DFIG SAFE OPERATION BASED WIND PARKS IN SERIES COMPENSATED SYSTEMS

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***Abstract*— *Sub-synchronous control interaction (SSCI) is the interaction between the power electronics control and the series compensated transmission system that occurs at frequencies below the system nominal frequency. SSCI may occur between the doubly-fed induction generator (DFIG) control system and the series compensated transmission line, to which the wind park (WP) is connected. DFIG control system is not only parameters, but also the WP operating conditions have significant impact on SSCI. In this paper the impact of WP operating conditions and DFIG control system parameters on SSCI are analyzed in details.. This paper also examines the accuracies of various analytical tools used for SSCI problem identification and proposes a new frequency scan analysis approach for accurate prediction of potential SSCI problems.*

Keywords*— *DFIG; Wind System; Transmission System and So On

1. INTRODUCTION

Recent studies have identified the vulnerability of series compensated doubly-fed induction generator (DFIG) based wind parks (WPs) to sub-synchronous interaction control (SSCI). This was confirmed in October 2009 with the SSCI incident in the Zorillo Gulf WP in Texas [3]-[5]. There has recently been a growing interest in developing effective SSCI mitigation methods. In, the impact of WP operating conditions and DFIG control system parameters on SSCI was analyzed using simple linearized models to identify the range of DFIG control system parameters for safe operation. However, these studies do not discuss the feasibility of the identified DFIG control system parameter range considering WT transient performance. It should be noted that, such a complementary study requires electromagnetic transient (EMT) simulations using detailed DFIG models that include the nonlinearities (in both electrical and control system model) and essential transient functions to fulfill the grid code requirement regarding fault-ride-though (FRT). The studies also disregard the DFIG input measuring filters although their impact on SSCI is significant.

This work has contributed to the research on wind energy by examining the advantages associated with the addition of an energy storage device to the DFlG design. This was done first from the standpoint of a single machine and then was considered for the case of a wind park. The research revealed benefits in terms of improved controllability of output power and also improved response following local disturbances, name1y symmetrical and asymmetrical faults. Although the work has given sorne insight into what can be gained through the use of energy storage devices, there is still much to be done in the areas of energy storage applications and wind energy.

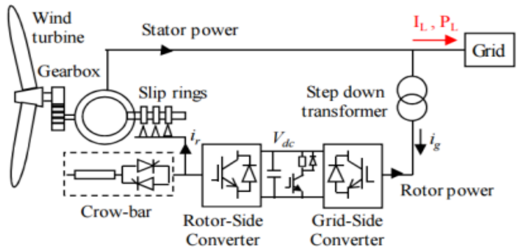
2. LITERATURE REVIEW

Nowadays, the wind power system has developed more and more rapidly over the world. Usually the wind plants are located in the remote areas which are far from the load centers. AC transmission and high voltage DC transmission are made use of to improve the transmission capacity as two main effective ways which can solve the problem of large scale wind power transmission is compensated. The paper describes the three kinds of impact varieties and impact mechanisms in the sub-synchronous oscillation phenomena of wind power system based on doubly fed induction generator (DFIG) wind generators. At last, we point out the important problem that should be stressed in the wind power system.

DUE to the recent rapid penetration of wind power into the power systems, some countries in central Europe, e.g., Germany, have ran out of suitable sites for onshore wind power projects, due to the high population density in these countries. Moreover, it has been found that the offshore wind power resources are much larger than onshore wind power sources]. Therefore, offshore wind farms have a great potential as large-scale sustainable electric energy resources. One promising solution for offshore wind farm is that of doubly fed induction generator (DFIG), which has gained recent attention of the electric power industry.

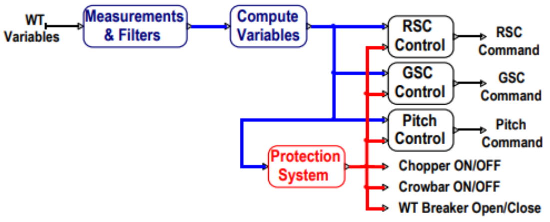
Because of their larger size and breadth, offshore wind farms require higher voltage and more robust transmission schemes to achieve adequate efficiency. The transmission system options to transmit the wind power to the shore are high-voltages (HVAC) or high-voltage dc (HVDC). Studies show that transmitting the offshore wind power through less-expensive HVAC is technically feasible for distances larger than250 km, if series-capacitive compensation is provided for the transmission line.

