# Performance of Wind Farm Employing Type-4 Wind Turbine with D-Statcom

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**Abstract**
Wind power is environmentally friendly and cost-predictable nature. It is widely recognized as a promising alternative electric power generation source at a time of uncertain fossil fuel costs and concern over the harmful effects of climate change. Various problems arise due to the rapid injection of wind power in the electrical grid, affecting the power quality. Harmonics and various power quality problems like voltage sag and swell are of common occurrence due to the voltage injected by the wind generators in the electrical grid. These may result into severe problems such as system frequency mismatch and change in power line capability. To reduce such problems a distributed static compensator (DSTATCOM) is employed. The DSTATCOM is an effective way of reducing power quality problems, removing the wind speed fluctuations and improving the transient stability of wind farm. Simulation results show the proposed effectiveness of wind farm stability and power quality. The generating system is modeled and simulated in MATLAB environment using Simulink and Simpower System toolboxes.
**Keywords:** Wind Farms (WF)**,** Wind Energy, Distributed static compensator (DSTATCOM)

## 1. INTRODUCTION

Wind energy is a clean, renewable way of generating electricity. The wind's energy is harnessed due to the uneven heating of the earth's surface, which creates different temperature and pressure areas known as anticyclones and depressions. As the atmospheric forces try to balance, air masses move from anticyclones to areas of depression therefore larger the depression, stronger the wind. A minimum wind speed of 10 to 15 kilometers an hour is required to start the turbine. The speed limit was established for financial as well as safety reasons: fast-moving parts experience increased wear and tear, while the extra electricity output is minimal. An internal gearbox multiplies the basic rotor speed of 12 to 15 rotations per minute to 1,500 rotations per minute so that the generator can operate effectively. Electronic power converters adjust the frequency of the current generated by the turbine to match that of the grid (50 Hz in India), while allowing for a variable rotor rotation speed depending on the wind.

The location of generation facilities for wind energy is determined by wind energy resource availability, often far from high voltage (HV) power transmission grids and major consumption centers. The WF is connected through distribution headlines. A commonly found situation in such scheme is that the power generated is comparable to the transport power capacity of the power grid to which the WF is connected. The main feature of this type of connections is the increased voltage regulation sensitivity to changes in load.

The wind turbine employing synchronous generator demands reactive power especially in the event of change in wind speed there will be variation of WF terminal voltage due to system impedance, if the variations are large then there are chances for the power disturbances to enter the power systems interconnected. Hence the key factor lies in successful functioning of WF which relies upon the system's ability to regulate the voltage. There will be a negative impact on the stability and power quality in the electrical system due to random nature of wind resources resulting into fluctuating electric power.

## 2. SYSTEM CONFIGURATION AND BASIC PRINCIPLE

A 10 MW wind farm consisting of five 2 MW wind turbines connected to a 25 kV distribution system exports power to a 120 kV grid through a 30 km, 25 kV feeder.

The Wind Farm (WF) employing Type 4 wind turbine consists of a synchronous generator connected to diode rectifier, a DC-DC IGBT-based PWM boost converter and a DC/AC IGBT-based PWM converter. The IGBT Voltage-sourced converters (VSC) are represented by equivalent voltage sources generating the AC voltage averaged over one cycle of the switching frequency. A similar method is used for DC-DC converter. This model does not represent harmonics, but the dynamics resulting from control system and power system interaction is preserved. The Type 4 technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The wind speed is maintained constant at 15 m/s. The control system of the DC-DC converter is used to maintain the speed at 1 pu. The reactive power produced by the wind turbine is regulated at 0 Mvar. For a wind speed of 15 m/s, the turbine output power is 1 pu of its rated power, the pitch angle is 8.8 deg and the generator speed is 1 pu.

Basic principle of DSTATCOM: A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator.

