Implementation of Multi Level Inverter for Grid Connected Applications Using Hybrid Wind Solar Power

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Abstract - **With the advancement of technology, electricity generation using wind has drawn an increased attention in the world. As the amount of wind power integrated into the system is increased, it causes power quality and stability problems. Therefore power utilities are developing stringent grid codes which are to be satisfied by the wind power producers. Voltage control capability, reactive range capability, frequency control ability and fault ride through capability are among the major requirements stipulated in the grid codes. Due to the variable speed operation capability of Doubly Fed Induction Generators (DFIGs), they are becoming popular in wind power generation. The voltage control of the DFIG wind farm has been identified as the latest challenge with the present grid code requirements. This paper presents the design methodology of a stator side controller of the DFIG, which produces the terminal voltage control in addition to the dc link voltage regulation. The developed controller is simulated using PSCAD/EMTDC software to verify the performance of the controller. Further, a 60 MW typical wind farm is modeled in both PSCAD/EMTDC and IPSA+ and applicability of the above controller is justified.**

Keywords – Wind Solar Power, Grid codes, Stator Side Controller.

I. INTRODUCTION

With the increased penetration of wind energy into power grids all over the World, more and more large-scale wind turbines and wind power plants have been installed in rural areas or offshore where the grids are generally quite weak. The operation and control of such remote wind turbines under non-ideal voltage conditions, including severe voltage sags, network unbalance, and harmonic voltage distortions, have attracted more and more attention [1–14]. With many excellent merits such as low rating converter capacity, variable speed constant frequency operation and independent power regulation capability, wind turbines based on doubly-fed induction generators (DFIGs) have become one of the mainstream types of variable speed wind turbine in recent years. Unlike wind generators with the full-sized grid-connected converters (such as permanent magnet synchronous generators), DFIG is very sensitive to aforementioned grid disturbances as its stator is directly connected to the grid and the rating of the back-to-back converter is limited. Recently, some improved operation and control strategies for DFIG were investigated under non-ideal grid voltage conditions. For the severe grid short-circuit fault and unbalanced grid voltage conditions, some improved excitation control strategies or an additional series voltage compensation method using a dynamic voltage restorer (DVR) have been proposed to effectively enhance the low voltage ride through (LVRT) capability of the DFIG system [1,2,15–19]. Besides, the overall operation performance of the whole DFIG system can be improved by coordinately controlling the rotor-side converter (RSC) and parallel grid-side converter (PGSC) during a network unbalance, and some enhanced operation functionalities such as eliminating the oscillations in the active or reactive power from the whole system, or suppressing the negative-sequence currents injected to the grid have been achieved [6,11]. To further improve the operation performance of DFIG system under distorted grid voltage conditions, some enhanced control strategies for the DFIG have been studied in [13,14]. As mentioned in [14], a rotor current PI regulator and a harmonic resonant compensator tuned at six times the grid frequency in the positive (dq)+ reference frame are designed to provide different operation functionalities, i.e., removing the stator or rotor current harmonics, or eliminating the oscillations at six times the grid frequency in the stator output active and reactive powers. However, due to the limited RSC control variables, the proposed method cannot eliminate the stator and rotor current harmonics and the output power pulsations in the DFIG simultaneously under network harmonic distortions. Therefore, harmonic power losses in the stator and rotor windings or the stator power oscillations and torque pulsations in the DFIG still exist, which might degrade the life time of the winding insulation materials or deteriorate the output power quality.

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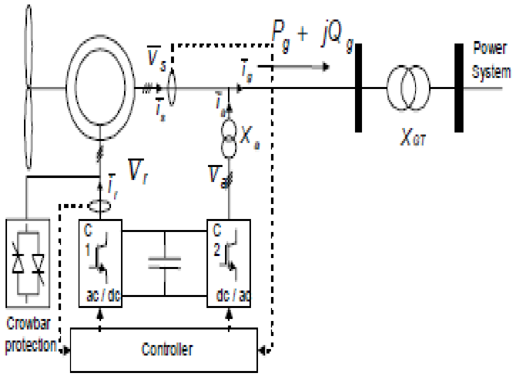

