MODERN CONTROL ASPECTS IN DOUBLY FED INDUCTION GENERATOR UNDER VARIES FAULT CONDITIONS

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Abstract: Wind power stations much placed in remote areas; so they are characterized by weak grids and are often submitted to power system disturbance like faults. In this proposed model , the behaviour of a wind energy conversion system that uses the structure of Doubly-Fed Induction Generator (DFIG) under faulty conditions is presented. The behavior of these machines during grid failure is an important issue. DFIG consists of an asynchronous machine, in which the stator is connected directly to the grid and its rotor, is connected to the grid via two electronic power converters (back-to-back converter). In the three-phase rectifier and the inverter with IGBTs the Pulse Width Modulation (PWM) and SPWM technique is respectively used. DFIG is analysed and simulated under varies faulty conditions in the environment of MATLAB/SIMULINK

1. INTRODUCTION

With the acute need for electrification and higher energy production in the country, wind energy is going to provide an increasingly significant share of the renewable based capacity [1]. In recent years there has been a continuous increase in installed wind power generation capacity throughout t h e world. When many wind turbines are added to the system, a grid becomes weaker as these types of generators require additional control equipment since they do not have any self-recovery capability like the conventional generators. This requires thorough study of the normal and dynamic performance of the wind turbines during and after a disturbance. The successful entry of Doubly Fed Induction Generator (DFIG) based wind turbine in to the competitive wind market stimulates to study the performance of the overall DFIG system under different operating and critical conditions. With increased penetration of wind energy and moving towards active networks, grid codes are being revised to reflect the new requirements. This has created a keen interest in many of the researchers to develop more detailed model particularly with respect to the fault analysis. The detailed 5th order model is the best suited model for studying the behaviour of the system during fault [2, 3]. In the electric power grid, a very high level of power quality cannot be always guaranteed in every part of the grid. There are several factors that can influence the power quality especially at a local point of connection to a connected consumer or generator electric system. From the generation side, there are ongoing trends towards a decentralisation of power plants with integration of a higher number of generation systems with lower nominal power values compared to conventional large-scale power plants. Furthermore, the power disposal characteristic becomes more fluctuating due to the increasing share of renewable energy sources as wind and solar power which mostly do not provide constant power disposal as steam-powered turbines and generators without adequate energy storage solutions. In addition, disturbances that affect the power quality in the electric grid can also be caused by consumer loads with nonlinear behaviour. This is especially the case for the usage of power electronic devices, e.g. for dynamic speed and torque control of electric motors, which is increasing not only for motor applications but also for generators as in some wind energy converter systems (WECS). Eventually, perturbations can be also produced by faults in the electric grid on a transmission or distribution level. As they are part of the decentral energy generation connected to the electric grid, WECS and other power stations based on renewable energy sources are expected to behave more like conventional power plants by fulfilling stricter grid code requirements. That means they have to operate according to the grid code limits despite the presence of power quality phenomena such as voltage dips and voltage swells, voltage unbalanced, harmonic distortion and frequency variations in order to support the proper function of the grid. As a result, WECS also experience long-term exposures to phenomena in the electric grid due to a low power quality. Among the different topologies, WECS equipped with doubly-fed induction generators (DFIG) are particularly sensitive to power quality events in the grid because the stator is directly connected to the grid and the power converters in the rotor are partially-rated. Thus, severe power quality phenomena can affect considerably the operation of such WECS and they can reduce their reliability and availability. Therefore, the performance of WECS with DFIG under certain phenomena in weak power systems in investigated in this paper. In [1] already the effects of voltage dips and voltage unbalances were evaluated. In this paper, the focus lies on voltage swells and harmonics. Power quality phenomena are presented and the related impact on wind energy conversion systems at the example of DFIG based systems is evaluated and mitigation measures are presented.

II. DFIG WIND ENERGY CONVERSION SYSTEM

DFIG, as mentioned earlier, is basically a conventional wound-rotor induction machine in which the stator is directly connected to the grid1 through a transformer, and the connection of the rotor to the stator (and grid) is via a back-to-back voltage source convertor. The rotor converter system consists of a grid side converter (GSC) and rotor side converter (RSC) connected via a DC link. A simplified schematic diagram of a DFIG based wind energy generation system is shown in Figure 1

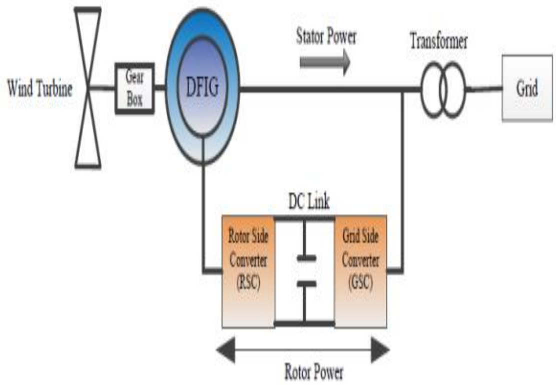

Fig .1 Configuration of DFIG wind Energy conversion system (one single generator) using back-to-back converter