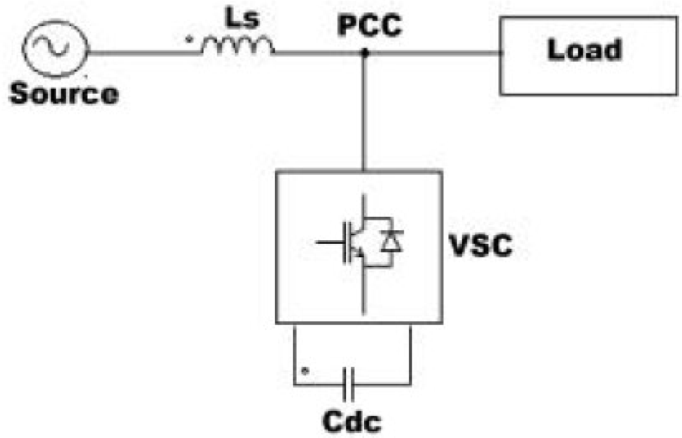



Figure-1 Basic structure of DSTATCOM

The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in figure 1. The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be recharged by the converter itself. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages. It is to be noted that voltage regulation at PCC and power factor correction cannot be achieved simultaneously. For a DSTATCOM used for voltage regulation at the PCC, the compensation should be such that the supply currents should lead the supply voltages; whereas, for power factor Correction, the supply current should be in phase with the supply voltages. The control strategies studied in this paper are applied with a view to study-ing the performance of a DSTATCOM for power factor correction and harmonic mitigation.

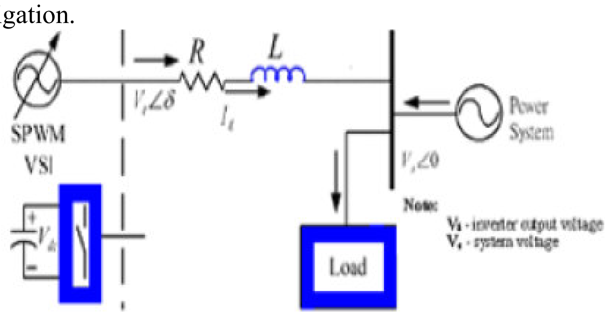



Figure-2 Basic Building Blocks of the D-STATCOM

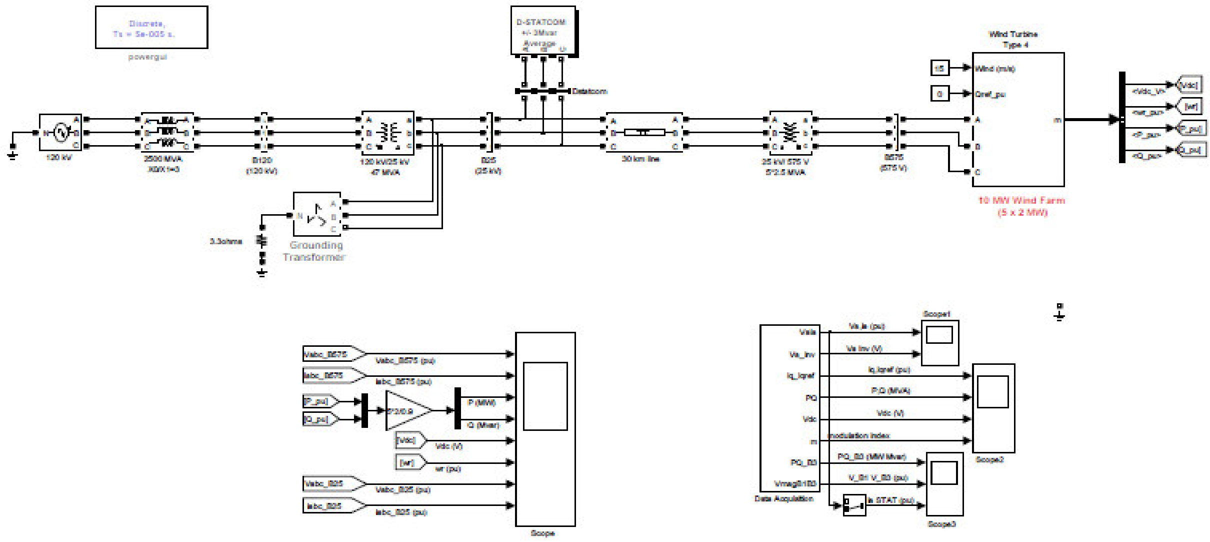
The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a D-STATCOM are shown in figure 2. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, coupling transformer and a control strategy. The basic electronic block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency.

The D-STACOM employs an inverter to convert the DC link voltage *Vdc* on the capacitor to a voltage source of adjustable magnitude and phase. Therefore the D-STATCOM can be treated as a voltage-controlled source. The D-STATCOM can also be seen as a current-controlled source.

