COMPARATIVE STUDY Of DFIG AND SQUIRREL CAGE INDUCTION GENERATOR (SCIG) USED IN WIND FARM AND REACTIVE POWER COMPENSATION

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Abstract—Wind Farms (WF) employing squirrel cage induction generator (SCIG) directly connected to the grid, represent a large percentage of the wind energy conversion systems around the world. In facilities with moderated power generation, the WF are connected through medium voltage (MV) distribution headlines. A situation commonly found in such scheme is that the power generated is comparable to the transport capacity of the grid. This case is known as Wind Farm to Weak Grid Connection, and its main problem is the poor voltage regulation at the point of common coupling (PCC). Thus, the combination of weak grids, Wind power fluctuation and system load changes produce disturbances in the PCC voltage, worsening the Power Quality and WF stability. This situation can be improved using control methods at generator level, or compensation techniques at PCC. In case of wind farms based on SCIG directly connected to the grid, is necessary to employ the last alternative. Custom power devices technology (CUPS) result very useful for this kind of application. In this paper is proposed a compensation strategy based on a particular CUPS device, the Unified Power Quality Compensator (UPQC). A customized internal fuzzy logic control scheme of the UPQC device was developed to regulate the voltage in the WF terminals, and to mitigate voltage fluctuations at grid side. The internal control strategy is based on the management of active and reactive power in the series and shunt converters of the UPQC, and the exchange of power between converters through UPQC DC–Link. This approach increase the compensation capability of the UPQC with respect to other custom strategies that use reactive power only. Simulations results show the effectiveness of the proposed compensation strategy for the enhancement of Power Quality and Wind Farm stability.

This guide is useful to anyone who would like to contribute to open source projects on MATLAB. Open Source is a Great Platform for MATLAB Enthusiasts to share idea. Thank you for your willingness to contribute.

Keywords—Active power, Reactive power, voltage fluctuations, Squirrel Cage Induction Generator, Wind Farm.

I. INTRODUCTION

With the increase in population and industrialization, the energy demand has increased significantly. However, the conventional energy sources such as coal, oil, and gas are limited in nature. Now, there is a need for renewable energy sources for the future energy demand [1].The other main advantages of this renewable source are eco-friendliness and unlimited in nature [2]. Due to technical advancements, the cost of the wind power produced is comparable to that of conventional power plants. Therefore, the wind energy is the most preferred out of all renewable energy sources [3]. In the initial days, wind turbines have been used as fixed speed wind turbines with squirrel cage induction generator and capacitor banks. Most of the wind turbines are fixed speed because of their simplicity and low cost [4]. By observing wind turbine characteristics, one can clearly identify that for extracting maximum power, the machine should run at varying rotor speeds at different wind speeds. Using modern power electronic converters, the machine is able to run at adjust able speeds [5]. Therefore, these variable speed wind turbines are able to improve the wind energy production [6]. Out of all variable speed wind turbines, doubly fed induction generators (DFIGs) are preferred because of their low cost [7]. The other advantages of this DFIG are the higher energy out put, lower converter rating, and better utilization of generators [8]. These DFIGs also provide good damping performance for the weak grid [9]. Independent control of active and reactive power is achieved by the decoupled vector control algorithm presented in [10] and [11]. This vector control of such system is usually realized in synchronously rotating reference frame oriented in either voltage axis or flux axis. In this work, the control of rotor-side converter (RSC) is implemented in voltage-oriented reference frame.

