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Voltage Stability in Wind Farm by Using STATCOM During Grid Fault

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Abstract— **Voltage stability is a main problem to attain the uninterrupted operation of wind farms equipped with doubly fed induction generators (DFIGs) during grid faults. This paper investigates the application of a static synchronous compensator (STATCOM) to support with the uninterrupted operation of a wind turbine driving a DFIG, which is connected to a power network, during grid faults. The control schemes of the DFIG rotor side controller (RSC) and grid side controller (GSC) and the STATCOM are suitably designed and synchronized. The STATCOM is placed at the bus point of common coupling (PCC) where the DFIG is connected to the power grid, for steady-state voltage regulation and transient voltage support. The simulation of the project was done in the MATLAB software environment. Results show that the STATCOM improves the transient voltage stability and therefore helps the wind turbine generator system to remain in service during grid faults.**

Index terms - DFIG, RSC, GSC, STATCOM.

I. Introduction

Wind power is the most reliable and developed renewable energy source. The share of wind power with respect to total installed power capacity is increasing worldwide. The Doubly Fed Induction Generator (DFIG) based wind turbine with variable-speed variable-pitch control scheme is the most popular wind power generator in the wind power industry. With the recent progress in modern power electronics, the concept of a variable-speed wind turbine (VSWT) equipped with a doubly fed induction generator (DFIG) is receiving increasing attention because of its advantages over other wind turbine generator concepts [1]–[4]. In the DFIG concept, the induction generator is grid-connected at the stator terminals; the rotor is connected to the utility grid via a partially rated variable frequency ac/dc/ac converter (VFC), which only needs to handle a fraction (25%–30%) of the total DFIG power to achieve full control of the generator.

In a real power system, a large wind farm generally consists of hundreds of individual wind turbines. It has been reported in [1] that with well-tuned converters, there is no mutual interaction between wind turbines in a wind farm, independently from the conditions of the power grid. Therefore, in my paper, only one wind turbine is used to represent the wind farm.

The VFC consists of a rotor-side converter (RSC) and a grid-side converter (GSC) connected back-to-back by a dc-link capacitor. When connected to the grid and during a grid fault, the RSC of the DFIG may be blocked to protect it from overcurrent in the rotor circuit [1], [3], [5],[15]. The wind turbine typically trips shortly after the converter has blocked and automatically reconnects to the power network after the fault has cleared and the normal operation has been restored. In [7], the author proposed an uninterrupted operation feature of a DFIG wind turbine during grid faults. In this feature, the RSC is blocked, and the rotor circuit is short-circuited through a crowbar circuit (an external resistor).

The DFIG becomes a conventional induction generator and starts to absorb reactive power. The wind turbine continues its operation to produce some active power, and the GSC can be set to control the reactive power and voltage at the grid connection. The pitch angle controller might be activated to prevent the wind turbine from fatal over speeding. When the fault has cleared and when the voltage and the frequency in the utility grid have been reestablished, the RSC will restart, and the wind turbine will return to normal operation. However, in the case of a weak power network and during a grid fault, the GSC cannot provide sufficient reactive power and voltage support due to its small power capacity, and there can be a risk of voltage instability. As a result, utilities, typically, immediately disconnect the wind turbines from the grid to prevent such a contingency and reconnect them when normal operation has been restored. Therefore, voltage stability is the crucial issue in maintaining uninterrupted operation of wind turbines equipped with DFIGs [8].

This paper investigates the application of a STATCOM to help with the uninterrupted operation of a VSWT equipped with a DFIG during grid faults. The STATCOM is shunt connected at the bus where the wind turbine is connected to the power network to provide steady-state voltage regulation and improve the short-term transient voltage stability. The DFIG and STATCOM control schemes are suitably designed and coordinated. The simulation of the project was performed in the MATLAB software environment.

II. MODELLING OF DFIG

The DFIG-based WECS basically consists of generator, wind turbine with drive train system, RSC, GSC, DC-link capacitor, pitch controller, coupling transformer, and protection system as shown in Fig.1. The DFIG is a wound-rotor induction generator with the stator terminals connected directly to the grid and the rotor terminals to the mains via a partially rated variable frequency ac/dc/ac converter, which only needs to handle a fraction (25-30 %) of the total power to accomplish full control of the generator. The functional principle of this variable speed generator is the combination of DFIG and four-quadrant ac/dc/ac VFC equipped with IGBTs. The ac/dc/ac converter system consists of a RSC and a GSC connected back-to-back by a DC-link capacitor. The rotor current is controlled by RSC to vary the electromagnetic torque and machine excitation. Since the power converter operates in bi-directional power mode, the DFIG can be operated either in sub-synchronous or in super-synchronous operational modes.

