# Analysis of Vector Controlled Onshore DFIG With STATCOM for Power Compensation

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**Abstract.** The wind power as a one of renewable energy resources with respect to increasing demanded load is highly required. Therefore the study of the effect due to dynamic nature of power system on wind farm is necessary for improvement. The increased consumption of electric power causes transmission lines to be operated on boundary limit to or even beyond their capacities causing in overloaded transmission lines and congestions. By controlling active and reactive power flow with keeping healthy voltage can be done with FACTS devices. This paper presents the impact of Static Compensator or STATCOM on the stability of grid integrated wind turbine system and the behavior in overloaded condition. For the present work doubly fed induction generator model is used for executing dynamic simulations and detailed analysis has been provided.

**Keywords:** DFIG, FACT, Voltage Fluctuation, STATCOM.

## 1 Introduction

With the increasing need for variable speed operation, , the Doubly Fed Induction Generator (DFIG) wind turbines are in great demand. Voltage control and reactive-power management are two major concerns for power system while grid connected DFIG is also affected due to continuous voltage fluctuations.

Voltages at the terminals of all equipment in the system are within suitable bounds. Both utility equipment and customer equipment are designed to function at a definite voltage mark. Prolonged operation of the equipment at voltages outside the permissible array should unfavourably upset their performance and perhaps cause them harm.

System steadiness is improved to make the most of transmission arrangement. Voltage and reactive power control have an important influence on system stability.

The reactive power flow is reduced so as to decrease secondary resistance and secondary reactance to applied lowest. This safeguards the transmission system functions proficiently, i.e., mainly for active power transfer.

Voltage control is problematical by two extra issues. First, the transmission system itself is a nonlinear consumer of reactive power, dependent on system loading. At very light load the system generates reactive power that should be absorbed, while at heavy load the system consume large reactive power that should be supplanted. The system's reactive power necessities also depend on the generation and transmission arrangement.

Thus, system reactive requirements differ in time as load levels and load and generation arrangements change. The bulk-power system is collection of many pieces of equipment, some of which can nosedive at any time. Therefore, the system is planned to endure the loss of any single equipment and to remain operating without impacting any customers.

# 2 Background

## 2.1 Doubly Fed Induction Generator(DFIG)

A Doubly Fed Induction Generator(DFIG) is one of the popular generators applied in wind turbines. The DFIG is an induction machine with an arrangement of wound rotor. The rotor and stator are both linked to electrical sources, hence the term ‘doubly-fed’. The rotor has a three phased windings which are keyed up with three-phase currents. These rotor currents helps in establishing the rotor magnetic field. The rotor magnetic field interact with the stator magnetic field to develop torque. The magnitude of the torque depends on the power of the two fields (the stator field and the rotor field) and the angular displacement between the two fields. Mathematically, the torque is the vector multiplication of the stator and rotor fields. Brush-less wound-rotor design for doubly fed electric machine has certain advantages in performance.

## 2.2 DFIG Operation

The AC-DC-AC converter used on the rotor which consists of two voltage-sourced converters, i.e., rotor-side converter (RSC) and grid-side converter (GSC the AC-DC-AC converter) used on the rotor which consists of two voltage-sourced converters, i.e., rotor-side converter (RSC) and grid side converter (GSC), which are associated “back-to-back.” Between the two converters a dc link capacitor is placed, as energy storage, in order to keep the voltage variations (or ripple) in the dc-link voltage diminutive. VSC with IGBT application are used for this purpose. The three-phase slip ring rotor winding is connected to converter of rotor side[6]. Simulations have been performed with considering converter on both sides.

