turbine (WT) manufacturers. In this work LVRT method for protection of DFIG during LV events are implemented and compared. The methods are Crowbar, DC Chopper, series dynamic resistances, and hybrid methods that combine DC chopper with Crowbar and DC chopper with series dynamic resistances respectively. These methods were tested under different types of fault including symmetrical and unsymmetrical faults and their performances were compared.

Keyword: DC, LV, LVRT, WT.

1. Introduction:

The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power supply reliability and quality. In addition, liberalization of the grids leads to new management structures, in which trading of energy and power is becoming increasingly important. The power electronics technology plays an important role in distributed generation and in integration of renewable energy sources into the electrical grid, and it is widely used and rapidly expanding as these of applications become more integrated with grid-based systems. During the last few years, power electronics has been undergoing a fast evolution, mainly due to two factors. The first one is the development of fast semiconductor switches, which are capable of switching quickly and handling high powers. The second factor is the introduction of real-time computer controllers that can implement advanced and complex control algorithms. These factors together have led to the development of cost-effective and grid-friendly converters. In this paper, new trends in power electronics technology for the integration of renewable energy sources and energy storage systems are presented. we describe current technology and future trends in variable speed wind turbines. Wind energy has been demonstrated to be both technically and economically viable. It is expected that current developments in gearless energy transmission with power electronics grid interface will lead to a new generation of quiet, efficient, and economical wind turbines. we present power-conditioning systems used in grid connected photovoltaic generation plants. The continuously decreasing prices for PV modules lead to the increasing importance of cost reduction of the specific PV converters. Energy storage in an electricity generation and supply system enables the decoupling of electricity generation from demand. In other words, the electricity that can be produced at times of either low demand low generation cost or from intermittent renewable energy sources is shifted in time for release at times of high demand, high generation cost or when no other generation is available. Appropriate integration of renewable energy sources with storage systems allows for greater market penetration and result in primary energy and emissions savings.

2. Related Work:

Protection of a doubly fed induction generator (DFIG) implemented for both wind farm and electricity structures could be very important for transient balance. Crowbar circuits had been used for safety of DFIGs; but, a crowbar circuit is insufficient in phrases of brief stability. Therefore, in this have a look at, the passive Low voltage Ride Through (LVRT) functionality method as well as the energetic LVRT functionality approach have been advanced for the motive of transient analysis of the DFIG. The performances of DFIG fashions with and without active LVRT were compared by **M. Kenan Dösog˘lu, (2016) [8]**. Modelling changed into performed in a MATLAB/SIMULINK surroundings. Comparisons have been made between behaviours of three-segment fault and a couple of-segment fault structures and among rotor dynamic systems and those without a rotor dynamic. Parameters blanketed DFIG output voltage, energetic electricity, pace, electrical torque versions and d–q axis stator current versions. In addition, a 34.5 kV bus voltage was tested. It become discovered that the machine became strong in a quick time when the lively LVRT turned into incorporated into the reduced order DFIG model.

Doubly-fed induction generator (DFIG)-based wind turbines utilise small-scale voltage sourced converters with a limited overcurrent face up to functionality, which makes the DFIG-based wind turbines very at risk of grid faults. Often, modern-day DFIG systems hire a crowbar protection on the rotor circuit to guard the rotor side converter (RSC) at some point of grid faults. This technique converts the DFIG to a squirrel cage induction generator, which does now not follow the new grid codes. The current grid codes need wind mills to live linked to the software grid all through and after electricity machine faults, in particular in excessive penetration degree of wind energy. Furthermore, the crowbar switch is steeply-priced. **Seyed Behzad Naderi,(2017) [9]** proposed a novel DC-hyperlink switchable resistive-type fault modern limiter (SRFCL) to enhance the LVRT functionality of the DFIG. The proposed SRFCL is hired in the DC facet of the RSC. The SRFCL solves crowbar safety activation troubles and removes subsequent complications inside the DFIG machine. **Seyed Behzad Naderi,(2017) [9]** proposed SRFCL does not have any tremendous impact on the general overall performance of the DFIG throughout ordinary operation. Whenever the fault, whether symmetrical or asymmetrical, occurs, the SRFCL no longer best limits rotor over-currents however also prevents rotor speed acceleration and restricts high torque oscillations even at some stage in zero grid voltage, as endorsed through some grid codes. To show the powerful operation of the SRFCL on the RSC fault modern-day hindrance, analytical analysis is carried out in every switching c program languageperiod.