Grid code requirements for the grid connection and operation of wind farms are discussed in [12]. Response of DFIG-based wind energy conversion system (WECS) to grid disturbance is compared to the fixed speed WECS in [13]. As the wind penetration in the grid becomes significant, the use of variable speed WECS for supplementary jobs such as power smoothening and harmonic mitigation are compulsory in addition to its power generation. This power smoothening is achieved by including super magnetic energy storage systems as proposed in [14]. The other auxiliary services such as reactive power requirement and transient stability limit are achieved by including static compensator (STATCOM) in [15]. A distribution STATCOM (DSTATCOM) coupled with fly-wheel energy storage system is used at the wind farm for mitigating harmonics and frequency disturbances [16]. However, the authors have used two more extra converters for this purpose. A super capacitor energy storage system at the dc link of unified power quality conditioner (UPQC) is proposed in [17] for improving power quality and reliability. In all above methods [15]–[17], the authors have used separate converters for compensating the harmonics and also for controlling the reactive power. However, in later stages, some of the researchers have modified the control algorithms of already existed DFIG converters for mitigating the power quality problems and reactive power compensation [18]–[26]. The harmonics compensation and reactive power control are achieved with the help of existing RSC [18]–[23]. Therefore, harmonics are injected from the RSC into the rotor windings This creates losses and noise in the machine. These different harmonics in rotating part may also create mechanical unbalance. Moreover, both reactive power compensation and harmonic compensation are achieved in all the se methods using RSC control. These methods increase the RSC rating. In [24] and [25], harmonic compensation and reactive power control are done using GSC. Therefore, the harmonics are not passing through machine windings in all these cases.

TABLE I

CURRENT DISTORTION LIMITS FOR GENERAL DISTRIBUTION SYSTEMS IN TERMS OF INDIVIDUAL HARMONICS ORDER (ODD HARMONICS)

I_{sc}/I_L	<11	11 ≤ h ≤17	17 ≤ h ≤ 23	23 ≤ h ≤ 35	35 ≤ h	TDD
< 20	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10	4.5	4.0	1.5	0.7	12
100 < 1000	12	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

To deschini and Emanuel [26] have compared three different control algorithms and finally concluded that combined modulation of both RSC and GSC are needed for compensating the harmonics and controlling the reactive power. However, the authors have used direct current control of GSC. Therefore, harmonic compensation is not so effective and total harmonic distortion (THD) is notlessthan5%asperIEEE-519standardgiveninTableI. The authors have also not verified simulation results experimentally. An indirect current control technique is simple and shows better performance for eliminating harmonics as compared to direct current control [27]–[30]. In this work, a new control algorithm for GSC is proposed for compensating harmonics produced by nonlinear loads using an indirect current control. RSC is used for controlling the reactive power of DFIG. The other main advantage of proposed DFIG is that it works as an active filter even when the wind turbine is in shutdown condition. Therefore, it compensates load reactive power and harmonics at wind turbine stalling case. Both simulation and experimental performances of the proposed integrated active filter-based DFIG are presented in this work. The dynamic performance of the proposed DFIG is also demonstrated for varying wind speeds and changes in unbalanced nonlinear loads at point of common coupling (PCC).

The voltage-source converter is widely used as an interface for the renewable energy systems before they are linked to the grid like in the photovoltaic and wind power system cases, with its advantages in fully control of dc-link voltage, active and reactive power, as well as power factor [1]–[3]. A grid filter is normally introduced to avoid the pulse width modulation carrier and side-band voltage harmonics coupling to the grid that can disturb other sensitive loads or equipment. For the megawatt-level wind power converter, due to the quite low switching frequency of the power switching devices(usually several kilohertz), a simple filter inductor consequently becomes bulky, expensive, and it may also bring poorer dynamics into the system [4]–[6]. In order to fulfill the modern grid codes [7]–[9], the wind turbine system is currently required to behave more like a traditional power source (e.g., synchronous generator), which implies that the wind turbine system should have the capability of reactive power support. Due to the doubly fed mechanism of the doubly fed induction generator (DFIG)-based wind turbine system, the reactive power can be supported either by the grid-side converter (GSC) or the rotorside converter (RSC). If the reactive power is provided by the GSC, in the case of the constant dc-link voltage, the modulation index is closely related to the filter inductance, and it will increase very fast to overmodulation, especially when overexcited (OE) reactive power is needed [10]. There are two ways to deal with this issue— increase the dc-link voltage, which gives higher switching loss and power rating, or design an optimized grid filter. Besides, if a small amount of reactive power is demanded by the transmission system operator, it is also of interest to compare the loss of the whole DFIG system, as the reactive power supported by the GSC only affects the loss of the GSC, while the reactive provided by the RSC not only influences the loss of the RSC, but also theloss of the generator itself. Then, the annual energy loss of the wind turbine system and cost of the reactive power can be calculated based on the annual wind profile at different compensation schemes.

