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# Controlling of DFIG Based Wind Energy Conversion System

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***Abstract*—The wind turbine with doubly-fed induction generator (DFIG) is gaining laurels in the growing wind market. Through a bidirectional converter in the rotor circuit, the DFIG can function as a generator in both the sub-synchronous and super-synchronous modes. DFIG is connected to back-to-back converters. In general, VAR compensation is a big problem in WECS. Capacitor banks must be added in parallel to the machine, which generates many problems, such as overvoltage's, etc. In this project, the grid side converter compensates for reactive power instead of providing an additional compensating device. The additional power is also extracted from the side of the rotor. The converter on the machine side controls the rotor speed using the v / f control technique, while the grid side converter controls the intermediate circuit voltage and ensures operation by passing the reactive power extracted from the system to zero using the oriented control technique to the tension. The network side current is controlled using the reference current generation in the p-q theory. The performance of DFIG is analyzed during the operation of sub-synchronous and super-synchronous generation mode using MATLAB / SIMULINK.**

***Index Terms*—doubly-fed induction generator (DFIG), wind energy conversion systems (WECS), voltage oriented control (VOC), p-q theory, utility grid, rotor side converter (RSC), grid side converter (GSC).**

## I. INTRODUCTION

Nowadays, consumption of conventional energy sources has increased, so efforts have been made to generate electricity from renewable energy sources such as wind, solar, etc., wind energy has become one of the most important and promising sources of renewable energy. This requires additional transmission capacity in better ways to maintain system reliability. Today the wind capacity of the world is approximately 50 GW and is expected to reach 160 GW in 2012. In the modern wind turbine generation system (WTGS), the Wind turbines are subject to load variation and the impact of sudden changes in wind speed. With greater penetration of wind energy into power grids, the wind of the doubly powered induction generator (DFIG) Turbines are used to a large extent because of their variable velocity characteristic and thus influence the dynamics of the system. This has created an interest in the development of appropriate models for the DFIG to be integrated into the studies of the energy system. The continuing trend of having a high penetration of wind energy, in recent years, has made the introduction necessary new practices In addition, to model electronic power converters, in the simplest scenario, it is assumed that the converters are ideal and the intermediate circuit voltage between the converters is constant. As a result, depending on in converter control, a controllable voltage source (current) can be implemented to represent the operation of the rotor side of the converter in the model.

## II. DOUBLY FED INDUCTION GENERATOR

### A. Introduction

The wound rotor induction generators (WRIG) are equipped with three-phase windings in the rotor and in the stator. They can receive energy both in the rotor and in the stator terminals. That's why they are called doubly fed induction generators (DFIG) or double output induction generators (DOIG) in generator mode. Both the operating modes of motorization and generation are feasible, provided that the electronic power converters that supply the rotor circuit through sliding rings and brushes is able to manage the energy in both directions.

### B. Operating Principle of DFIG

The main high power wind energy conversion systems (WECS) are based on doubly fed induction generators (DFIG). The stator windings of the DFIG are connected directly to the grilles and the rotor windings are connected to networks via power electronic converters one after the other. The back-to-back converter consists of two converters, i.e. the lateral rotor converter (RSC) and the network-side converter (GSC) connected back-to-back. Between the two converters a capacitor of the intermediate circuit is placed, as energy storage, to maintain the voltage changes in the voltage of the small intermediate circuit. The control of the DFIG is more complicated than the control of a standard induction machine to control the DFIG, the rotor current is controlled by an electronic power converter. Wind turbines use a DFIG consisting of an electronic WRIG and AC / DC / AC power converter. The stator the winding is connected directly to a three-phase 50Hz network while the rotor is fed at variable frequency through the AC / DC / AC converter through sliding rings to allow DFIG to operate at variable speeds in response to wind change speed as shown in Fig.1. A typical application for DFIG is wind turbines, as they operate at a limited speed around 20-25% range. Other applications for the DFIG system are pumped, volumetric energy storage systems storage power plants, etc. The total system is that the converter on the machine side controls the speed, while the converter on the network side controls the dc-link voltage and ensures operation in the power factor of the unit (i.e. zero reactive power). Through a bidirectional converter in the rotor circuit, the DFIG can operate as a generator both in sub-synchronous and in super-synchronous mode. Depending on the operating conditions, the current is supplied or extracted from the rotor (which is the case of the super-synchronous mode), then flows from the rotor through the converter to the network.