Doubly-fed induction generator (DFIG)-based totally wind mills utilise small-scale voltage sourced converters with a restrained overcurrent resist functionality, which makes the DFIG-based wind turbines very liable to grid faults. Often, modern DFIG structures hire a crowbar protection on the rotor circuit to shield the rotor aspect converter (RSC) during grid faults. This method converts the DFIG to a squirrel cage induction generator, which does not comply with the new grid codes. The current grid codes want wind mills to live connected to the software grid at some point of and after electricity device faults, particularly in excessive penetration stage of wind power. Furthermore, the crowbar switch is pricey. **Seyed Behzad Naderi,(2017) [10]** proposed a novel DC-link switchable resistive-kind fault current limiter (SRFCL) to enhance the LVRT functionality of the DFIG. The proposed SRFCL is employed inside the DC facet of the RSC. The SRFCL solves crowbar protection activation troubles and eliminates next headaches in the DFIG system. The proposed SRFCL does no longer have any significant effect on the general performance of the DFIG for the duration of ordinary operation. Whenever the fault, whether symmetrical or asymmetrical, takes place, the SRFCL now not most effective limits rotor over-currents however also prevents rotor speed acceleration and restricts high torque oscillations even during 0 grid voltage, as encouraged with the aid of some grid codes.

Doubly fed induction generator (DFIG) is determined to be the maximum successful wind electricity generator in previous couple of decade. The direct coupling of stator makes the generating system suffering from the disturbance. Previously mills had been allowed to disconnect on the prevalence of a fault. However, disconnection makes the complete grid volatile. Grid code demands the generator to remain linked as nicely desires to meet the operating irregularity together with rotor current, stator current and dc-hyperlink voltage. **Shivundu Vats, (2018) [11]** proposed scheme capable of restricts those uncertainties and makes guarantee of converters, rotor circuit and dc-link capacitor protection. The proposed technique consists of energetic manipulate scheme the use of demagnetizing manipulate and passive manage scheme consists of the collection damping resistor (SDR).

In contemporary strength systems with tremendous penetration of wind-turbines (WTs), improvement of low voltage ride via (LVRT) capability of WTs geared up with doubly-fed induction mills (DFIGs) is an important issue. Thus, **Jackson J. Justo,(2019) [12]** proposed a low voltage trip through (LVRT) method, which include of a capacitor linked in collection with an inductor both linked in parallel to a resistor. The configuration is then connected to a small collection resistor via a pair of antiparallel-Thyristors. The circuit and its switching manipulate scheme of the proposed LVRT circuit are designed to: decrease the transition instances, hold the RSC connection to the rotor-windings, and decrease oscillations of dc-hyperlink voltage. In this case, the capacitor is entitled to dispose of ripples generated inside the rotor voltage while the inductor reduces the ripple in rotor modern-day. Different fault situations had been studied to validate the performance of the proposed scheme the usage of MATLAB/Simulink platform. Comparative outcomes and evaluation are provided with traditional LVRT techniques. This paper proposed a low voltage trip through (LVRT) scheme to decorate the fault experience-via capability of the DFIG based WTs at some stage in transient-country.

3. Methodology:

The schematic diagram of the proposed LVRT configuration to provide continuous operation during the PSFs for the DFIG is shown in Fig. 1. To improve the ride-through capability of the DFIG during the PSFs, the SRFCL is connected in series with the RSC (between the RSC and the DC link capacitor), as shown in Fig. l. The suggested SRFCL is composed of three main parts, which are described as follows: 1) A diode bridge rectifier that consists of D_1 to D_4 diodes. 2) A non-super-conductor magnet (copper coil) that is represented by a resistor r_d and an inductance L_d. 3) A parallel connection of a fu lly controllable semiconductor switch (SS), such as *IGBT*, *IGCT etc*., and a discharging resistor (*r*) that are connected in series with the DC inductance.

