SIMULATION AND ANALYSIS OF WIND TURBINE DRIVEN DOUBLY FED INDUCTION GENERATOR (DFIG)

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ABSTRACT: This Paper deals with the concept of DFIG driven by wind turbine. The vector control strategy will be selected such that maximum power from wind turbine is extracted. The rotor of DFIG is connected with two back to back AC-DC-AC PWM convertors. The grid side convertor maintains the DC link voltage constant. The machine side convertor regulates the rotor speed constant irrespective of wind speed. An analysis is made in terms of active power sharing between the DFIG & the grid taking into account the power stored or discharged by the BESS. The overall proposed strategy will be simulated in MATLAB-SIMULINK platform and will be analyzed. The successful entry of DFIG based wind turbine into the competitive wind market stimulates to study the performance of the overall DFIG system under different operating conditions. The DFIG system consists of a Wound Rotor Induction Generator (WRIG) with the stator windings directly connected to the constant frequency three-phase grid and with the rotor windings connected to grid through a bidirectional back-to-back IGBT based voltage source converter. The DFIG is feeding a non linear load with HAPF as interfacing device. The main objective of this Paper is the power quality improvement of a non linear load fed by a wind driven DFIG, hence performance analysis of the DFIG for a wind turbine application (for both during steady state operation and transient operation) is also a part of the Paper.

I. INTRODUCTION

Overview

Renewable energy sources (RES) and distributed generation (DG) has attracted attention world-wide due to soaring prices of fossil fuels. Both are considered to be important in improving the security of energy supplies by decreasing the dependency on fossil fuels and in reducing the emissions of greenhouse gases. Wind power is sometimes considered to be DG, because the size and location of some wind farms make it suitable for connection at distribution voltage. Wind is a renewable energy resource that is growing in importance as a means to address the national and global issues of air pollution, grid reliability, dependence on foreign oil, climate change, etc. Renewable and nonconventional distributed energy resources, such as, wind, solar PV, micro turbines, fuel cells, diesel generators etc. are gradually becoming more popular as energy efficient and low-emission energy sources.

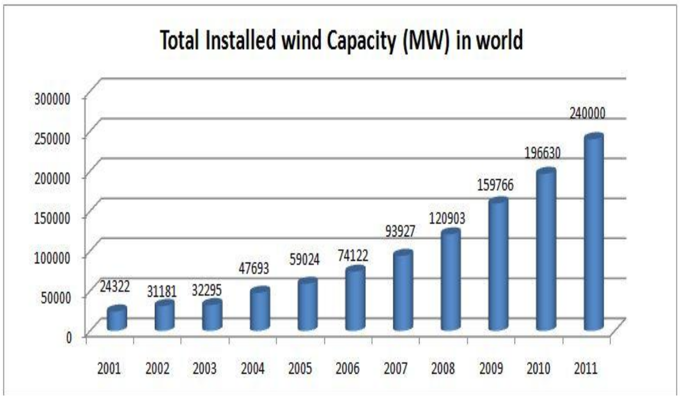

Fig 1.1 Statistical data of total installed wind capacity in world

Power Quality Issues

Any power problem manifested in voltage, current or frequency deviations that result in failure or mis operation of customer equipment.

IEEE defined power quality disturbances have been organized into seven categories based on wave shape:

1. Transients
2. Interruptions
3. Sag / under voltage
4. Swell / Overvoltage
5. Waveform distortion
6. Voltage fluctuations
7. Frequency variations

Transients

Impulsive

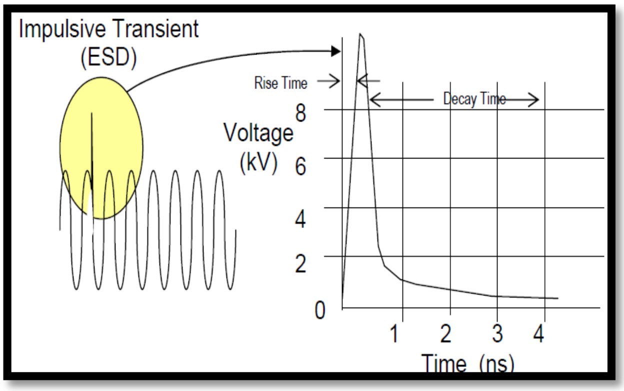

Fig 1.2 Transient Conditions

Time: - [1000 ns = 1 µs] [1000 µs = 1 ms] [1000 ms = 1 second]

Effect:- Loss Of Data, Possible Damage.

