Power Quality Improvement of Wind Energy Conversion System Using Unified Power Quality Conditioner

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Abstract — This paper presents a comparison between Unified Power Quality Conditioner UPQC controller and normal power converter to be used for DFIG control system. Implementation of unified power quality conditioner (UPQC) in wind energy conversion system (WECS) more performance improvement is observed than the normal power converter system. This work deals with two types of UPQC models which is developed for checking its control strategy validity in wind energy conversion system based Double fed induction generator (DFIG) since UPQC has the same structure of the DFIG converters . This paper mainly focuses on efficient control system of unified power quality conditioner that makes it possible to reduce the voltage fluctuations like sag and swell conditions, as well as current and voltage harmonics mitigation in wind energy conversion system. The UPQC which can be used at the PCC for improving power quality is modeled and simulated using proposed control technique and the performance is compared by applying it to a wind energy conversion system with UPQC and with normal power converter. With the help of MATLAB/SIMULINK environment Dynamic models of the DFIG and UPQC are developed.

I. INTRODUCTION

The increasing use of nonlinear loads is the main cause for increased current and voltage harmonics issues. As well as, the penetration level of different size of renewable energy systems based on solar energy, wind energy, fuel cell, nuclear, etc., installed at distribution, transmission levels is increasing significantly. This integration of renewable energy sources in a power system is further imposing new challenges to the electrical power industry to accommodate these newly emerging distributed generation systems [1]. Generally, in various systems like power electronics, signal processing and other control systems, the nature of load characteristics have changed at all. These nonlinear loads draw non-linear current and disturb electric power quality. The quality degradation leads to several problems such as weak power factor, low efficiency, and increasing heat of transformers and so on [2]. Extensive research works have been carried out to check electric power networks having nonlinear loads and quantify the problems associated with. Conventionally passive L–C filters were used to mitigate harmonics and capacitors were employed to be used for power factor correction of the ac loads. However, passive filters have several advantages such as fixed compensation, large size, and resonance. [3]

The increased distortion due to the harmonic pollution in various power networks has took the attention of power electronics and power system engineers to develop dynamic

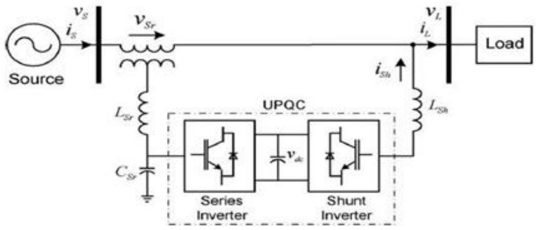

Fig. 1: Unified power quality conditioner (UPQC) system model

and adjustable solutions to the power quality issues. Such equipment, always known as active power filters (APF's), and are also called active power line conditioners (APLC's), instantaneous reactive power compensators (IRPC's), active power filters (APF's), and active power quality conditioners (APQC's). Recently, on load balancing neutral current compensation, harmonics, sags, swells, reactive power associated with linear and nonlinear loads many publications have also appeared [3]. Simultaneously, The Unified Power Quality Conditioner (UPQC) is one of the best solutions to solve problems related to both current and voltage in power system [4 - 5]. The UPQC illustrated in the general model which is shown in Fig. 1 [6].

II. UPQC TECHNIQUE

Now days, with the advancement in complex electronics industries, there are lots of problems associated with the power system and it has become necessary to provide a dynamic solution with high degree of accuracy and fast speed of response in order to mitigate and deals with these kinds of issues. The active power filtering has appeared as one of the best solutions for mitigation of major power quality problems [7]. In Parallel with advancement in the field of power electronic devices and automated control systems, it is very common to come across the situation where compensation of both current and voltage related problems are required. Recently, The UPQC which is integration of shunt and series APF is one of the most suitable as well as effective device in this concern [8]. A comprehensive review on the UPQC to enhance the electric power quality at distribution and transmission levels for various type of power generation system has been reported in [9]. Developments up to date, new designs and different aspects of UPQC in this area of research have been briefly addressed. An effort is made to put the UPQC interesting features in category through an acronymic organization list. These acronyms could be used to clearly identify particular application, utilization, configuration, and/or characteristic of the UPQC system under study. It is desirable that this review on UPQC will serve as a useful reference guide to

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the researchers working in the area of power quality enhancement utilizing APFs [9]. The main purpose of UPQC is to solve the problems coming from both source side and load side, such as voltage sag, voltage swell, distortion in the supply voltage, harmonic currents, reactive currents etc. [10].

The UPQC generally classified in two main categories based on:

1. The physical structure and
2. The voltage sag compensation.

Voltage sag compensation type is one of the important functionalities of UPQC [9].

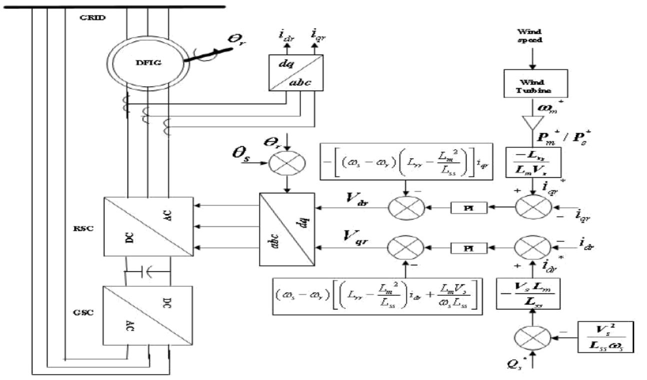

Fig. 2: Vector Control diagram of DFIG

The RSC control diagram presented is directly established from the equations of the DFIG model. For the speed control, a Proportional Integral (PI) corrector with anti-wind-up loop has been designed. The three-phase reference rotor currents are generated by the RSC controller implementing a "modulated hysteresis current controller". Fig. 3. Represent the RSC control developed with the help of Matlab/Simulink software to be used in our proposed system.