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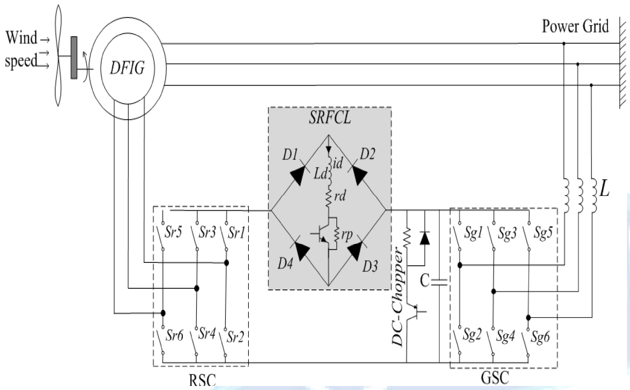

Fig. 1. The proposed fault ride through configuration for the DFIG-based wind turbine during various power system faults.

With this arrangement, the rotor transient over-currents are effectively limited at the time ofthe occurrence of the fault and its clearance, thanks to the SRFCL. In Fig. 1, the DC inductance does not have a significant impact on the normal operation of the DFIG. 3But, when a fault occurs, the DC inductance effectively suppresses *dildt* initiated in the first moments of the fault (which is significantly higher in the first cycle) and also limits the rotor over-current successfully during the fault period. It should be noted that the DC link current (i_{dc}) , is a periodic DC current and its value depends on the switching pulses of the RSC and the rotor currents. So, in Fig. 3.1, utilising just an inductance without a rectifier diode-bridge in series with the RSC causes a voltage drop due to Ldi/dt across the inductance in the DC link and, as a result, disturbs the normal operation of the back-to-back connected VSCs, as well as the DFIG. 3To solve this problem and to provide the DC route for the DC inductance current (i_d) , the rectifier diode-bridge is utilised in the proposed SRFCL as shown in Fig. 1. Overall, by applying the proposed SRFCL, the DFIG can ride through the voltage sag during the fault. In the proposed LVRT configuration, the resistor in parallel connection with the SS is employed to consume the excess active power of the generator during the fault. Therefore, the r_p can provide a balance between input active power to the turbine and output power from the generator during the fault. The DFIG-based wind turbine may have a DC-chopper installed at the DC-link [2]. This module not only protects the DC- link from over-voltage during the fault but it can also enhance overall system performance during the normal operation, especially when there is an imbalance between the active power of the RSC and the GSC [2]. Meanwhile, the limited rotor fault current by the SRFCL reduces the charging current to the DC-link capacitor. The overall structure ofthe control circuits for the rotor side and the gird side converters are shown in Fig. 32. In the rotor side converter, the active power control P_{actual} is based on the wind conditions during the normal operation. P_{ref} *is* calculated with regard to maximum power point tracking (MPPT) and as a result, the d-axis reference current of rotor i_{dr} is obtained. In the gird side converter, the DC link voltage $E_{dc,actual}$ is compared to the reference value $E_{dc,ref}$ In the DC-link voltage control and the grid side current control, PI controllers are utilized for regulation. In addition, the reactive power Q_{actual} in both the rotor side and the grid side converters is directly regulated by reference value, Q_{ref} The control circuit of the proposed SRFCL is shown in Fig. 33. In the normal operation of the power system, the SS is closed and bypasses the r_p. Therefore, the SRFCL does not have any eff ect on the normal operation of the DFIG. 3Furthermore, in this condition, by selecting the proper value for the L_d, it is possible to achieve a nearly constant DC current through the DC inductance. It is evident that increasing the inductance of the L_d decreases the ripple of i_d. This leads to a short circuit of the L_d during the steady state operation. In the meantime, when the fault occurs in the power system, the DC inductance prevents *dildt* at the first moment of the fault. If the fault lasts for a long time, the current through the DC inductance will increase. When the DC inductance current reaches to a threshold value, I_C, the SS is switched off and the r_p, evacuates the L_d. In addition, when the DC inductance current decreases below the value of I_C, the control circuit turns on the SS. Consequently, by turning on and turning offthe SS, the i_{dc} remains limited during the fault period. By using a suitable value for the r_p, it can be ensured that the i_d is limited to the I_C. In this condition, the excess active power ofthe generator will be absorbed in the DC inductance. As a result, the SRFCL prevents rotor speed acceleration. Moreover, by consuming the active power during the fault, the r_p mitigates severe electrical torque oscillations at the time ofthe occurrence and the clearance ofthe fault. It is clear that the proposed SRFCL can increase the life ofthe turbine shaft and the gearbox