Control of the DFIG is achieved by control of the VFC, which includes control of the RSC and control of the GSC. The objective of the RSC is to independently regulate the stator active and reactive powers, which are represented by Ps and Qs, respectively. The reactive-power control using the RSC can be applied to keep the stator voltage (Vs) within the desired range, when the DFIG feeds into a weak power system without any local reactive compensation. When the DFIG feeds into a strong power system, the command of Qs can be simply set to zero. Fig.2 shows the overall control scheme of the RSC. In order to achieve independent control of the stator active power Ps and reactive power Qs by means of rotor current regulation, the instantaneous three-phase rotor currents irabc are sampled and transformed to d–q components idr and iqr in the stator-flux-oriented reference frame. The reference values of idr and iqr can be determined directly from Qs and Ps commands, respectively. The actual d–q current signals (idr and iqr) are then compared with their reference signals (i∗dr and i∗qr) to generate the error signals, which are passed through two PI controllers to form the voltage signals vdr1 and vqr1. The two voltage signals (vdr1 and vqr1) are compensated by the corresponding cross-coupling terms (vdr2 and vqr2) to form the d–q voltage signals vdr and vqr. These are then used by the PWM module to generate the IGBT gate control signals to drive the rotor-side IGBT converter.

$$V_{qs} = r_s I_{qs} + \omega_e \lambda_{qs} + \frac{d}{dt}\lambda_{qs} \qquad (1)$$

$$V_{ds} = r_s I_{ds} - \omega_e \lambda_{qs} + \frac{d}{dt}\lambda_{ds} \qquad (2)$$

$$V_{qr} = r_r I_{qr} + (\omega_e - \omega_{r)} \lambda_{dr} + \frac{d}{dt}\lambda_{qr} \qquad (3)$$

$$V_{dr} = r_r I_{dr} + (\omega_e - \omega_{r)} \lambda_{qr} + \frac{d}{dt}\lambda_{dr} \qquad (4)$$

. Where Vqs , Vds, Vqr , Vdr are the q and d-axis stator and rotor voltages, respectively. Iqs ,Ids , Iqr , Idr are the q and d-axis stator and rotor currents, respectively.