Causes:-Lighting, ESD, Switching.
Possible Solution: - TVSS

Interruptions

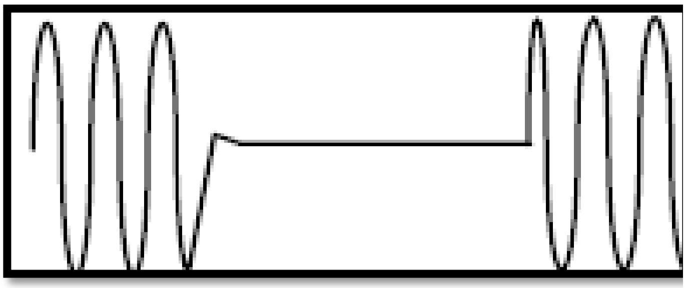

Fig 1.3- Interruption condition

Instantaneous 0.5 to 30 cycles
Momentary 30 cycles to 2 seconds
Temporary 2 seconds to 2 minutes
Sustained greater than 2 minutes
Causes: - Switching, Utility Fault, Circuit Breaker tripping, Component Failure.
Possible Solution: - UPS.

1.2.3 Sag

Sag

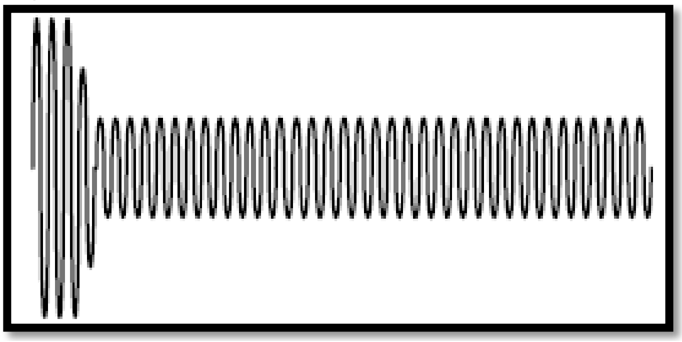

Fig 1.4- Sag Condition

Time: - 0.5 cycles to 1 minute.
Effect: - System halt, loss of data, Shutdown.
Causes: - Startup load, fault.
Possible Solution: - Power Conditioner, UPS.

Swell / Overvoltage

Swell

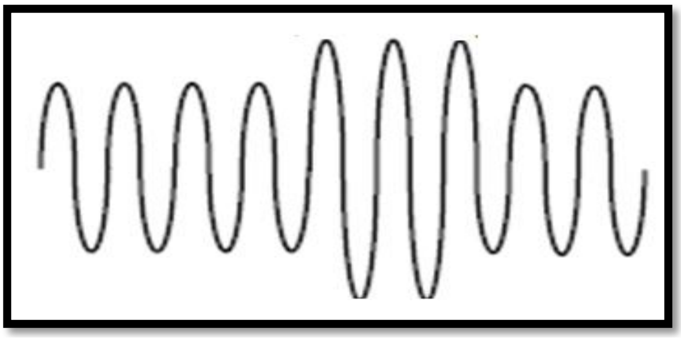

Fig 1.5 Swell Condition

Effect: - Equipment Damage, Reduced life.
Causes: - Utility fault, load change.
Possible Solution: - Power Conditioner, UPS.