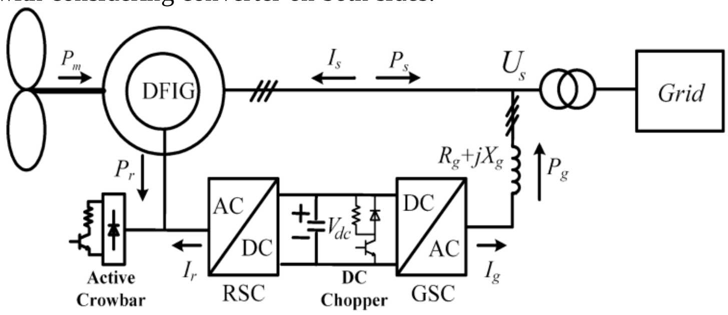



**Fig. 1.** The wind turbine and Doubly Fed Induction Generator System[4].

## 2.3 Static Synchronous Compensator

The STATCOM is a parallel connected reactive compensation device which is capable of developing and/or enthralling reactive power whose output can be disparate so as to uphold control of certain parameters of the electrical power systems. The STATCOM working characteristics is rotary ssame as that of synchronous compensator without the mechanical inertia, due to the STATCOM we use solid state power switching devices as it provides speedy controllability of the three phase voltages, both in magnitude and phase angle. STATCOM gives voltage support to system buses by modulating bus voltages during dynamic volatility in order to provide eficent transient characteristics, we perk up the transient stability limits and to damp out the system oscillations owing to these disturbances.

Usually a STATCOM is installed to support electricity networks that have a reduced power factor and often pitiable voltage regulation. There are however, additional uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based piece of equipment, with the voltage source following a reactor. The voltage source is produced from a DC capacitor and therefore a STATCOM has very little active power potential. However, its active power capability can be increased if a appropriate energy storage device is linked across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage basis. The rejoinder time of a STATCOM is shorter than that of a static VAR compensator (SVC), mainly due to the high-speed switching time provided by the IGBTs of the voltage source converter. The STATCOM also equip revised reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM contracts linearly with the AC voltage.

### 2.4 Reasons for choosing STATCOM

Capacitors are typically connected to fixed speed wind turbines to improve the system voltage because they are a sink of reactive power. Mechanically switched fixed shunt capacitors can get improved the system's voltage stability limit, but is not very responsive to voltage changes. Also, voltage in harmony by the wind generators equipped with only rigid capacitors can become higher than the voltage limit of 1.05 pu. Hence, a fixed capacitor cannot dole out as the lone source of reactive power compensation.

The main significant advantages of using STATCOM over a thyristor based SVC is that its compensating current is not reliant on the voltage level at the connection point which means that the compensating current is not lowered as the voltage drops.

The output of the wind power plants and the totality load diverge continuously all through the day. Reactive power compensation is necessary to maintain normal voltage levels in the power system. Reactive power imbalances, which can critically affect the power system, can be minimized by reactive power compensation devices such as the STATCOM. The STATCOM can also contribute to the small voltage ride through obligation because it can operate at full capacity even at lower voltages.

In this paper, a voltage source converter (VSC) PWM technique based STATCOM is planned to soothe grid connected DFIG based wind turbines. If the principal voltage of the inverter side becomes superior than the system side, the current passes the AC power system through the leakage reactance (X) of the transformer, and inverter generates reactive power for the power system (capacitive case). If the secondary voltage of the inverter side becomes larger than the system side, the reactive current passes from AC system to the inverter and inverter observe reactive power..

### 2.5 Voltage Sourse Converter in DFIG

At the current state of improvement, most DFIG power electronics utilize a two-level six switch converter as shown in fig. 2. Two-level refers to the number of voltage level that can be formed at the output of each bridge leg of the converter. A two-level converter can characteristically output zero volts or Vdc, where Vdc is the voltage of the dc link. Fig. 4 shows two such converters linked in a back-to-back array with a DC link between the two converters. The switching elements in higher power converters are probable to be Insulated gate Bipolar Transistors (IGBTs). The six switch converter can synthesis a three-phase output voltage which can be of subjective magnitude, frequency and phase, within the restraint that the peak line voltage is less than the DC link voltage. The converter is able of changing the output voltage almost immediately. The boundary is related to the switching frequency of the pulse-width modulated switching devices, and delays introduced by any filtering on the output (typical on the grid-side converter). The converter switches are switched ON and OFF with a preset frequency but with a pulse-width that is wide-ranging in order to control the output voltage.

