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Voltage Stability Control by Statcom under fault condition for wind Farms

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Abstract— Huge Wind generating stations (WGSs), close to the traditional power generating stations are the feasible solution for delivering clean energy. Although a series of technical provocation appear when grid penetration levels of wind power become high. Mainly the older WGSs are facing difficulties in ensuring high – grade power into the grid, as urge by the more and more stringent grid codes. However, wind flow by nature is intermittent. Thus a proven solution to these problems is to install FACTS devices in the system. From this, STATCOM is procure vogue, therefore a system with WGS and STATCOM is proposed. A statcom control architecture with the ability to correlate the control between the positive and the negative sequence of the grid voltage proposed. The results justify the effect of the positive- and the negative-sequence voltage compensation by a statcom on the operation of the FSIG-based wind farm. The theoretical studies are verified by simulations and measurement results on MATLAB.

Index Terms— Induction generator, low-voltage ride through, statcom wind energy.

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I. INTRODUCTION

Wind generation setup in India has notably expanded in recent years. As of 1st half of this year ie. 2018 the total installed wind generating was 34.293 GW, the fourth largest installed wind generating capacity in the world. Wind power capacity is mainly spread across the South, West and North regions. Wind power costs in India are reducing rapidly. The levelised rate of wind power reached a record low of 2.43 (3.5¢ US) per kWh during auctions for wind system by end of 2017. In 2017, central council announced the applicable guidelines for tariff-based wind power auctions to bring more clarity and minimize the risk to the developers. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine.

In the fixed-speed wind trubine operation, all the fluctuation in the wind speed are transmitteed as fluctautions in the mechanical torque, electric power on the grid and tends to huge fluctautions. During the normal operation, wind trubine produces a continuous variable output power. These power variations are mainly caused by the effect of turmoil, wind shear, and tower-shadow and of control system in the power system.

Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc.

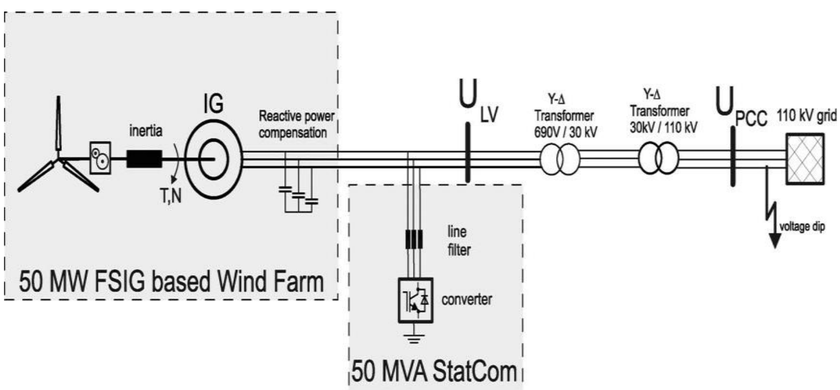

Fig. 1. Structure of the investigated system: FSIG-based wind farm and StatCom connected to the grid.

This paper proposes the application of a StatCom that is connected to an FSIG-based wind farm and used to control the positive- and the negative-sequence voltage during grid faults. The main theme of this paper lies in the coordination of the positive- and the negative-sequence voltage control by the StatCom and the related effect on the wind turbine behavior. While the positive-sequence voltage compensation leads to an increased voltage stability of the wind farm, the negative sequence voltage compensation leads to a reduction of torque ripple, increasing the lifetime of the generator drive train. First investigations have been published in [21], but here, deeper analysis and measurement results are presented.

II. SYSTEM DESCRIPTION

The aarchitecture of the system is shown in Fig. 1 of a 50-MW wind mill with squirrel cage induction generators straightly coupled to the grid and a 50-MVA statcom. A cluster model of the wind mill is used as usual here, which means that the sum of the turbines is designed as one generator using the standard T-equivalent circuit. The statcom is designed as controlled voltage sources. Both devices are connected to the same low voltage bus and then connected to the medium voltage bus by a transformer. The medium voltage level is connected to the high voltage level by a second transformer.

III. WIND FARM UNDER VOLTAGE DIP

The torque of the induction generator T^+shows a quadratic dependence of the positive-sequence stator voltage magnitude V_a^+[25]. It can be calculated using

$$T^+(s) = 3.\frac{p}{2}\frac{R_r}{s\omega_s}\frac{(V_s^+)^2}{\left(R_s+{}^{R_r}/_s\right)^2+j\,(X_s+X_r)^2} \qquad (1)$$

When the grid voltage is unbalanced, i.e., it contains a negative sequence, the stator currents become unbalanced too. According to Wang *et al.* [24], a small amount of negative sequence voltage V_s^-can lead to a high amount of negative sequence currentsI_s^-, described by

$$I_{s,pu}^- = \frac{V_s^-}{\omega_s.\sigma.L_s.I_{s,N}} \qquad (2)$$

where σ is the leakage factor, *IS,N*is the rated stator current, and *Ls* is the stator inductance. The negative-sequence currents do not contribute a lot to the average torque *T*+; thus, they can still be calculated using

$$T^+ \approx 3.\frac{p}{2\omega_s}.V_s^+.I_{sd}^+ \qquad (3)$$

but the negative-sequence currents cause torque oscillations of double grid frequency. The magnitude of the negative-sequence torque *T*−can be calculated using

$$T^- \approx 3.\frac{p}{2\omega_s}.V_s^+.I_s^-. \qquad (4)$$

It becomes clear that the average torque is reduced due to the decreased positive-sequence voltage.