Waveform Distortion

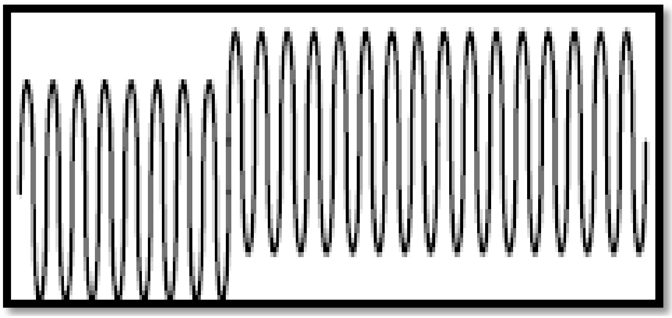

Fig 1.6 waveform Distortion

Effect: - Transformer heated ground fault current.
Causes: - Faulty Rectifier, Power Supply.
Possible Solution: - Replace defective equipment.

Harmonics

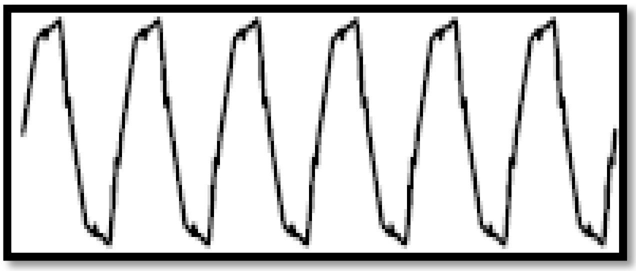

Fig 1.7 Harmonics

Effect: - Transformer heated ground fault current.
Causes: - Electronic loads (non-linear lads)
Possible Solution: - Reconfigure distribution, install K-factor transformers, use PFC power supplies

II. DOUBLY FED INDUCTION GENERATOR

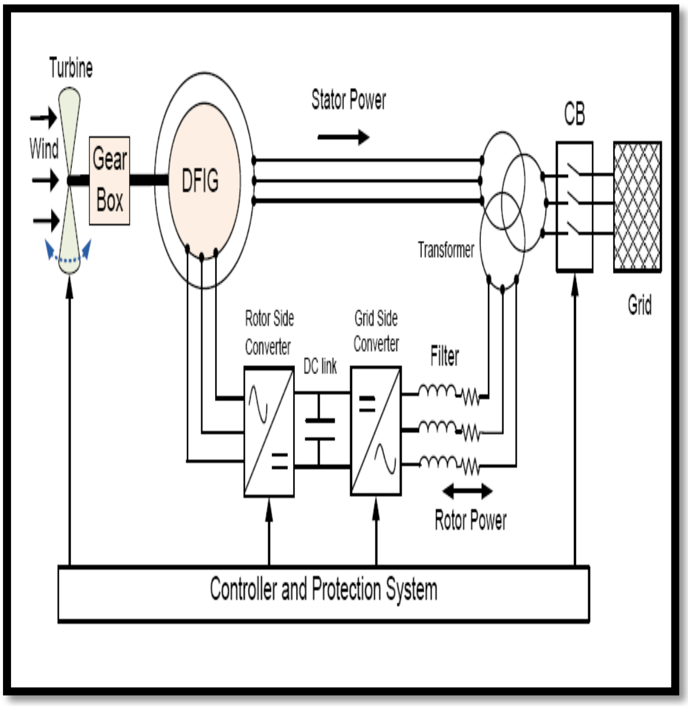

Fig 2.1 DFIG System

- DFIG or Double Fed Induction Generator has a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings.
- The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to-back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency can freely differ from the grid frequency (50 or 60 Hz). By using the converter to control the rotor currents, it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generator's turning speed.

Reason for Selection of DFIG:-

- As the rotor circuit is controlled by a power electronics converter, the induction generator is able to both import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances.
- The control of the rotor voltages and currents enables the induction machine to remain synchronized with the grid while the wind turbine speed varies. A variable speed wind turbine utilizes the available wind resource more efficiently than a fixed speed wind turbine, especially during light wind conditions.
- The cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25-30 %, is fed to the grid through the converter, the rest being fed to grid directly from the stator. The efficiency of the DFIG is very good for the same reason.