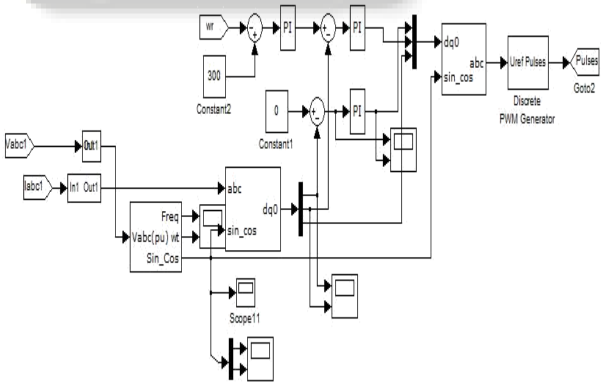

Fig. 3: RSC developed in MATLAB/SIMULINK

III. GSC VECTOR CONTROL

The GSC is used to regulate the voltage of the DC bus connected between the RSC and the GSC. The power factor is set to unity, or in a way to fulfill the command strategy. The direct axis current is used to regulate the GSC reactive power and the quadrature axis current is used to regulate the DC bus voltage. This method also gives the possibility to control independently the active and reactive power exchanged between the GSC and the electrical grid. PWM control has been used for this converter with a switching frequency of 10kHz [13]. Fig. 4. Represent the GSC controller implemented in Matlab / simulink software to be used for our proposed system .

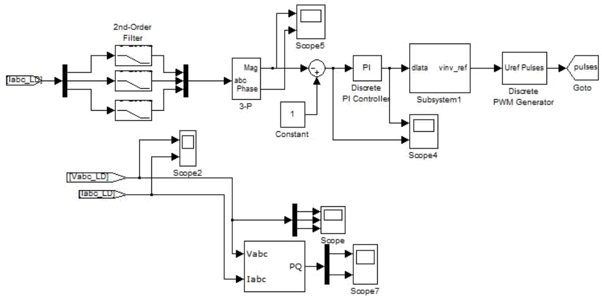

Fig 4: GSC developed in MATLAB/SIMULINK

A. Shunt Inverter Control

The UPQC shunt inverter controlling block diagram shown in fig .3 using synchronous reference frame theory where the sensitive load currents are (I_{La} , I_{Lb} I_{Lc}). The measured currents of load are transferred into d_{q0} frame using sinusoidal functions through d_{q0} synchronous reference frame conversion. The sinusoidal functions are obtained through the grid voltage using PLL. Here, the currents are divided into AC and DC components.

The active part of current is i_d while i_q represent the reactive one. AC and DC elements can be derived by a low pass filter. Controlling algorithm corrects the system's power factor and compensates the all current harmonic components by generating the reference currents as relation (2):

$$i_{fd}^* = \tilde{i}_{ld} \ , \ i_{fq}^* = i_{lq}$$

$$i_{sd} = \bar{i}_{lq} \ , \ i_{sq} = 0$$

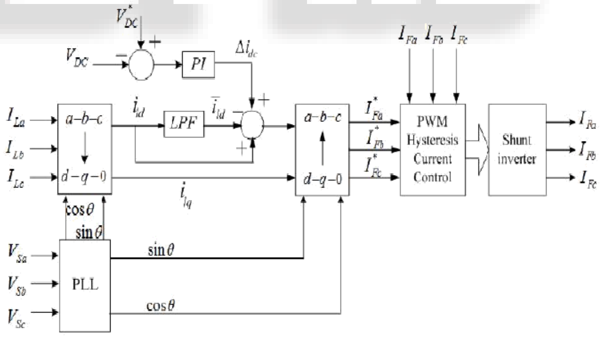

Fig. 5

B. DC Link Voltage Control

As mentioned above in last section a PI controller function is tracking the error exists between the measured and desired values of capacitor voltage in order to control the D.C link voltage as Fig. 4. Very large increasing in proportional gain make the control system unstable and so much reduction decreases the responding speed of control system. Integral gain of controller corrects the steady state error of the voltage control system.

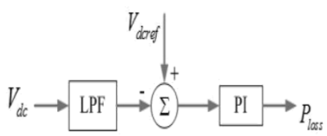

Fig. 6: DC Link Voltage Control Block Diagram.

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If this gain value is selected large, the resulted error in steady state is corrected faster and too much increase in its value ends in overshoot in system response [14].

IV. CONCLUSION

UPQC topology has been proposed in this paper, which has the capability of compensating the load. The proposed method is validated through simulation studies in a wind energy conversion. This paper has compared harmonic mitigation, power compensation and voltage regulation in wind energy conversion system through reduction of total harmonic distortion due to the connection of UPQC and normal converters in it. It also discussed capability of the both shunt and series power inverter of the UPQC to achieve a green active and reactive power source with compensation capability and suggest the various type of UPQC to be under light. Simulation results demonstrated that active filter behavior has additional function to improvement impact on the system power factor and reduction of the power loss.

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