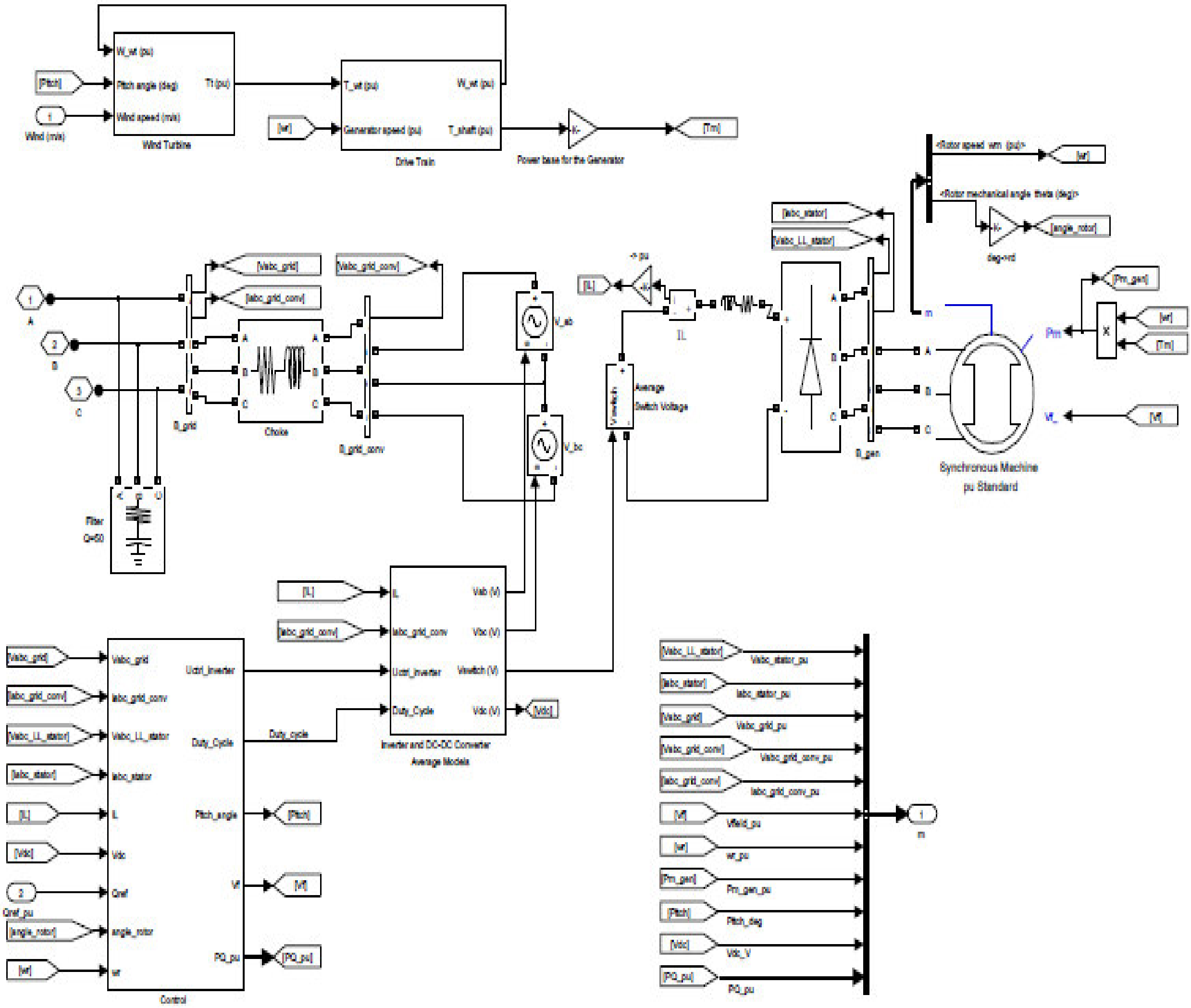
Figure 2 shows the inductance *L* and resistance *R* which represent the equivalent circuit elements of the stepdown transformer and the inverter will is the main component of the D-STATCOM. The voltage *Vi* is the effective output voltage of the D-STATCOM and δ is the power angle. The reactive power output of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the DSTATCOM. The construction controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D-STATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor-based inverter, Vi, is controlled in the same way as the distribution system voltage, Vs.

Voltage Source Convertors (VSC): A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonic.