Limitations of DFIG

DFIG wind turbines are able to control active and reactive power independently, the reactive power capability of those generators depend on the active power generated, the slip and the limitation due to following design parameters

- rotor voltage,
- stator current,
- rotor current

The stator voltage is given by the grid which can be assumed fairly constant, and is not influenced by the wind turbine design. The stator current limit depends on the generator design, whereas the rotor voltage and rotor current limits depend on generator as well as power converter designs. The size of power converter is limited (about 25-30% of the total MVA rating). The rotor voltage limitation is essential for the rotor speed interval, because the required rotor voltage to provide a certain field is directly proportional to the slip. Hence, the rotor speed is limited by the rotor voltage limitation

Benefits:-

- Increment in transmission system reliability & availability.
- Improvement in transient stability on power grids.
- Utilization of Existing Transmission Grids.
- Smart Control of Power Flow.
- Positive Environmental Impact.

III. WIND TURBINE

Wind Turbine Topologies

Fixed Speed Wind Turbine (Type A)

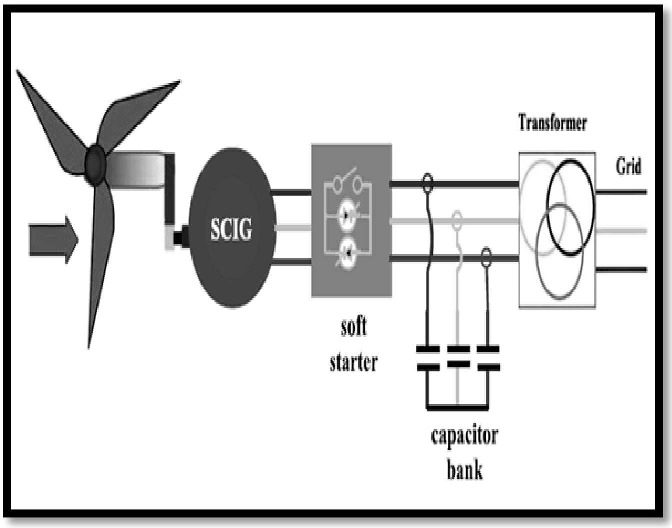

Fig. 3.1 Fixed Speed Wind Turbines (Type A)

It consists of a squirrel-cage induction generator coupled to the power system through a turbine transformer, the generator operating slip changes slightly as the operating power level changes and the rotational speed is therefore not entirely constant

Variable speed wind turbine

Variable-speed wind turbines are designed to achieve maximum aerodynamic efficiency over a wide range of wind speeds

Type B wind turbine (WRIG with soft starter)

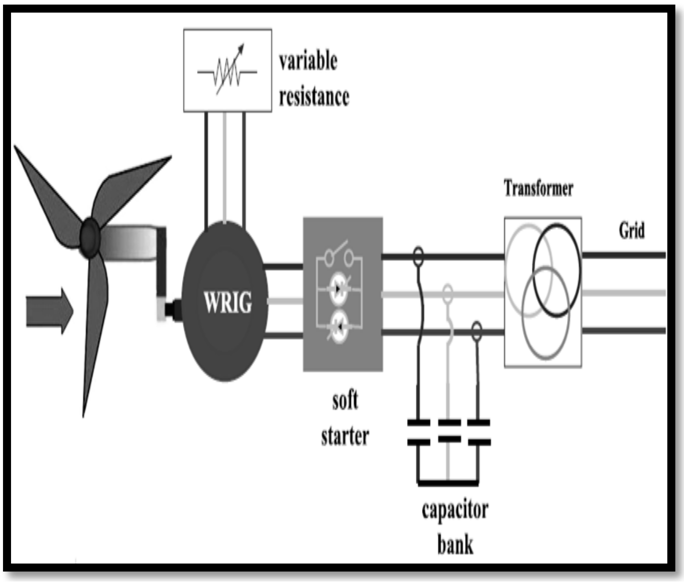

Fig. 3.2 Type B wind turbine (WRIG with soft starter)

The generator is directly connected to the grid. A capacitor bank performs the reactive power compensation. A smoother grid connection is achieved by using a soft-starter. Typically, the speed range is 0 to10% above synchronous speed

Type C wind turbine (DFIG with partial scale converter)