3. METHODOLOGY



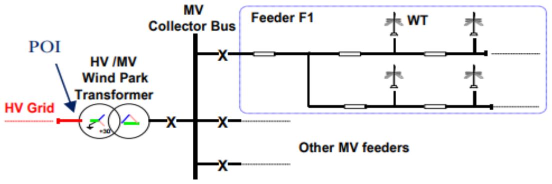
Schematic diagram of DFIG WT.

In WTs with DFIG, the stator of the induction generator (IG) is directly connected to the grid and the wound rotor is connected to the grid through an ac-dc-ac converter system as shown in Fig. The ac-dc-ac converter system consists of two voltage source converters: rotor side converter (RSC) and grid side converter (GSC). A line inductor and shunt harmonic ac filters are used at the GSC to improve power quality. A crowbar is used to protect the RSC against overcurrent and the dc capacitor against overvoltage. During crowbar ignition, the RSC is blocked and the IG consumes reactive power. To avoid the crowbar ignition during faults, the dc resistive chopper is used to limit the dc voltage.

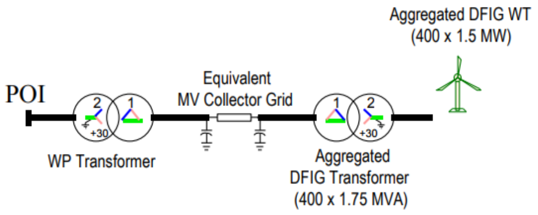


Simplified diagram of DFIG WT control and protection system.

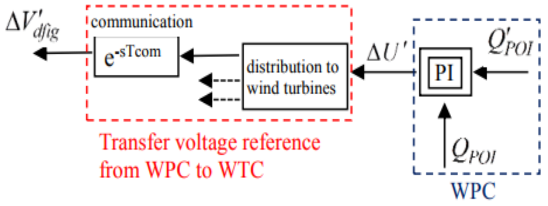
The simplified diagram of DFIG control and protection system is shown in above Figure. The sampled signals are converted to per unit and filtered at "Measurements & Filters" block. The input measuring filters are of low-pass (LP) type. The "Compute Variables" block computes the variables used by the DFIG control and protection system. The "Protection System" block contains cut-in and cut-off speed relays, low voltage and overvoltage relays, GSC and RSC overcurrent protections, dc resistive chopper control and crowbar protection. The "Pitch Control" block limits the mechanical power extracted from wind by increasing the pitch angle when the wind speed is above its rated value. DFIG converters are controlled using vector control techniques.



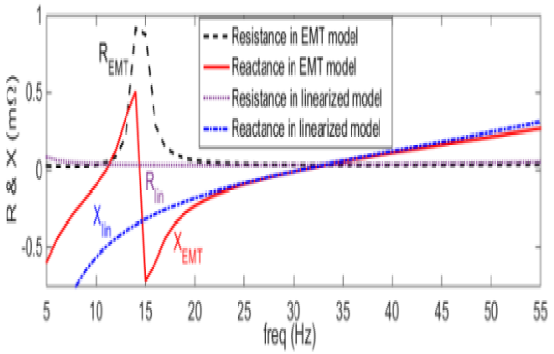
Simplified single-line diagram of a typical wind park.



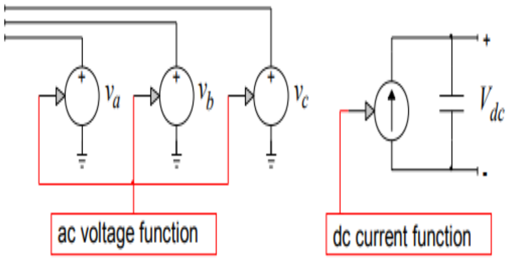
Wind park EMT model.



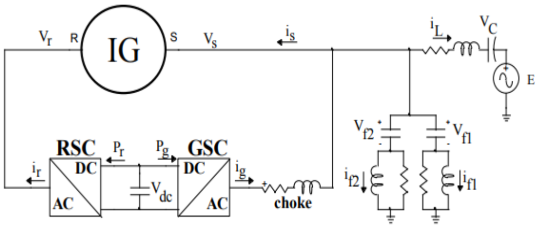
Reactive power control at the POI (Q-control function).



Impedance seen from DFIG terminals when Line-2 is disconnected.