4. Result and Discussion:

Consists of the following elements with different details of modeling level which depend on the study type Wind Speed Model, Aerodynamic Model of the Turbine, Model for the Shaft coupling and gearbox, Generator Model, Models for the power electronic circuits if any (Inverter/Converters), Controller models, and Protection system. Figure 2 shows the overall DFIG wind generation system. In DFIG turbines, the induction generator is a wound-rotor induction machine. The stator is directly connected to the grid while the rotor is connected through a back-to-back power converter. Because only part of the real power output flows through the rotor circuit, the power rating of the converter need only be about 25% - 30 % of the rated turbine output [1]. The grid side converter is connected to the grid via three chokes to filter the current harmonics. A control system is employed to regulate the rotor frequency (and thus the voltages and currents in the rotor) to extract the maximum possible power from the wind. Modeling of the DFIG consists of modeling of the Machine, the rotor-side converter (RSC), the grid-side converter (GSC) schemes, the control system and the protection system.

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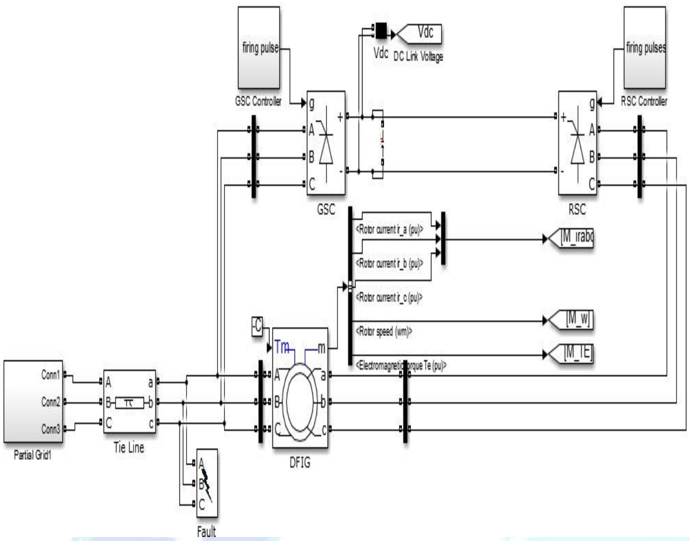

Fig. 2: Schematic diagram of DFIG WTGs Control structure without protection scheme