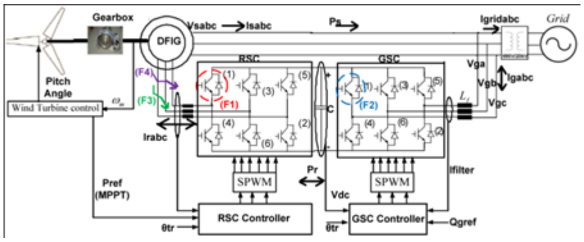

Fig. 1. DFIG system with power electronic converters

PCrotor is used to generate or absorb the power of the Pg in order to keep the DC voltage constant as shown in Fig.1. At steady state for a converter without AC / DC / AC losses, the Pg is equal to Pr and the wind turbine speed is determined by the power generated by Pr absorbed or PCrotor. The sequence of phases of the alternating voltage generated by PCrotor is positive for sub-scale and negative speed for Super-synchronous speed. The frequency of this voltage is equal to the product of the frequency of the network and to the absolute value of the slip. Pcrotor and PCgrid have the ability to generate or absorb reactive power and can be used to control reactive power or voltage at the network terminals. Fig. 1, Shows the DFIG system with electronic power converters.

### C. *Characteristics of the DFIG*

As a renewable resource, the wind has several important characteristics that include which it is difficult to predict that its direction and speed vary rapidly and randomly. These features complicate the conversion process Wind energy in electricity.

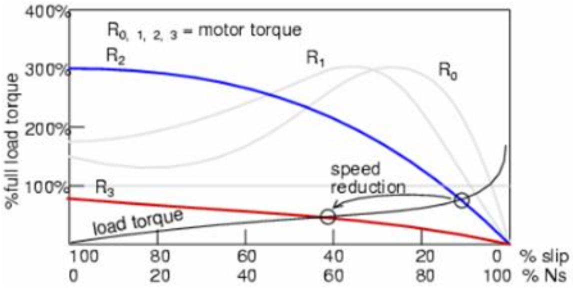

Fig. 2. Torque-Speed characteristics of the DFIG

The negative value of the slip is to operate the machine above the synchronous speed in the direction of the rotating field. Since the direction of the torque is reversed simultaneously (opposite to the direction of the rotating field), the symbol the machine must be powered by a mechanical energy source to neutralize the opposite torque. In the process, the machine acts as a generator that powers the source. For s>1, the machine turns in a direction opposite to that of the rotating field and the internal torque. To maintain this condition, the machine must be guided by a source of mechanical energy. This way of working with the induction machine is known as obstruction and is equivalent to an electric braking method.

## III. CONTROL SCHEME

### A. *Introduction*

In WECS, the machine initially takes the reactive power to start. Therefore, VAR compensation is a big problem in WECS. Capacitor banks, if added in parallel to the machine, can generate over voltages. If a further Compensating devices such as STATCOM / SVC, etc., added, can generate complexity in the control and can cause uneconomic expenses. In this system, DFIG with backup converter, the network converter acts as a compensation device and keeps UPF on the side of the grid. Numerous controlled voltage control and control techniques are reported the control of the reference current generation is simple and easy to implement.

### B. *Voltage Oriented Control (VOC)*

The inverter connected to the network can be controlled with different schemes. One of the schemes is known as voltage oriented control (VOC), as shown in figure.3.1. This scheme is based on the transformation between stationary abc reference frames and synchronous frames dq. The control algorithm is implemented in the synchronous voltage network frame of reference, in which all the variables are DC components in steady state. This facilitates design and inverter control. To perform the VOC, the grid voltage is measured and its tolerance angle is determined for voltage orientation. The angle is used for the transformation of variables from the stationary frame abc to the synchronous frame dq through the transformation abc / dq or from the synchronous frame to the stationary frame through the dq / abc transformation as shown in Fig. 3. Several methods are available for detecting the voltage angle of the θg network. Supposing that the network voltages, vag, vbg, vcg are sinusoidal balanced waveforms in three phases, θg. It can be obtained from,

$$\theta_g = \tan^{-1}\left(\frac{V_\beta}{V_\alpha}\right) \quad (1)$$

The above equation indicates that it is not necessary to measure the phase network voltage c vcg as shown in Fig. 3. In practice, the network voltage can contain harmonics and distort, then digital filters or block in phase the loops (PLL) can be used to detect the voltage angle of the network θg. where Q*g is the reference for the reactive power, which can be set to zero for the operation of the power factor of the unit, a Negative value for the operation of the initial power factor or a positive value for the operation of the delayed power factor.

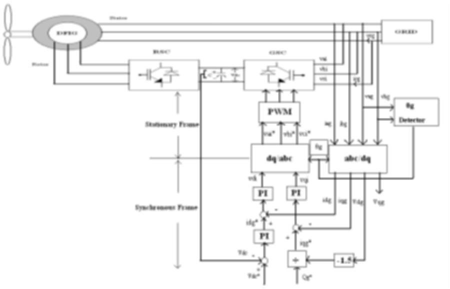

Fig. 3. Block diagram of voltage-oriented control

### C. Reference Current Generation Control

Regarding to the quantity that has to be measured and analyzed in order to generate the current reference signal of the (shunt) active filter control system, there are three kinds of strategies:

i. Load current detection.
ii. Supply current detection
iii. Voltage detection.