IV. CONTROL OF THE SYSTEM

The statcom control structure is based on the voltage oriented vector control scheme as usually applied to three-phase grid-connected converters. It is a cascade control structure with inner proportional integral (PI) current controllers in a rotating *dq* reference frame with grid voltage orientation. The overall control structure is shown in Fig. 2.

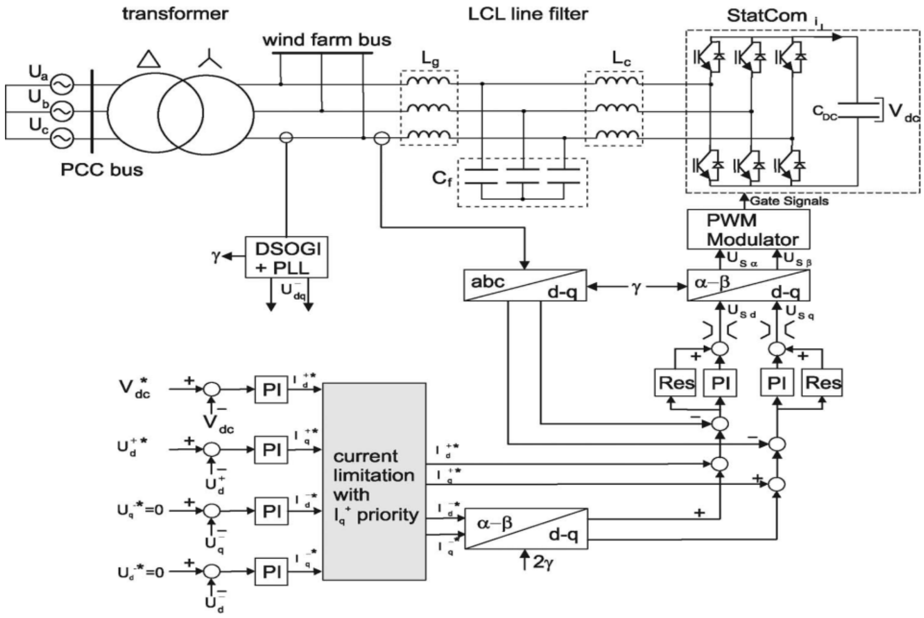

Fig. 2. Proposed control structure of the statcom to control the positive- and the negative-sequence voltage independently.

V. SIMULATION RESULTS FOR UNBALANCED GRID FAULTS

Simulation results for the operation of the induction generators and the stabilization by the statcom under an unbalanced grid voltage dip of 500-ms duration are shown. An unbalanced fault (single phase amplitude drops to 50%) is assumed at the high voltage bus of the power system (see Fig. 1). The simulation results are shown in Fig. 5. The unbalanced grid fault leads to a negative-sequence voltage at the medium voltage bus [see Fig. 5(a)]. The operation of the system without statcom support is shown in the left part of Fig. 5.The reduction of the positive sequence voltage leads to a decrease in torque and an acceleration of the rotor. The important difference

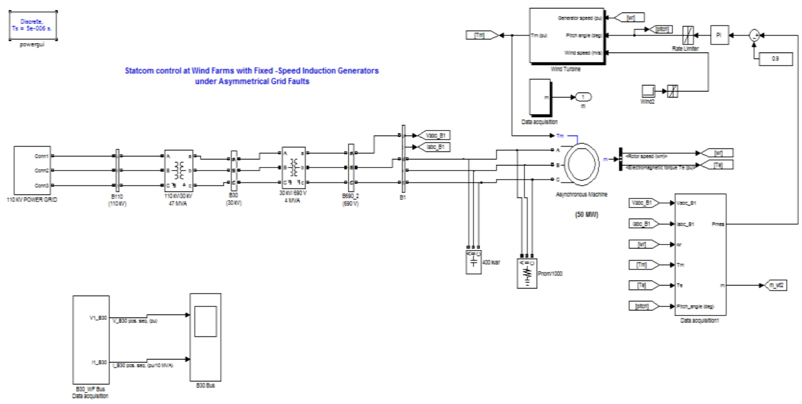

Fig 3: Simulink Model without STATCOM

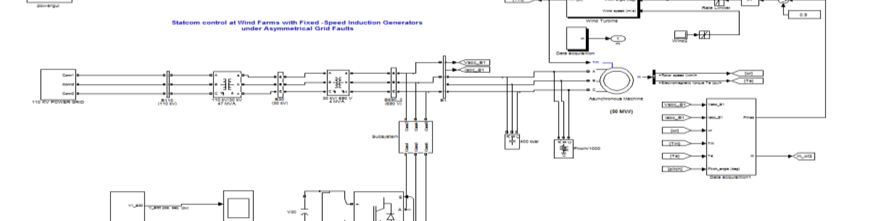

Fig 4: Simulink Model with STATCOM

Compared to a balanced grid fault are the heavy torque oscillations [see Fig. 5(c)] of the system caused by the negative-sequence voltage. For this simulation case, the grid voltage fault does not lead to a voltage instability because the generator can return to the rated operation point after the fault, but there is very high stress on the mechanical parts of the system due to the torque oscillations.