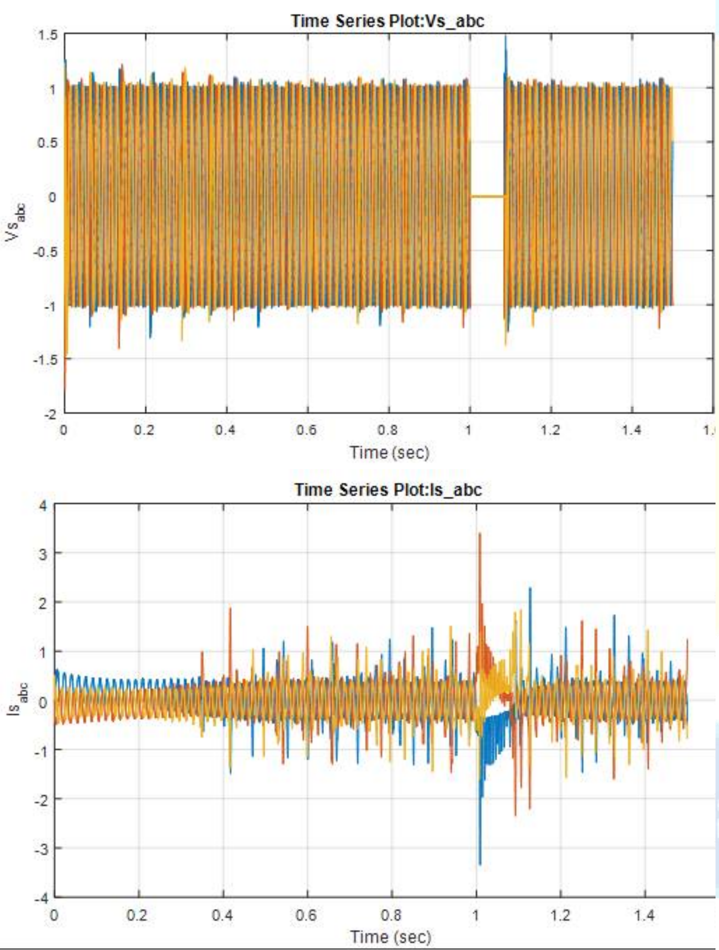

Fig 3. Stator voltage and current without protection scheme

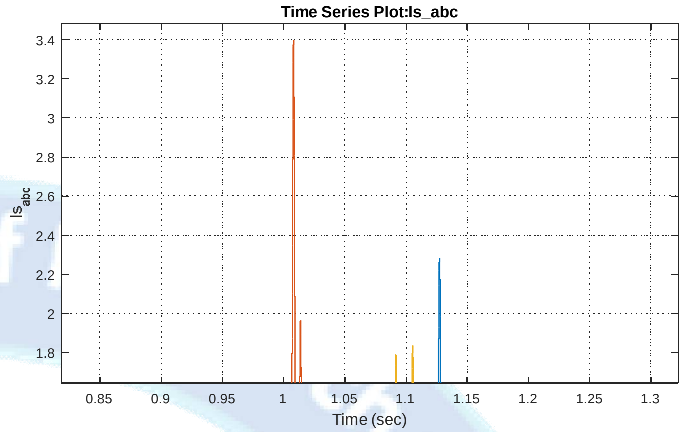

Fig 4. Enlarge view of stator current before and after the fault.

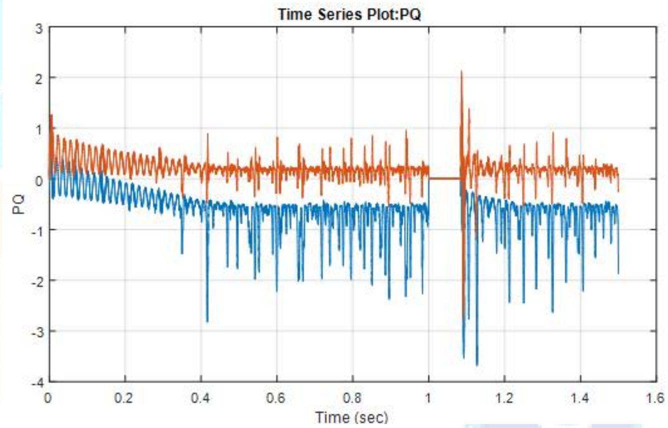

Fig 5. Active and reactive power without protection scheme

5. Conclusion:

In this work two hybrid low voltage protection schemes for DFIG were simulated and evaluated using MATLAB/SIMULINK. This includes DC Chopper with crowbar, and DC Chopper with SDR LVRT. The SDR protection method has a better performance with various grid faults, and this method can be an effective alternative with the Crowbar protection in the industrial environment.

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