### 2.6 Vector Control of Both side Converter Circuit

**The Rotor Side Converter (RSC)**: Rotor-side converter (RSC) implements the voltage to the rotor windings of the doubly-fed induction generator. The purpose of the rotor-side converter is to administer the rotor currents such that the rotor flux array is optimally leaning with respect to the stator flux in order that the preferred torque is developed at the shaft of the machine. The rotor-side converter uses a torque controller to normalize the wind turbine output power and the voltage (or reactive power) deliberate at the machine stator terminals. The power is controlled in order to trail a pre-defined turbine power-speed characteristic to track the maximum power point. The real electrical output power from the generator contacts, adds to the total power losses (mechanical and electrical) is compared with the orientation power obtained from the wind turbine characteristics. Generally, a Proportional-Integral (PI) regulator is used at the exterior control loop to reduce the power error (or rotor speed error) to zero. The output of this regulator is the reference rotor current irqref that have got to be injected in the rotor winding by rotor-side converter[4]. This q-axis part control the electro- magnetic torque (Te). The actual irq component of rotor current is compared with irqref and the fault is reduced to zero by a current PI regulator at the inner control loop. The resultant of this current controller is the voltage Vrq obtained from the rotor-side converter.

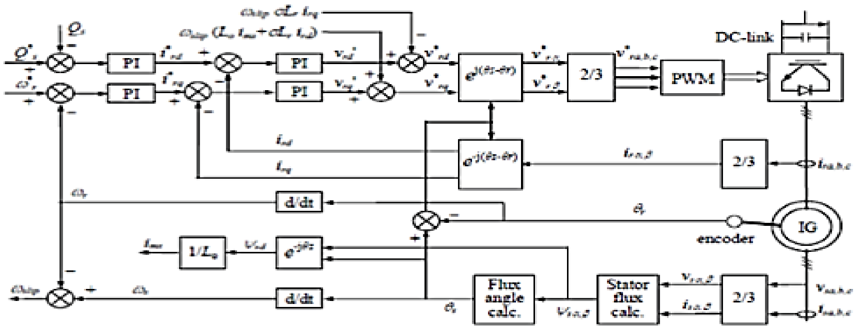



**Fig. 2.** Vector Structure of Rotor side Converter [4]

**The Grid-Side Converter (GSC) :** The grid-side converter aims to manage the voltage of the dc bus capacitor. furthermore, it is allowable to generate or take up reactive power for voltage hold up requirements. The function is realize with two control loops. Exterior regulation loop be expressed by of a dc voltage regulator. The output of the dc voltage regulator is the indication current icdref for the current regulator[4]. The inner current parameter loop consists of a current regulator scheming the enormity and phase of the voltage generated by converter as of the icdref produced by the dc voltage regulator as well as specified q-axis icqref reference.

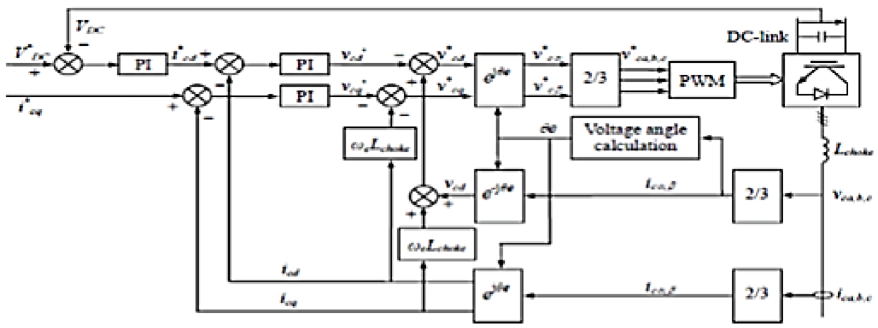
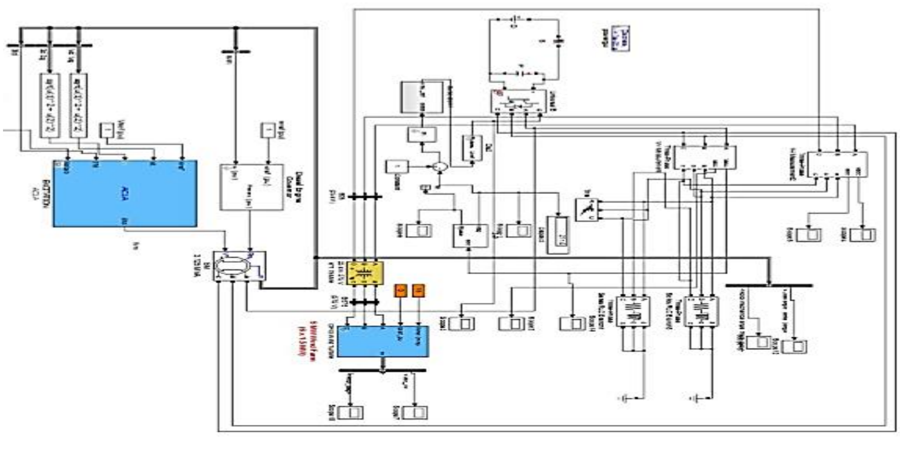