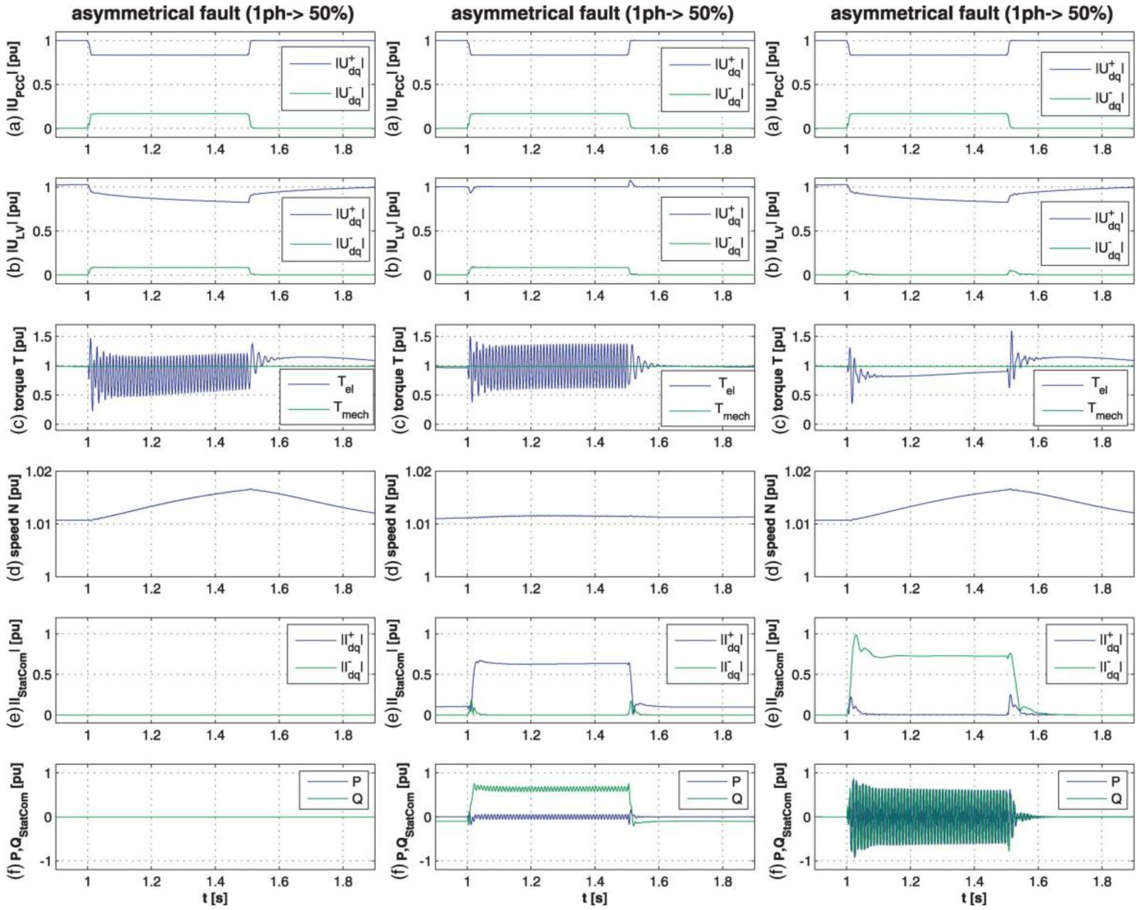

Fig. 5. Simulation results during unbalanced grid fault (1 ph →50%) (left) without statcom, (middle) with statcom and positive-sequence voltage compensation, and (right) with statcom and negative-sequence voltage compensation. (a) Positive and negative-sequence voltage components at PCC. (b) Positive- and negative-sequence voltage components at low voltage. (c) Torque. (d) Speed. (e) Statcom positive and negative current components. (f) Statcom P, Q.

VI. CONCLUSION

Voltage control architecture for a STATCOM for fixed speed induction generator based wind mills under balanced and unbalanced grid voltage condition has been developed. The adapted model controls both the positive and the negative sequence of the voltage independently with priority on the positive sequence voltage. During the balanced faults the positive sequence voltage variant are large and they will be compensated by STATCOM. During the unbalanced grid faults both positive sequence and negative sequence voltage variants will occur and they will be compensated to a great extent using this STATCOM control structure. This work relates to the coordination of the positive and the negative sequence voltage control by the STATCOM and the related effect on the wind turbine behaviour.

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