The generator is called DFIG because the power is fed from both stator and the rotor circuits to the grid. The rotor circuit handles typically about 25-30% of the generator rated power, this percentage allows the DFIG to have about ± 30 % operational speed range around the synchronous speed and reduces the rating and the cost of the rotor converter [28, 36]. The size of the converter is not related to the total generator power but to the selected speed range and, hence, to the "slip" power, thus the cost of the converter increases when the speed range becomes wider. The selection of the speed range, therefore, is based on the economic optimization of investment costs and on increased efficiency. Since the DFIG is connected to the grid, the high transient currents due to the grid disturbances may destroy the power electronic devices of the rotor converter. A protection system called "crowbars" are being used in which the rotor winding can be short circuited during the fault period via a small resistance and released when the fault is cleared.

III. PROBLEM STATEMENT

Power quality is the ability to use the energy delivered in the desire manner and to give sufficiently high grade electrical services to the customer. Synchronization of the voltage frequency section permits electrical system to perform their intended manner while not important loss of performance or life. The word is used to explain electric power that drives an electrical load and the load's ability to perform properly. Without the proper power, an electrical device may malfunction. Fail untimely or not operate, which effects the distribution system. There are the some power quality problem defines

A.Voltage Sag

A decrease of the normal voltage level with ranging from 10-90% at any instant of period and for duration of 0.5 cycle to 1 min. Longer duration of low voltage called a ‘sustained sag’.

B. Voltage Swell

Voltage swell is defined as temporary increase of the voltage, at the power frequency, external normal tolerances. Or it happens when a heavy load turns off in a power system, with duration of more then one cycle and typically less than a few seconds.

C. Harmonics

A harmonic frequency is a multiple of the fundamental frequency and this frequency of the ac electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

IV. SYSTEM DESCRIPTION

The wind energy converter with DFIG topology has proven to be an efficient and cost-effective solution for variable speed wind turbines within a certain rotational speed range for the generator. The whole WEC system is depicted in Fig.1. The wind rotor is in most cases connected to the rotor shaft of the generator through a gearbox that increases the rotational speed at the generator side.

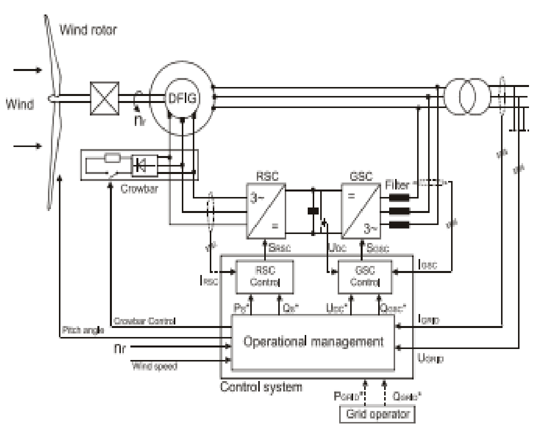

Fig. 2. Typical configuration of a wind energy converter system with a doubly-fed induction generator

The stator windings are connected through a step-up transformer to the grid. The rotor windings are connected to the grid through two voltage source converters (VSC) in back-toback topology. Two-level VSC are commonly used, each consisting of six insulated gate bipolar transistors (IGBTs) and respective antiparallel diodes. The rotor-side converter (RSC) is used to apply three-phase voltages at the rotor windings usually via slip rings. With appropriate amplitude, phase and frequency the flow of currents and consequently the active and reactive power at the stator terminals is controlled. Similarly, the grid-side converter (GSC) can control the active and reactive power exchange between the rotor and the grid. A crowbar circuit is usually connected to the rotor. Its purpose is to protect the power electronic switches of RSC in the case of severe grid faults by choking any transient over-currents into its power resistor. The variable rotor speed can be obtained by the rotor-side converter. By this configuration, a decoupling of the rotor electrical frequency and the grid frequency is reached. Normally, the variable speed is in a range of ±30% around the synchronous speed. Variable-speed WECS can harvest much more energy compared to fixed-speed WECS because they can adjust their speed in order to always operate at the optimum rotational speed at which the conversion efficiency of the wind rotor is maximum [7], [8]. The maximum rotor power depends on the slip, and since the rotational speed range is limited, the rotor power is only a fraction of the stator power. This allows significant cost savings as the power electronic converters can be partially rated to only 25%–30% of the total power of the generator. Furthermore, the power efficiency is higher because there are lower switching and conduction losses in the converters compared to a full feeding via a converter.

V.SIMULATION RESULTS

The voltage quality in weak power systems is often low with a high total harmonic distortion (THD) and unbalance between the three phases . Grid faults that cause voltage dips, voltage swells and voltage unbalance are also frequent in weak rural grids. In the following sections simulations are used to investigate how the performance of the DFIG-based WECS is affected by voltage dips, voltage swells and voltage harmonics.