## 3. MATLAB IMPLEMENTATION

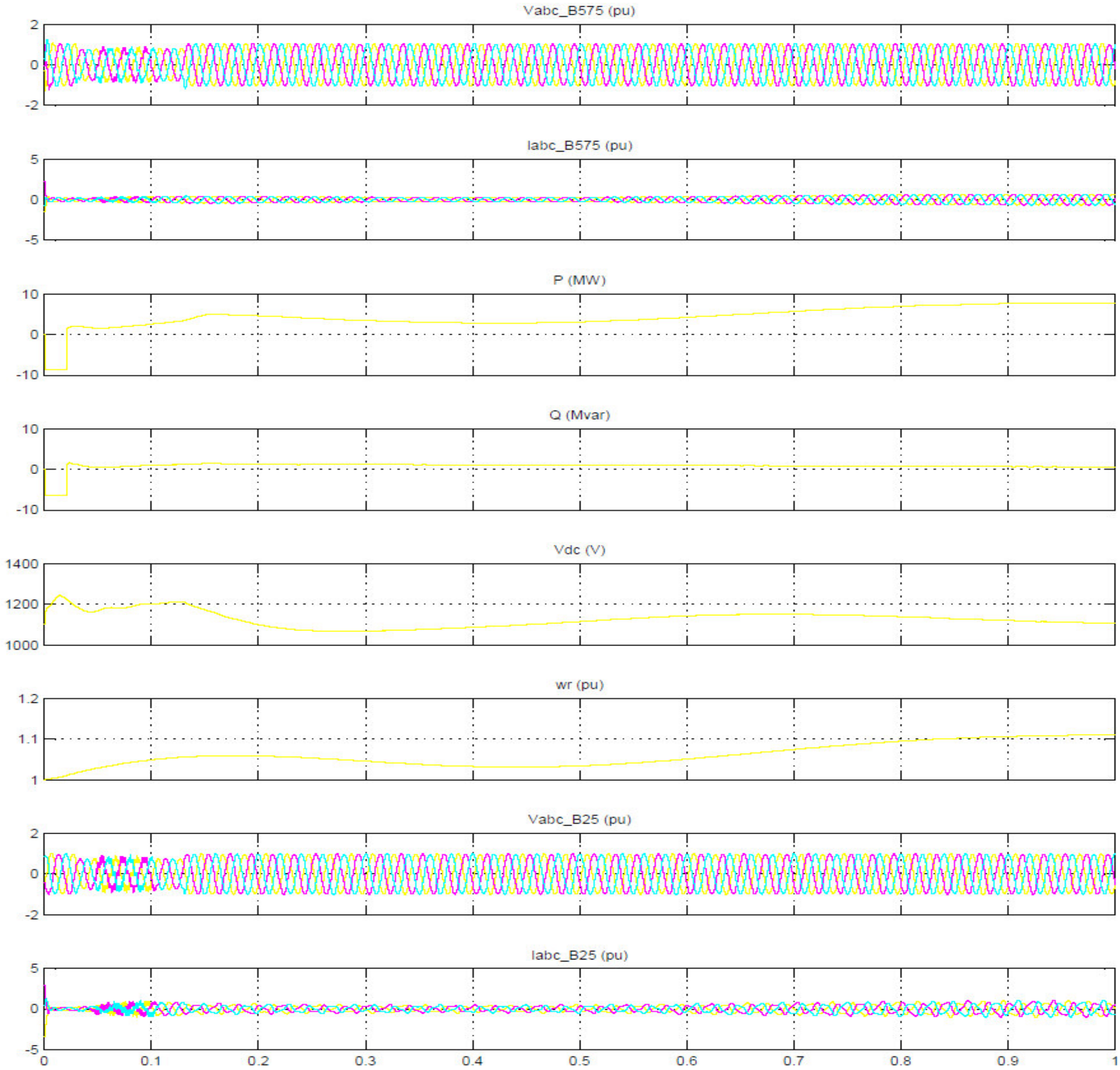


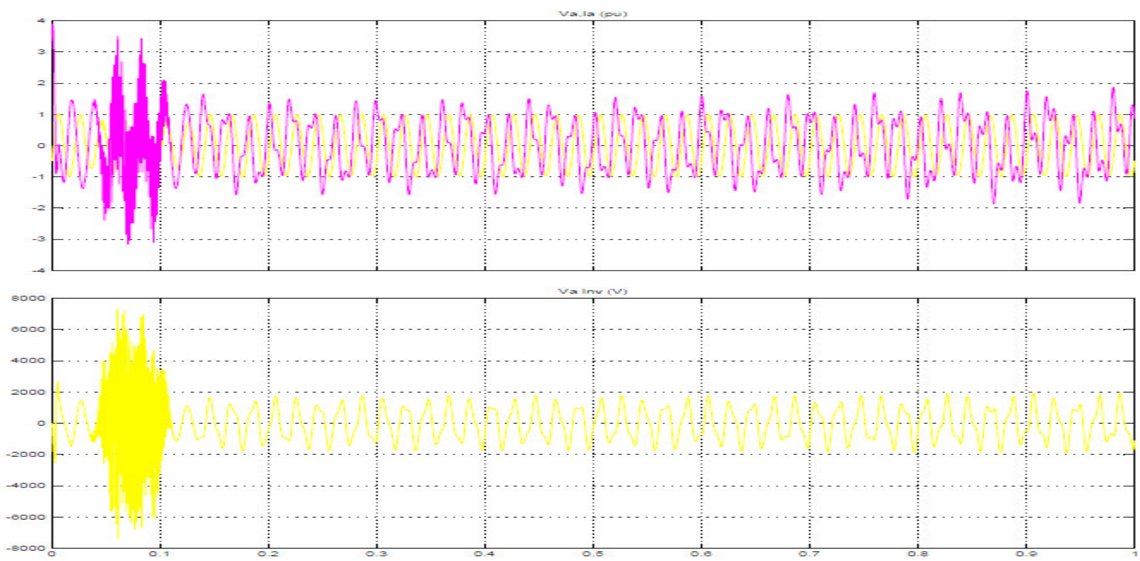