The detection of the charging current and the detection of the supply current are recommended for locally active derivation filters. For high-powered non-linear individual consumers. Voltage detection is recommended for: (a) active derivation filters operating in complex equipment (called "unified conditioner"), whose destiny is to equip the primary distribution substations; (b) active derivation filters located in the distribution system and supported by utility In addition, the active filters in the series are mainly based on the detection of the supply current. There are mainly two types of control strategies for analyzing and extracting current or voltage harmonics from distorted waveforms Load current detection and supply current detection are recommended for shunt active filters working locally, for individual non-linear high-power consumers. Voltage detection is suggested for: (a) shunt active filters functioning in complex equipment’s (so called “unified power quality conditioner”), whose destination is to equip the primary distribution substations; (b) shunt active filters located in the distribution system and supported by utilities. Also the series active filters are mostly based on supply current detection. There are mainly two kinds of control strategies for analyzing and extracting current or voltage harmonics from the distorted waveforms.

i. Frequency–domain: based on the Fourier analysis in the frequency-domain;
ii. Time-domain: based on the theory of instantaneous reactive power in the three-phase circuits and often called p-q theory.

In 1983,Akagi etc. all have proposed the "The Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits", also known as instantaneous power theory, or p-q theory. The p-q theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages and currents in the a-b -c coordinates to the a-ß-0 coordinates, followed by the calculation of the p-q theory instantaneous power components.

$$p = v_a i_a + v_b i_b + v_c i_c \tag{2}$$

The relation of the transformation between each component of the three phase power system and the orthogonal coordinates are expressed in space vectors shown by the following equations in terms of voltage and current as shown in above equation. This instantaneous reactive theorem performs instantaneously as the reactive power is detected based on the instantaneous voltages and currents of the three phase circuits.

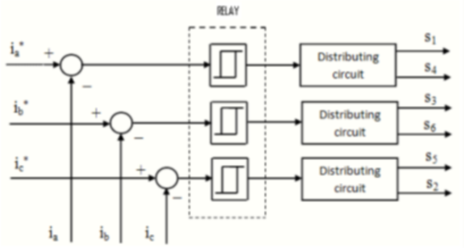

Fig. 4. Block diagram of current control

Basic p-q theory has proven to be inaccurately when the load voltage system is distorted and/or unsymmetrical. In order to compensate the limitations, the method has been improved and extended.

## IV. SIMULATION RESULTS

The operating modes of the DFIG machine, i.e. sub-synchronous generation and super-synchronous generation, are simulations and waveforms for speed and stator, rotor power and torque in each of the operating modes listed above. The rotor speed is controlled by v / f control and the reactive power of the network side and $V_{dc}$ are controlled by the use of voltage-oriented control techniques. The lateral current of the electrical network is controlled using the reference current control techniques under the p-q theory.

### A. Sub-Synchronous Generating Mode

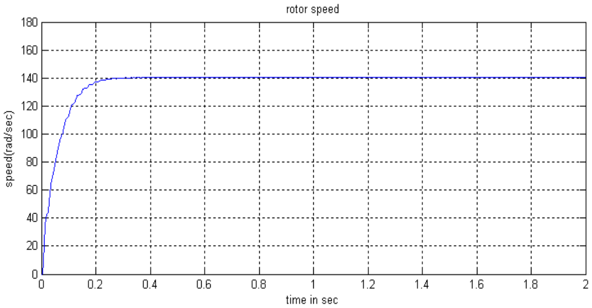

Fig. 5. Speed output waveform

In sub-synchronous generating mode the rotor power is injected into the machine in order to make the air gap power as constant. Since the slip is positive in sub-synchronous operation mechanical power is lower than air gap power ($P_m < P_{ag}$).