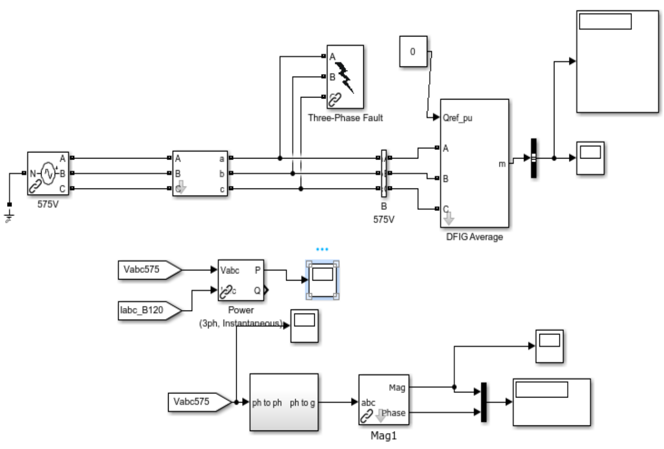

Fig.3 Simulink model of proposed system

Symmetrical (LLG) fault creation

The performance of the DFIG during voltage dips has been investigated in different works in the literature. A detailed analysis is found in [12] and [1]. For comparison purposes a severe voltage dip is also considered in this paper: an instantaneous voltage drop down to zero volts is simulated for a time duration of 250 ms while the generator operates at maximum rotational speed and power output. The fault occurs at the grid-side of the WECS transformer and the voltage drop experienced by the wind turbine terminals is shown in Fig. 3. A standard field-oriented control strategy aligned with the stator flux has been used with cascaded power and current control with proportional integral (PI) controllers and space vector modulation.

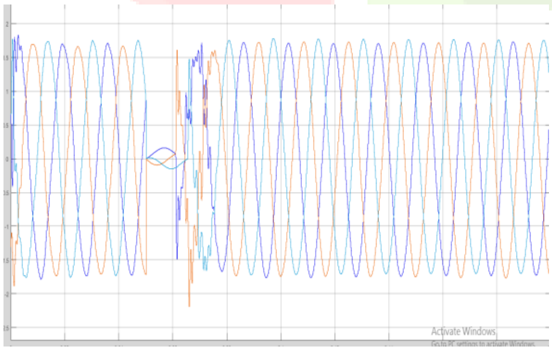

Fig.4 grid voltage

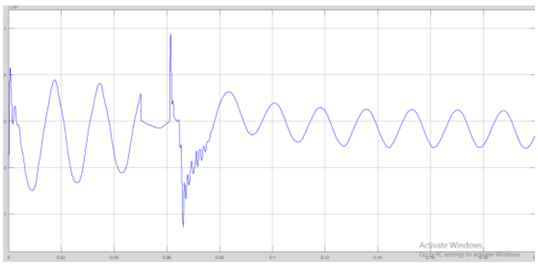

Fig.5 active power

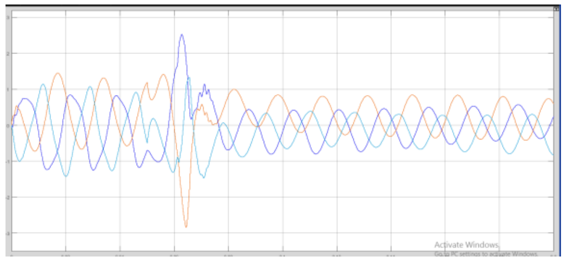

Fig.6 RSC currents

Unsymmetrical (LLG)fault creation

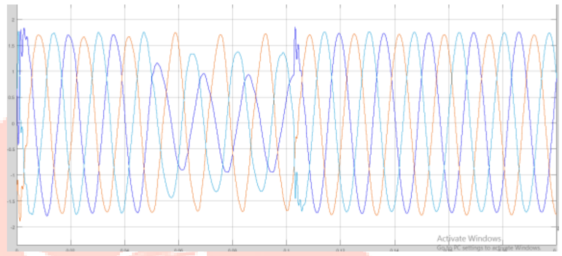

Fig.7 grid voltage

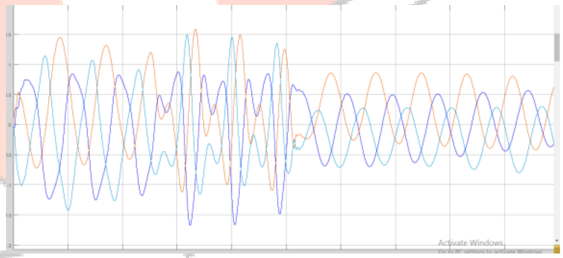

Fig 8 Rotor currents

CONCLUSION

This paper presented different power quality phenomena typically found in weak electrical power systems in which wind farms are frequently connected. Wind energy conversion systems equipped with doubly-fed induction generators have been presented. The dynamic response and operating performance of the DFIG-based WECS have been investigated under severe voltage dips, voltage swells and voltage harmonic distortion and possible mitigation measures proposed in literature have been briefly presented. Following works will deal with advanced control strategies that are able to eliminate the negative effects on the DFIG caused by grid disturbances and harmonics presented in this paper

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