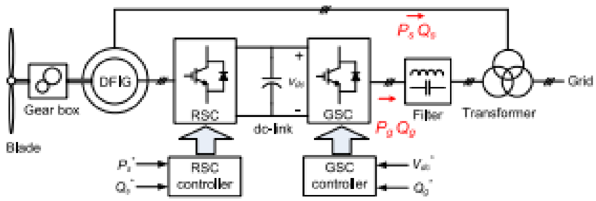

Fig1:Typical DFIG configuration in a wind turbine system (GSC: grid-side converter; RSC: rotor-side converter).

II. WIND TURBINES

If the mechanical essentialness is used particularly by equipment, for instance, a pump or crushing stones, the machine is by and large called a Windmill. A wind turbine is a machine for changing over the engine imperativeness in wind into mechanical essentialness. If the mechanical essentialness is then changed over to control, the machine is known as a wind generator. As wind turbines increase in size and rise to more conspicuous statures to misuse higher imperativeness winds, their towers require more materials and include a greater rate of the wander's cost. Viable advancement techniques can upgrade material sums and decrease costs. In this part territory 3.2 inspect about the sorts of wind turbines like level center wind turbines, vertical center wind turbines and their purposes of interest and blocks. Zone 3.3 looks at the force in the wind. Territory 3.4 is about working of wind turbine. Portion 3.5 is analyzes about self-excitation of wind turbine creating framework. Finally Section 3.6 diagrams the part.

.1 Types of wind turbines

Wind turbines are requested into two general sorts: even turn and vertical center point. A level center point machine has its bleeding edges turning on a center parallel to the ground. A vertical turn machine has its edges turning on a center point inverse to the ground. There are different available diagrams for both and each sort has certain central focuses and shortcomings. Then again, differentiated and the even center point sort, not a lot of vertical turn machines are available financially.

III. DOUBLY-FEDINDUCTION GENERATOR

As the penetration of large scale wind turbines into electric power grids continues to increase, electric system operators are placing greater demands on wind turbine power plants. One of the most challenging new interconnection demands for the doubly fed induction generator (DFIG) architecture is its ability to ride through a short-term low or zero voltage event at the point of common coupling (PCC), resulting from a fault on the grid. During extreme voltage sags high per unit currents and shaft torque pulsations occur unless mitigating measures are taken.

Low voltage ride through requirements were first proposed by German electric transmission operators E.ON and VE-T in2003 .In the U.S. FERC order 661A stipulates that the wind turbine must remain connected to the grid and provide faultclearing current in the event that the voltage at the high side of the step up transformer to the transmission system drops to zero volts for a maximum of nine cycles, as the result of a three phase fault .Similar low/zero voltage ride through requirements have evolved in most European countries, each with varying specifications on minimum voltage level and requiring provisions of real or reactive power during fault events While many grid codes also stipulate ride through of single and two-phase faults, only balanced faults are considered in this paper. In a conventional DFIG wind turbine the machine stator windings are connected to the grid PCC via collection and/or transmission transformers and excited at the grid frequency.