Fig.1: DFIG in wind power generation

II. DESIGN OF THE STATOR SIDE CONVERTER CONTROLLER

A Stator side converter controller algorithm

Akagi's instantaneous active and reactive power theory has been widely used in active filter designing for harmonic elimination [11, 12]. The above SSC controller algorithm was also developed based on the Akagi's instantaneous active and reactive power theory. Generator terminal voltages (*t a V* , *t b V* & *t c V*), dc link voltage (*dc V*) and converter output currents (*ac I* , *bc I* & *cc I*) are measured and fed into the controller in order to derive the six gate pulses for the IGBTs of the converter. The terminal voltages *t a V* , *t b V* & *t c V* are fed into the controller and transform them into αβ components using equations 1 and 2 and then calculate *T V* and *Tpu V* using equations 3 and 4.

$$V_\alpha = \sqrt{\frac{2}{3}}\left(V_{ta} - \frac{1}{2}\left(V_{tb} + V_{tc}\right)\right) \qquad \text{.......... (1)}$$

$$V_\beta = \sqrt{\frac{2}{3}}\left(0 - \frac{\sqrt{3}}{2}\left(V_{tb} - V_{tc}\right)\right) \qquad \text{........... (2)}$$

$$V_T = V_\alpha^2 + V_\beta^2 \qquad \text{...... ... (3)}$$

$$V_{Tpu} = \frac{V_{t,rms}}{V_{base}} \qquad \text{........... (4)}$$

The terminal voltage error is obtained by comparing the measured voltage with the reference. The required reactive power injection, *inj Q* , is estimated by comparing the voltage error with the droop characteristic of the controller. In this controller, a droop as shown in Fig. 2 is used to control the generator terminal voltage. Hence, it eliminates unnecessary reactive power circulation among the wind farm generators while maintaining the reactive power injection/absorption within the limit.

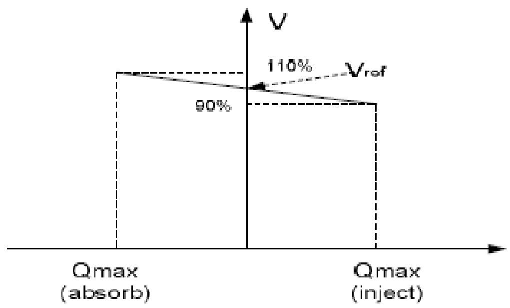

Fig. 2 Droop characteristics of the controller

Similarly, dc link voltage is compared with the dc link voltage reference and the error is regulated through a PI controller, which gives the active power, *inj P* , to be injected by the converter to regulate the dc link voltage. Then using the estimated *inj P* , *inj Q* , α *V* , β *V* the required α *I* , β *I* values to inject the estimated active and reactive power are calculated:.

$$I_\alpha = \frac{V_\alpha P_{inj} - V_\beta Q_{inj}}{V_T} \qquad \text{..................... .(5)}$$

$$I_\beta = \frac{V_\alpha Q_{inj} + V_\beta P_{inj}}{V_T} \qquad \text{.................. ... (6)}$$

III. CONCLUSION

Advancement of the wind power technology set very high targets for wind power generation in the world. However, large amount of wind power integration into the grid causes power quality and stability problems due to the intermittent characteristics. Therefore, strict grid codes are being developed for wind farm connections. Voltage control capability, frequency control ability and fault ride through capability are among their primary concerns. DFIGs are popular in wind power development due to their variable speed operation capability. The voltage control at the DFIG wind farm has been identified as the latest challenge with the present grid code requirements. In this paper, SSC controller has been designed to control the terminal voltage of the DFIG through reactive power control in addition to the dc link voltage control. The designed controller was modeled and simulated in PSCAD/EMTDC software and the results confirm the controller performance. Further, the applicability of the above controller has been studied on a 60 MW wind farm modeled in IPSA+. Results of the IPSA+ analysis shows that with the unity power factor operation of DFIGs, the wind farm cannot support the grid code requirement.

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