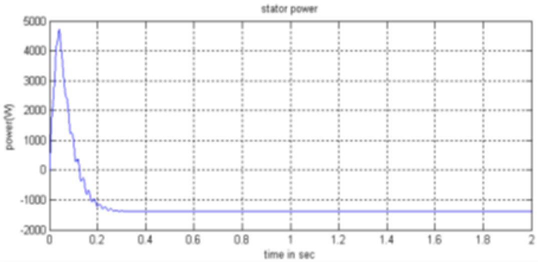

Fig. 6. Stator power waveform

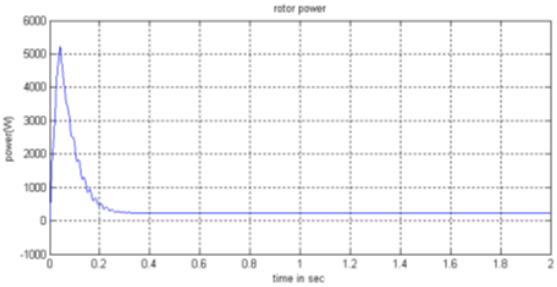

Fig. 7. Rotor power waveform

### B. *Simulation Results for Voltage Oriented Control Scheme*

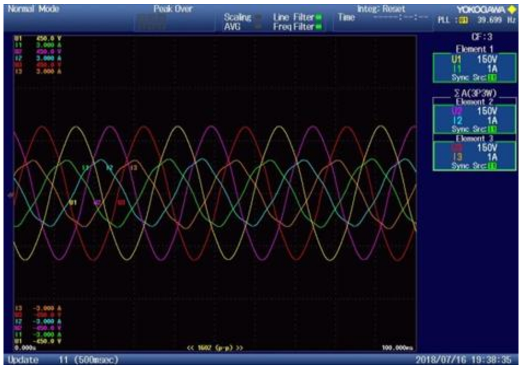

Fig. 8. Stator voltage waveform

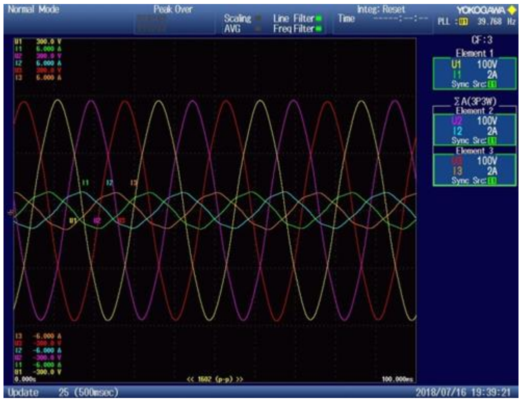

Fig. 9. Stator current waveform

The main objective of the grid side converter is to maintain dc-link voltage constant for necessary action. The voltage oriented control technique is approached to solve this issue. The PWM converter is current regulated with the direct axis current is being used to regulate the DC link voltage whereas the quadrature axis current component is used to regulate the reactive power.

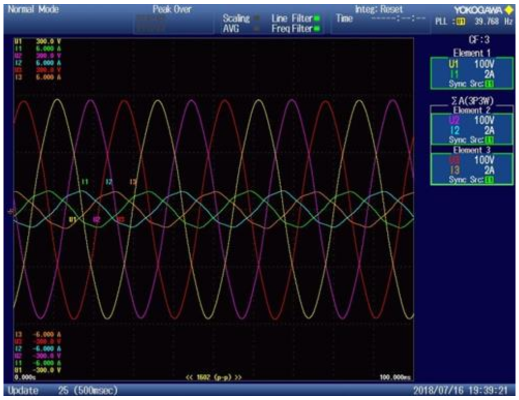

Fig. 10. Rotor voltage waveform

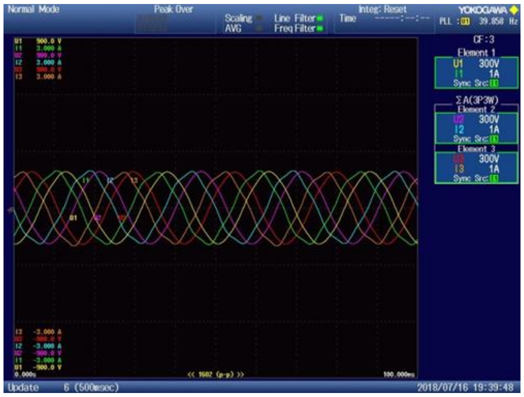

Fig. 11. Rotor current waveform

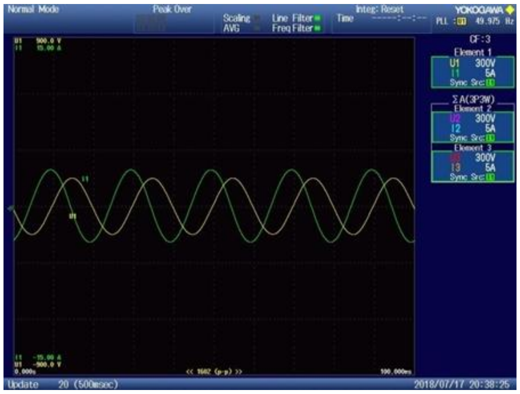

Fig. 12. DC-Link voltage output waveform

## V. CONCLUSION

Detailed models of the DFIG have been analyzed with required parameters and their generating mode of operation is explained clearly with help of waveforms obtained from simulation results. The various response of the system are observed in both super and sub-synchronous generating mode of operation. The control scheme of machine-side converter and grid-side converter has been simulated by using MATLAB/SIMULINK.

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