The rotor windings of the DFIG are connected to an ac–converter commonly referred to as the machine side converter (MSC). The ac side of a second dc–ac converter, commonly referred to as the grid side converter (GSC), is connected in parallel with the machine stator windings and PCC.Severe voltage sags and the resulting stator flux response place significant electrical stress on the MSC and mechanical stress on the gearbox. In the stationary frame the stator flux is equal to the integral of the stator voltage minus stator resistive drop. An abrupt stator voltage change produces a constant dc component of stator flux in proportion to the voltage drop

This dc stator flux component appears as an oscillatory electromagnetic field(EMF) when translated into the synchronous and rotor reference frames .Deep sags and correspondingly large EMF in the rotor reference frame cause the MSC to go into over-modulation, resulting in loss of rotor current regulation .The uncontrolled rotor currents can exceed the semiconductor device ratings and result in damage the MSC. In addition, this commonly precipitates high transient stator currents and transient torque spikes .Several options have been proposed to improve low voltage FIG ride through. Two modification to the rotor circuit including the addition of either an silicon controlled rectifier(SCR) rotor crowbar circuit [or a three phase rectifier and modulated resistive load have demonstrated improvement in the DFIG ride-through capability As an alternative, brief disconnection of the stator windings during a voltage sag via an SCR static switch has also been shown to reduce torque and current spikes for sags to 15% of nominal.

A modified rotor current control method has been shown to protect the MSC for wind turbine terminal voltage down to about 30% of nominal, with residual torque spikes and oscillations .From an alternate perspective, the authors of first proposed using an inverter connected to the Y point of the DFIG, In series with the stator windings, for the purposes of damping synchronous frame stator flux oscillations. The presence of the converter in series with the stator winding allows a direct handle with which to access the stator flux state variable. The use of a series connected grid side converter was first considered for the purposes of voltage sag ride briefly in , but it properties and limitations were not studied in depth to develop a definitive solution. Further exploration of the series grid side converter DFIG architecture ,revealed excellent potential for voltage sag ride through but also short comings in power processing capability. A unified DFIG architecture in which the series grid side converter is partnered with a parallel grid side rectifier is presented as an alternative for both DFIG wind turbine power processing and robust voltage sag ride through.

IV. Control Strategy of The RSC

In cases of non severe faults, the fault current provided by the DFIG consists of the stator fault current and the grid side fault current of the grid side converter (GSC). However, since the capacity of GSC is only 25–30% of the rated capacity of wind turbine, the grid side fault current provided by the GSC is so small that it has limited influence on the fault current provided by the DFIG. Hence, in this paper, only the dynamic response characteristics and stator fault current are taken into consideration. The synchronous dq reference frame is chosen to model the

DFIG based on the fifth-order two-axis representation, and the model of DFIG is commonly known as "Park model" [15].

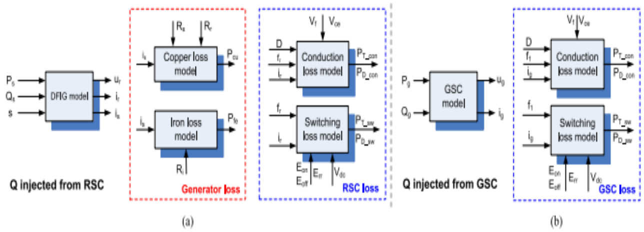

Fig2: Framework of power loss estimation. (a) Reactive power is injected by the RSC. (b) Reactive power is injected by the GSC.