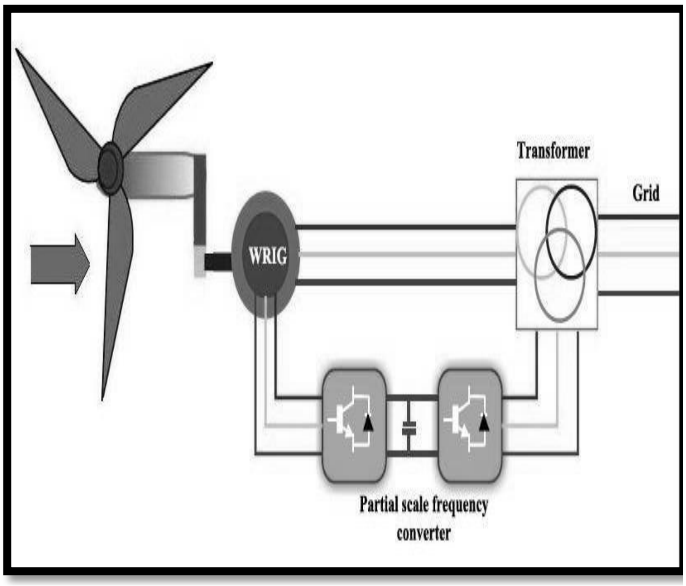

Fig 3.3 Type C wind turbine (DFIG with partial scale converter)

This configuration, known as DFIG based wind turbine, corresponds to the limited variable speed wind turbine with a WRIG and partial scale frequency converter (rated at approximately 30% of nominal generator power) on the rotor circuit. It has a wider range of dynamic speed control compared with that of Type B wind turbine, depending on the size of the frequency converter.

Type D wind turbine (DFIG/PMSG with Full scale converter)

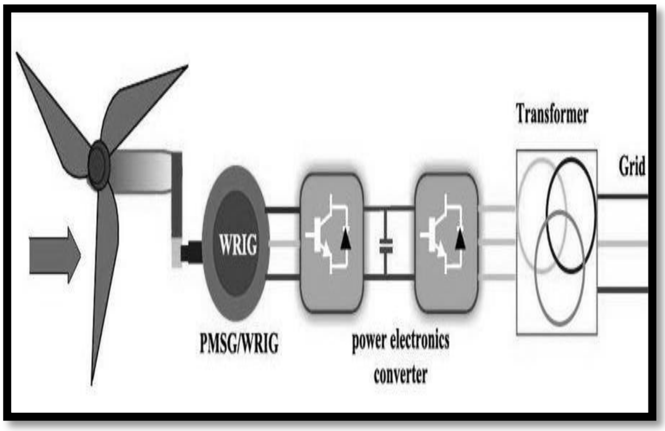

Fig 3.4 Type D wind turbine (DFIG/PMSG with Full scale converter)

This configuration corresponds to the full variable speed wind turbine, with the generator connected to the grid through a full-scale frequency converter. The generator can be excited electrically (WRSG/WRIG) or by a permanent magnet (PMSG).