**Fig. 3.** Vector Structure of Grid  side Converter[4]

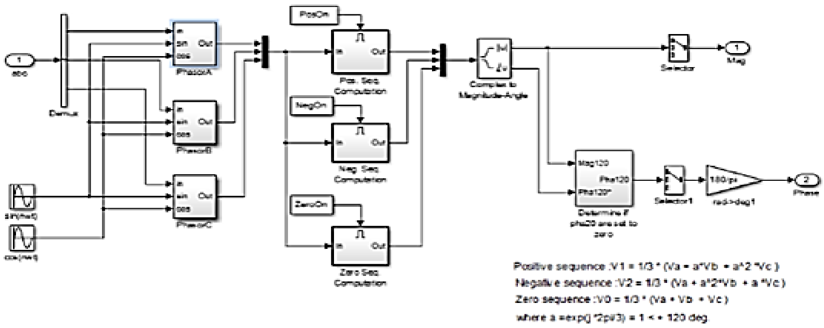
## 3 Simulation and Results

### 3.1 Simulation Model

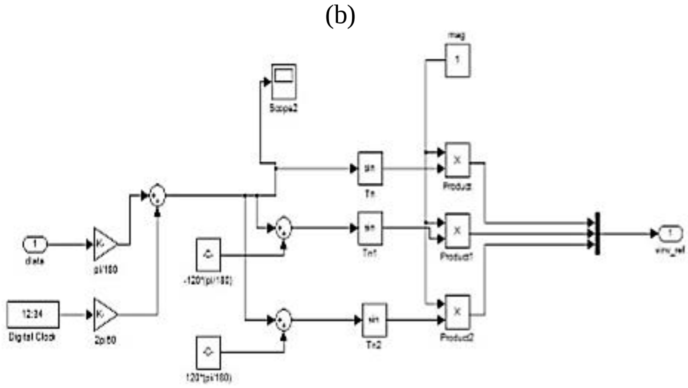
Vector control of DFIG has been performed for analysis purpose of output voltage. The value of parameters used in simulation analysis is considered with real values of 99MW capacity of  Damanjodi windmill, India.



(a)




(b)



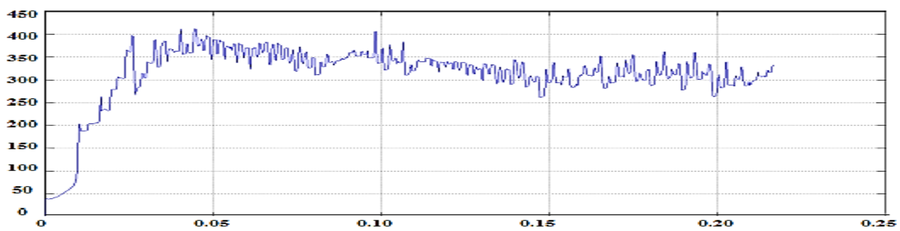
(c)