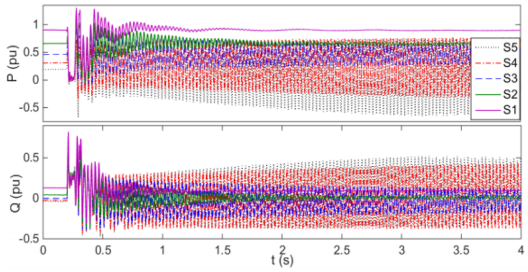
AVM diagram of DFIG converters.



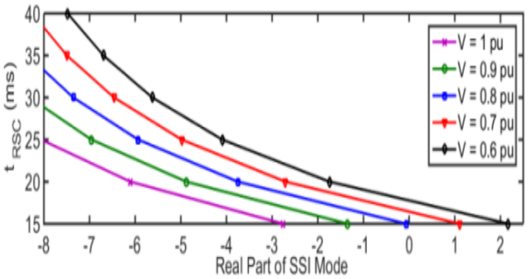
Radially compensated wind park model used in eigenvalue analysis.

Table I: EMT simulations (impact of WP operating conditions)

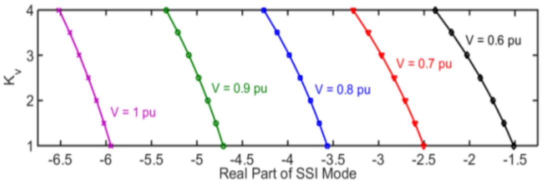
	S1	S2	S3	S4	S5	S6	S7	S8	S9
V (pu)	1	0.9	0.8	0.7	0.6	0.8	0.8	0.8	0.8
Q_{POI} (pu)	0	0	0	0	0	0.2	-0.2	0	0
# of WTs	400	400	400	400	400	400	400	300	200



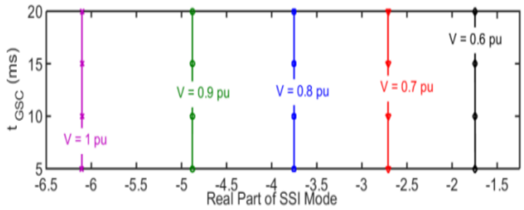
Impact of wind speed on SSCI mode damping.



Impact of RSC rise time on SSCI mode at different wind speeds.



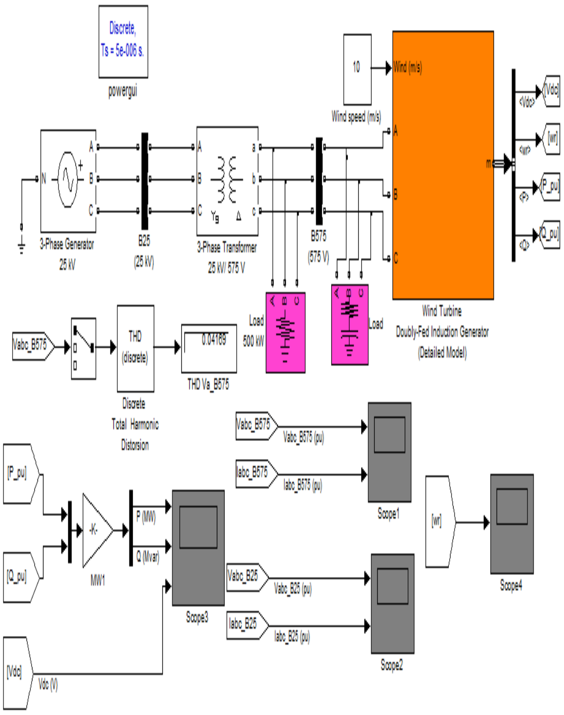
Impact of voltage regulator gain on SSCI mode at different wind speeds.



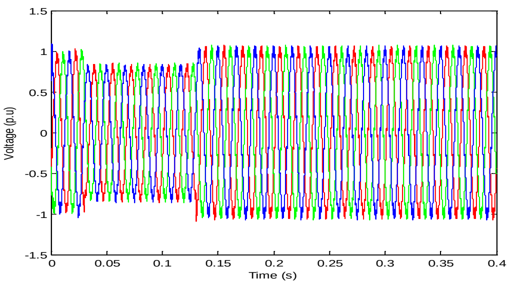
Impact of GSC rise time on SSCI mode at different wind speeds.

The RSC operates in the stator flux reference frame and the GSC operates in the stator voltage reference frame. Both RSC and GSC are controlled by a two-level controller. The slow outer control calculates the reference dq-frame currents and the fast inner control allows controlling the converter ac voltage reference.