V. Simulation Results

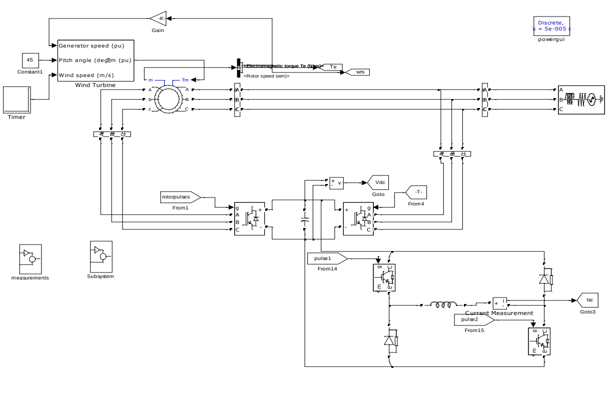

Fig: Simulation circuit of Conventional Wind System

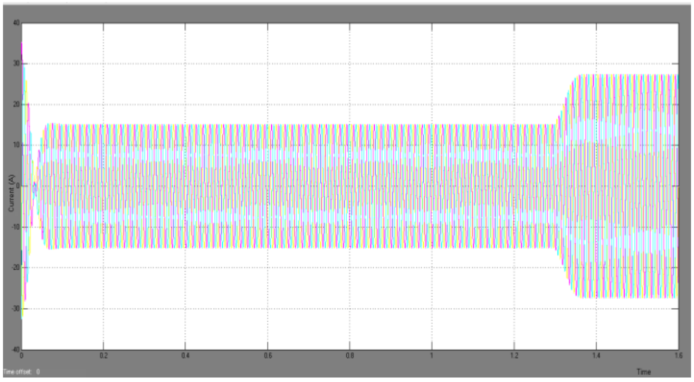

Fig: Load Current

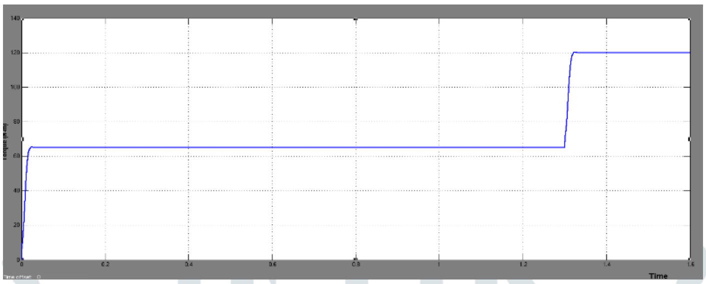

Fig: SGIG Torque

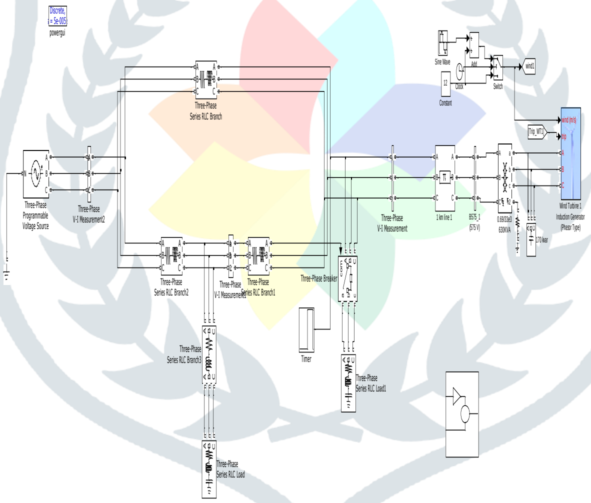

Fig: WECS Without UPQC

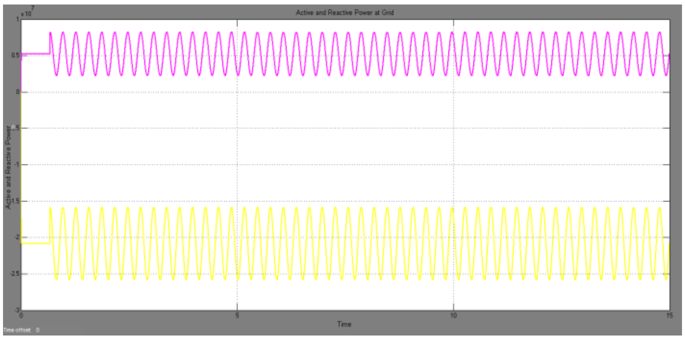

Fig: Active and Reactive Power at Grid

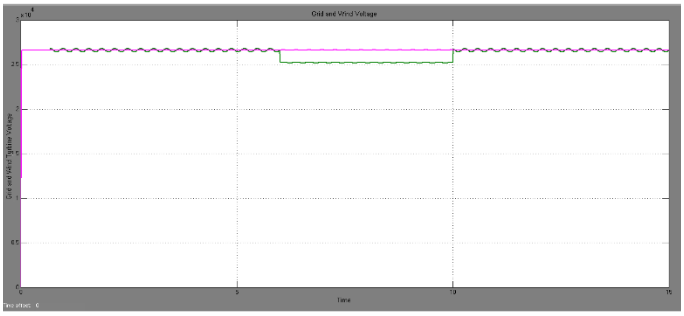

Fig: Grid and Wind turbine voltage

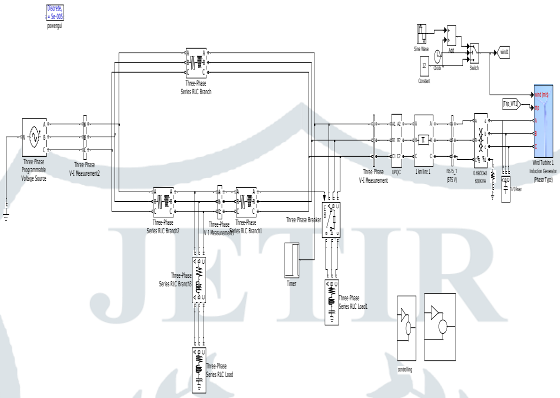

Fig: Wind Energy Conversion System with UPQC

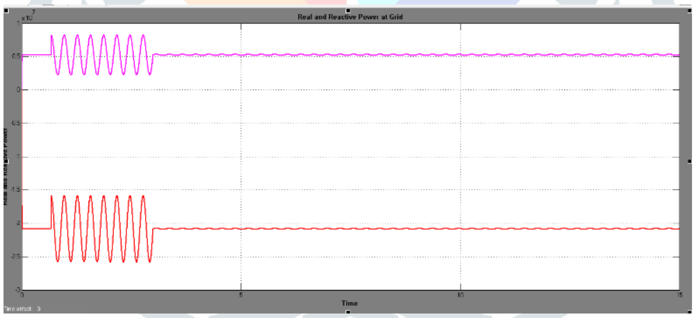

Fig: Active and Reactive Power at Grid

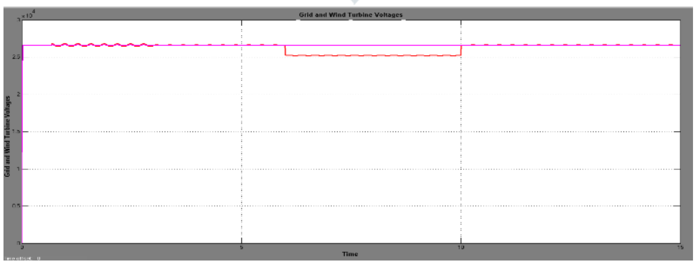

Fig: Grid and Wind turbine voltage

By observing the Grid connected wind energy conversion system with and without UPQC. The active power and reactive variation is veryless with the UPQC. Similarly the voltage fluctuations also very less.

VI. Conclusion

The GSC control algorithm of the proposed DFIG has been modified for supplying the harmonics and reactive power of the local loads. In this proposed DFIG, the reactive power for the induction machine has been supplied from the RSC and the load reactive power has been supplied from the GSC. The decoupled control of both active and reactive powers has been achieved by RSC control. The proposed DFIG has also been verified at wind turbine stalling condition for compensating harmonics and reactive power of local loads. This proposed DFIG-based WECS with UPQC has been simulated using MATLAB/Simulink environment, and the simulated results are verified. Dynamic performance of this proposed GSC control algorithm has also been verified for the variation in the wind speeds and for local nonlinear load.

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