IV. SIMULATION AND RESULTS

Model of DFIG

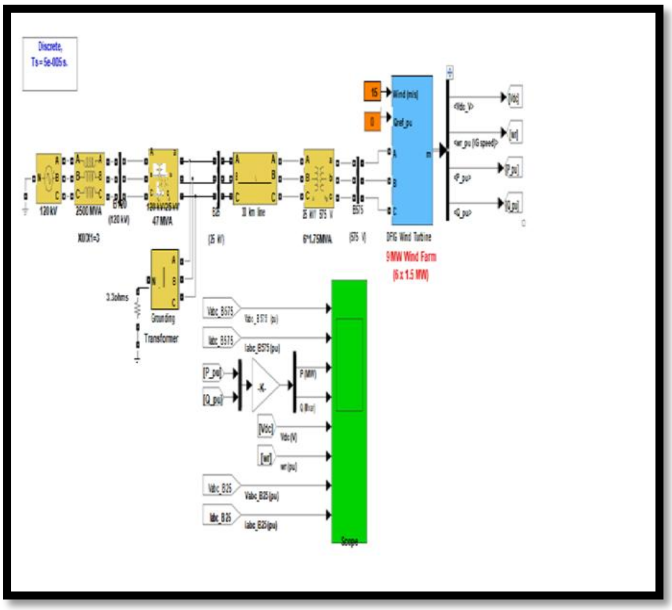

Fig 4.1Simulation Model of DFIG with grid connection

V. SIMULATION MODEL OF DFIG

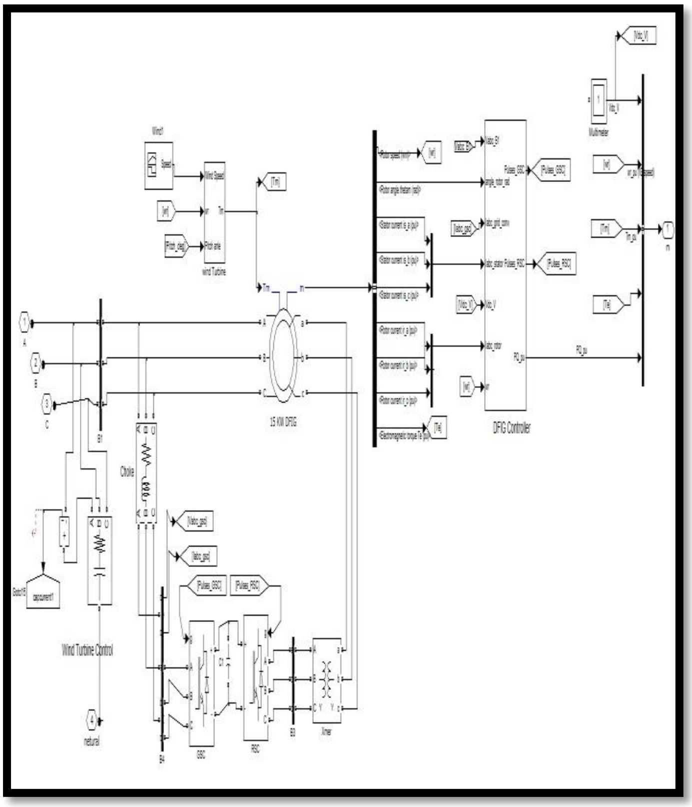

Fig 4.2-Simulation model of DFIG

For secure and reliable operation of grid connected wind generation plant, plant operators must satisfy grid code requirements such as grid stability, power quality improvement, grid synchronization and power control etc. To satisfy the grid code requirements of wind turbine, usually grid side converter is playing a major role. The grid side converter is modeled to control the active and reactive power independently along with dc-link voltage. The rotor side converter is modeled to control the reactive power and maintain the power factor unity irrespective of the transient condition. STATCOM is connected between wind power generation system and non linear load; it improves the power quality by keeping the total harmonic distortion within specified limits, thus improving the overall performance of the system. In variable speed wind turbine power generating system the harmonic distortions are present at the generator output, that too varying with the wind conditions. The purpose of power electronic interface is to maintain the dc link voltage constant over the varying wind conditions, but it does not comply with IEEE-519 standards. When wind power generation system supplies electrical power to non linear loads, the system performance shows more severe harmonic conditions. In this paper, performance analysis of Wind DFIG-STATCOM connected to grid is analyzed under different balanced/unbalanced load conditions are done. Further a wind turbine driven, 15 KW doubly fed induction generator (DFIG); is simulated using MATLAB/Simulink environment. The performance of grid interconnected DFIG feeding a non linear load, with STATCOM is analyzed. The waveforms of supply voltage, supply current, capacitor current, load current, controller current, frequency as well as neutral current are analyzed. The test system is simulated for three cases linear/non linear load and variable wind speed operation. The various simulation results are discussed briefly.