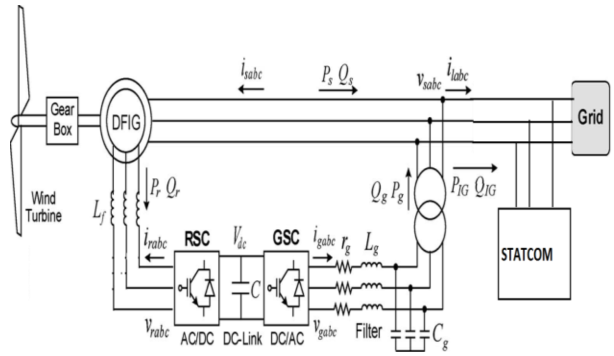

Figure 1. DFIG Model

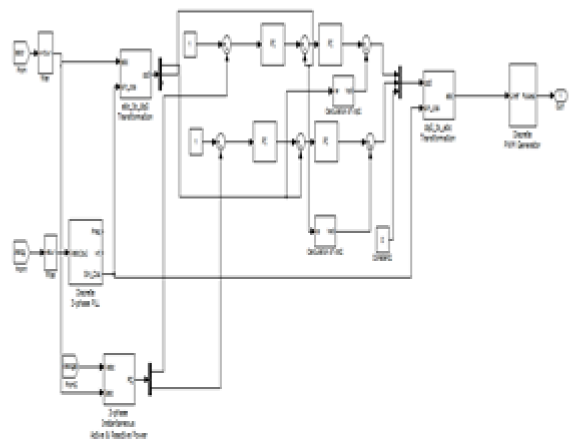

Figure 2. Rotor side controller

III.MODELLING AND CONTROL OF STATCOM

The STATCOM is a static compensator and is used to regulate voltage and to improve dynamic stability. A STATCOM can supply the required reactive power under various operating conditions, to control the network voltage actively and thus, improve the steady state stability of the network. The STATCOM can be operated over its full output current range even at very low voltage levels and the maximum var generation or absorption changes linearly with the utility or ac system voltage. The maximum compensating current of the SVC decreases linearly with the ac system voltage and the maximum var output decreases with the square of the voltage. This implies that for the same dynamic performance, a higher rating SVC is required when compared to that of a STATCOM. For an SVC, the maximum transient capacitive current is determined by the size of the capacitor and the magnitude of the ac system voltage. In the case of a STATCOM, the maximum transient capacitive overcurrent capability is determined by the maximum turn-off capability of the power semiconductors employed. Fig.3 shows the schematic of SVC and its VI characteristics. Fig.4 shows the schematic of the STATCOM and its VI characteristics. The main function of a STATCOM is to provide reactive power support and thus improve voltage stability.

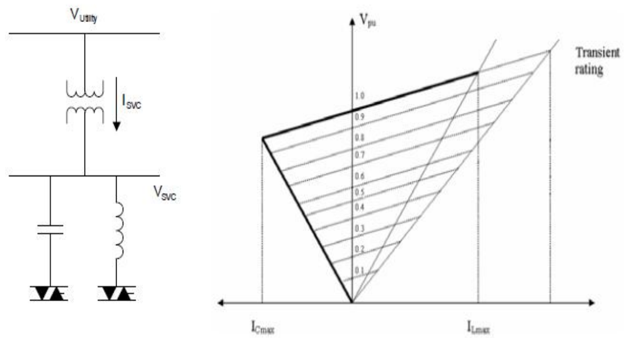

Figure 3. SVC and its VI characteristics

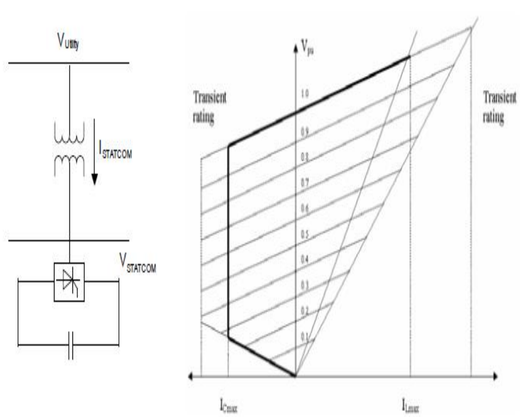

Figure 4. STATCOM and its VI characteristics

A. *Location Of STATCOM*

The STATCOM is placed at the point of common coupling (PCC) bus because of the following two reasons:

1. The location of the reactive power support should be as close as possible to the point at which the support is needed because of the change in voltage and consequent power loss (I^2R loss) in transmission line associated with the reactive power flow.

2. The effect of voltage change is most significant at this node.

The location of STATCOM is shown in Fig.5 and the STATCOM controller is shown in Fig.6.

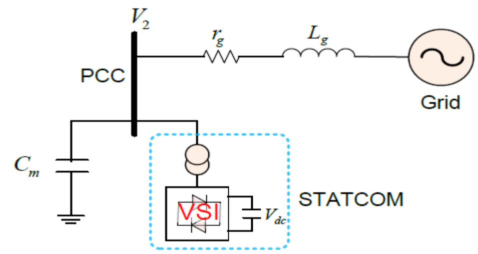

Figure5 Location of STATCOM

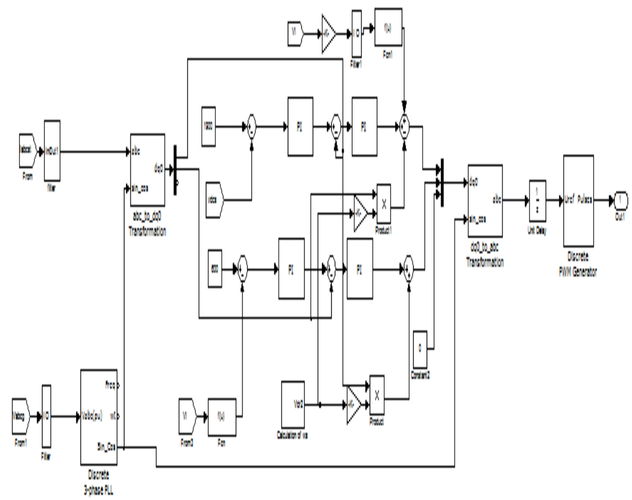

Figure 6.STATCOM Controller

IV. SIMULATION RESULTS AND DISCUSSION

The simulation of the project was performed in the MATLAB software environment. The wind energy system and its voltage stabilization is simulated and the output results are obtained. It shows that the grid voltage is maintained as a constant value at the time of grid fault. The STATCOM injects reactive power in order to avoid the change in grid voltage.