**Fig. 4.** (a) Simulation model of DFIG with STATCOM, (b) Proportional Integral controller used in DFIG, (c) Subsystem Model of STATCOM

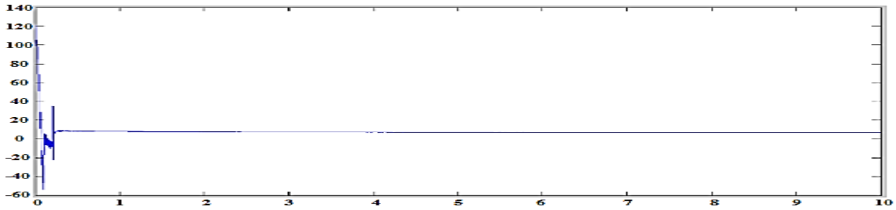
Proportional Integral controller is used in DFIG controller for better result as PI controller improves dynamic response. Here vector control is implemented so that active power and reactive power can be controlled by current components. Phase and the magnitude of the three phase is calculated and fed to the PI controller.Harmonics can be compensated by using this model. This stator flux field oriented control improvises the output by diminishing the fluctuations. Simulations have been performed using MATLAB software.

### 3.2 Result Analysis

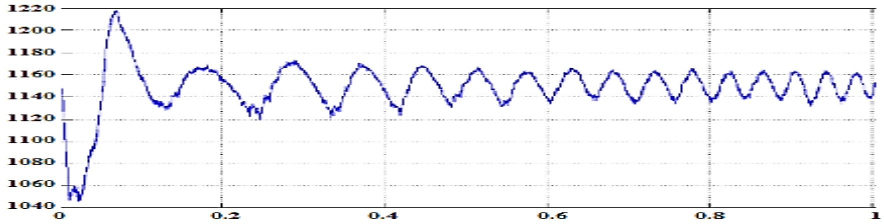
Fig. 5 (a)shows simulated result of compensated graph of statcom applied to DFIG and it indicates the maximum value of 400 occurs at time 0. 04 sec. The minimum value is around 264 at 0.15 sec(approx). The setting time is 0.02 sec. İn Fig. 5(b) rotor angle characteristics can be analyzed and steady state condition is achieved at 0.04sec. The DC output of grid side converter is shoen in next figure and the difference in between maximum voltage and minimum voltage is decresing as the time increasing. From that it can be assumed that the total harmonic distortion is also decreasing. The average volatage value is near about 1150volts.




(a)




(b)

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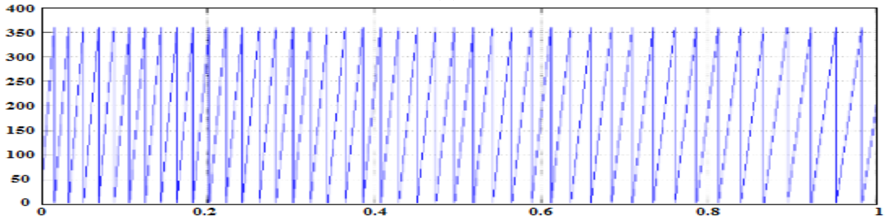


(d)

**Fig. 5.** (a) Compensate graph of the STATCOM, (b) Load angle characteristics with respect to time (c) DC output voltage of Converter, (d) Rotor angle characteristics

From the above dicsussion , stator flux oriented control of PI controller is working better in DFIG with STATCOM for power compensations. The DC output voltage fluctuation is approximately 22volt after 1 sec with an average output voltage of 1150 volt. The frequency of rotor angle is remaining stable in this vector controlled model .

# 4 Conclusion

In this paper vector control strategy to PI controller with reactive and active power compensation is performed. Rotor Side Convertor (RSC) controls stator active and reactive power and Grid Side Convertor(GSC) controls DC bus voltage and reactive power. The model includes the variation in wind speed for the simulation of characteristics of the wind turbine. In related to the results, this model is capable of delivering stable output voltage with maintaining the power quality and this is achieved by eliminating harmonics of the utility grid by vector control. For future work, various experiments will be performed to verify the other usefulness of PI regulator with vector control schemes.

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