Simulation Results:

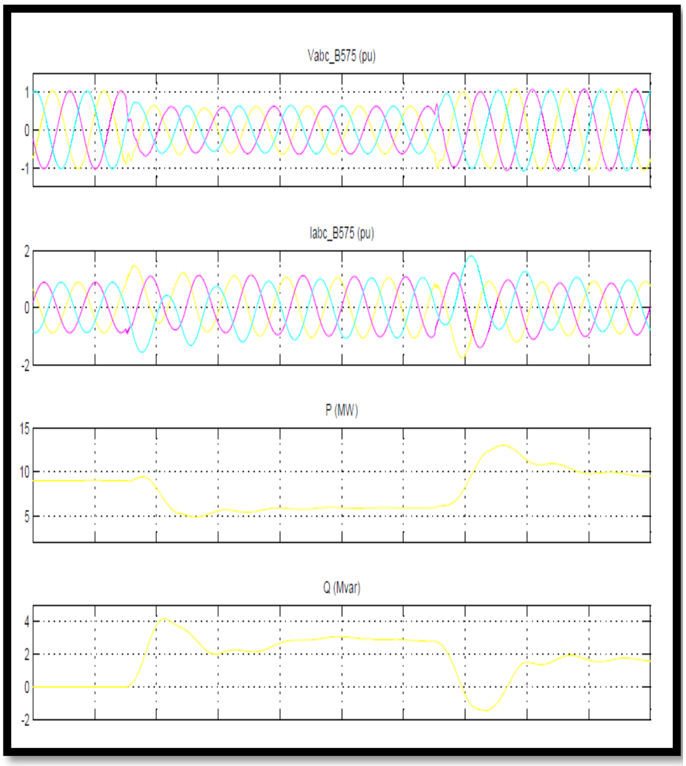

Fig 4.3- Vabc, Iabc, P and Q

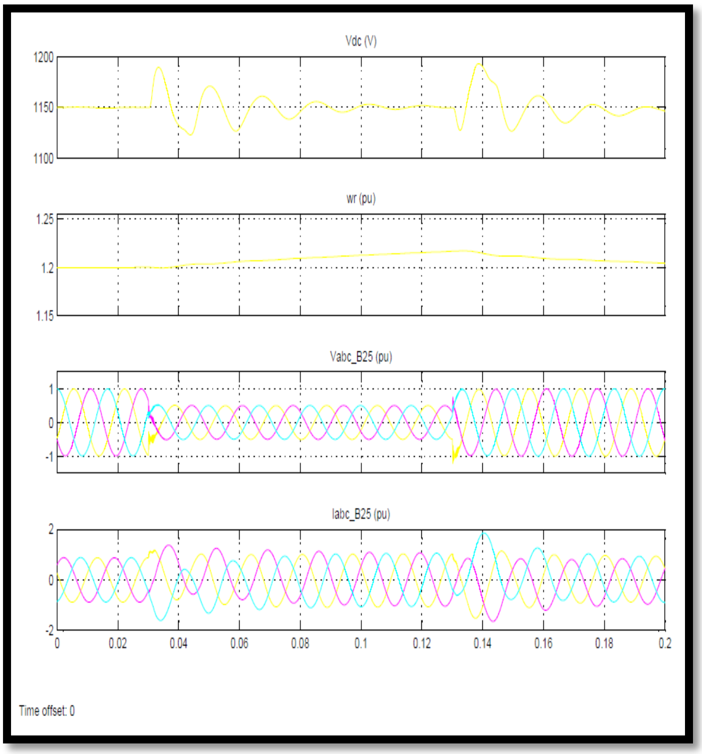

Fig 4.4-Vdc, Wt, Vabc, Iabc

VI. CONCLUSION

The STATCOM is analyzed to be most reasonable solution for the new generation wind farm for voltage stability specially when connected to weak grid system. The DFIG system consists of a Wound Rotor Induction Generator (WRIG) with the stator windings directly connected to the constant frequency three-phase grid and with the rotor windings connected to grid through a bidirectional back-to-back IGBT based voltage source converter. The DFIG is feeding a non linear load with HAPF as interfacing device. The main objective of this Paper is the power quality improvement of a non linear load fed by a wind driven DFIG, hence performance analysis of the DFIG for a wind turbine application (for both during steady state operation and transient operation) is also a part of the Paper.

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