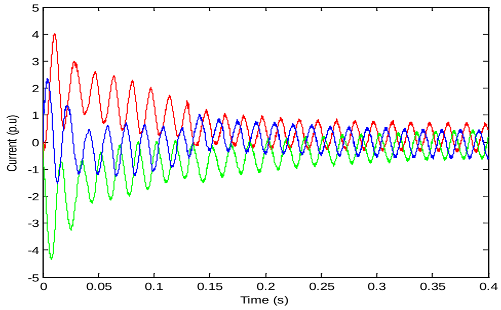
4. SIMULINK DIAGRAM



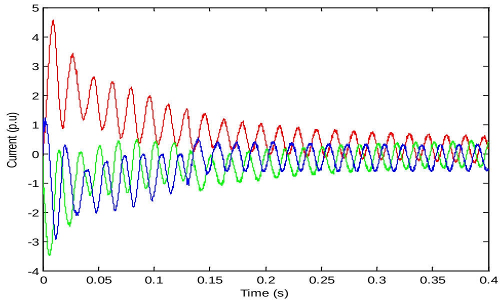
5. SIMULATION OUTPUT



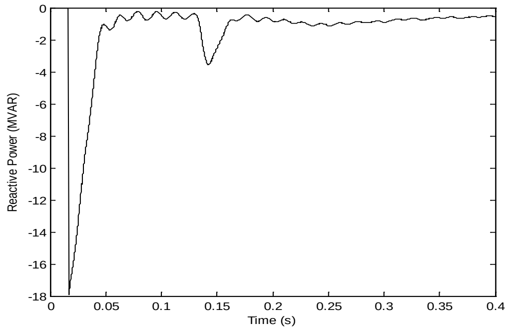
Grid output voltage vs time characteristics



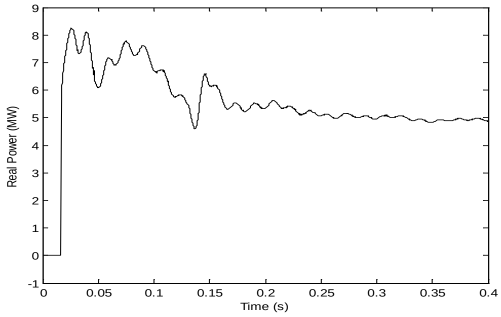
Grid output current vs time characteristics



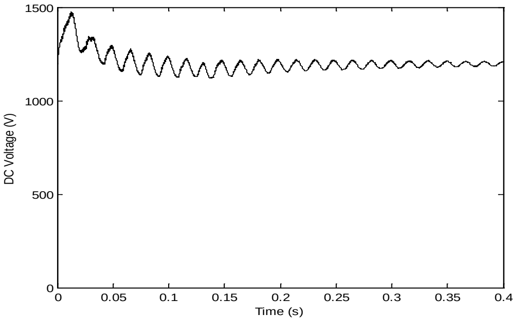
Rotor side output current vs time characteristics



Reactive power vs time characteristics



Real power vs time characteristics



Common link DC output voltages vs time

6. CONCLUSION

This paper presented a methodology for modifying the DFIG control system parameters to ensure safe operation in a series compensated system while maintaining acceptable DFIG transient response to faults. A severe SSCI problem in a practical DFIG based series compensated WP is mitigated by applying the presented methodology. The desired SSCI mode damping is achieved by increasing the RSC rise time. The resulting sluggish inner current loop response is compensated by increasing the voltage regulator gain. This paper also demonstrated that the DIFG input measuring filters have significant impact on SSCI. The SSCI mode damping decreases with the increase in phase-shift introduced by the input measuring filter. Therefore, high order filter usage should be avoided. The SSCI mode damping can be improved further by increasing the filter cut-off frequency. On the other hand, the DFIG control sampling frequency introduces a strict limit for the highest possible filter cut-off frequency. The linearized model of the electrical system is in dq reference frame and it disregards the DFIG input measuring filters. This causes large discrepancies between eigenvalue analysis and EMT simulation results, especially when DFIG input measuring filter introduces a large phase-shift. This paper also proposed a new frequency scan analysis approach for accurate prediction of SSCI problems. The proposed approach considers the contribution of the WP to the resonance condition. The accuracy of the proposed approach has been confirmed with several EMT simulations for various WP operating conditions and DFIG control system parameters.

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