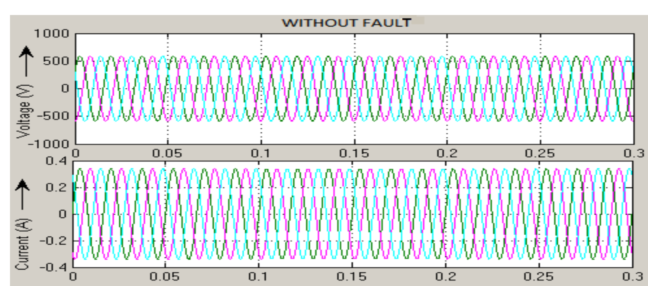

Figure7. Without Fault Grid Voltage and Current.

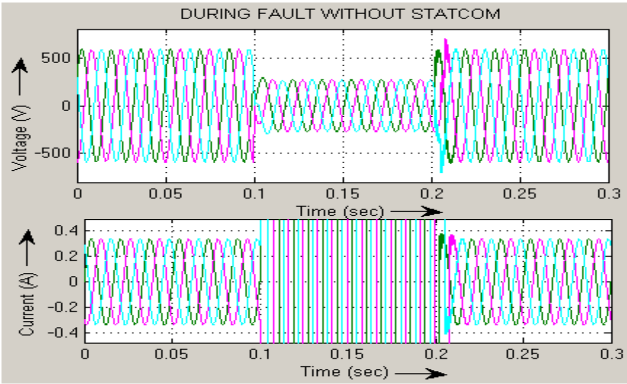

Figure 8.Voltage And Current During Fault Without STATCOM.

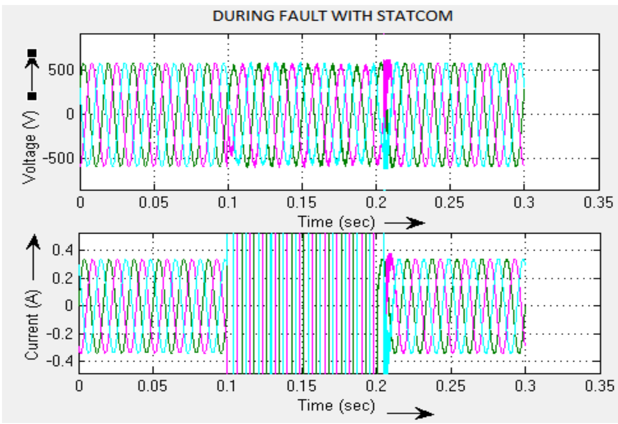

Figure 9. Voltage And Current During Fault With STATCOM.

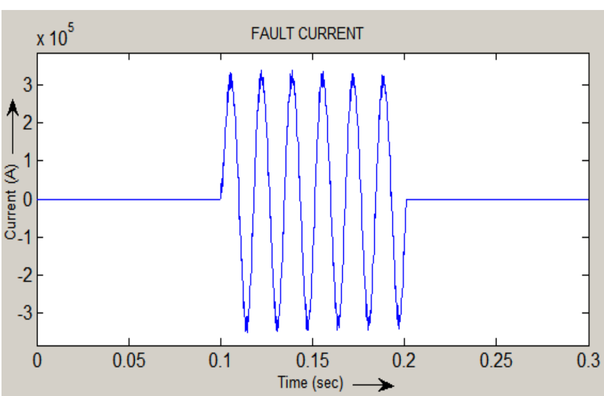

Figure.10. Fault current

Without fault grid voltage and current waveform as shown in fig.7. From fig.8 we can see that the grid voltage is reduced at 0.1s due to the fault occurred in the grid and it is cleared at 0.2 s. The STATCOM regulates the grid voltage by injecting the reactive power it is shown in fig.9.The fault current waveform is shown in Fig.10.

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