MATLAB diagram of wind farm using Type 4 wind turbine

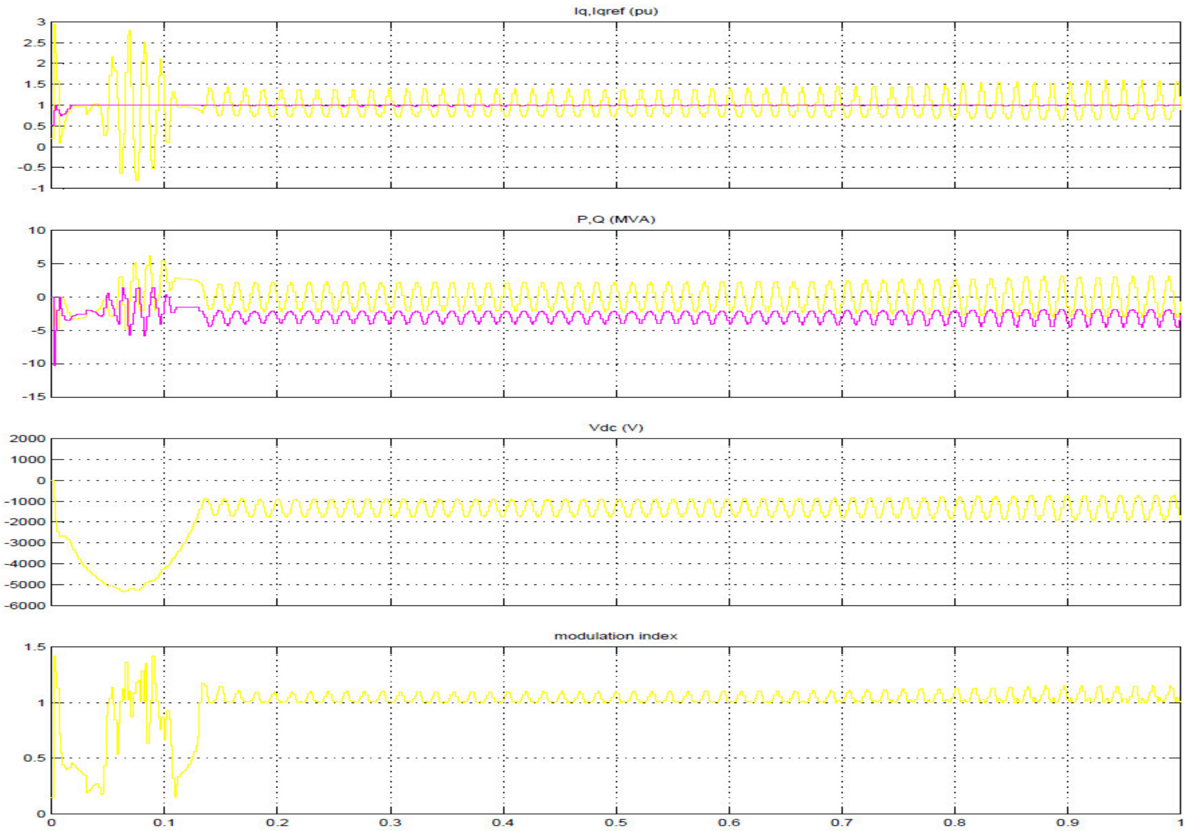


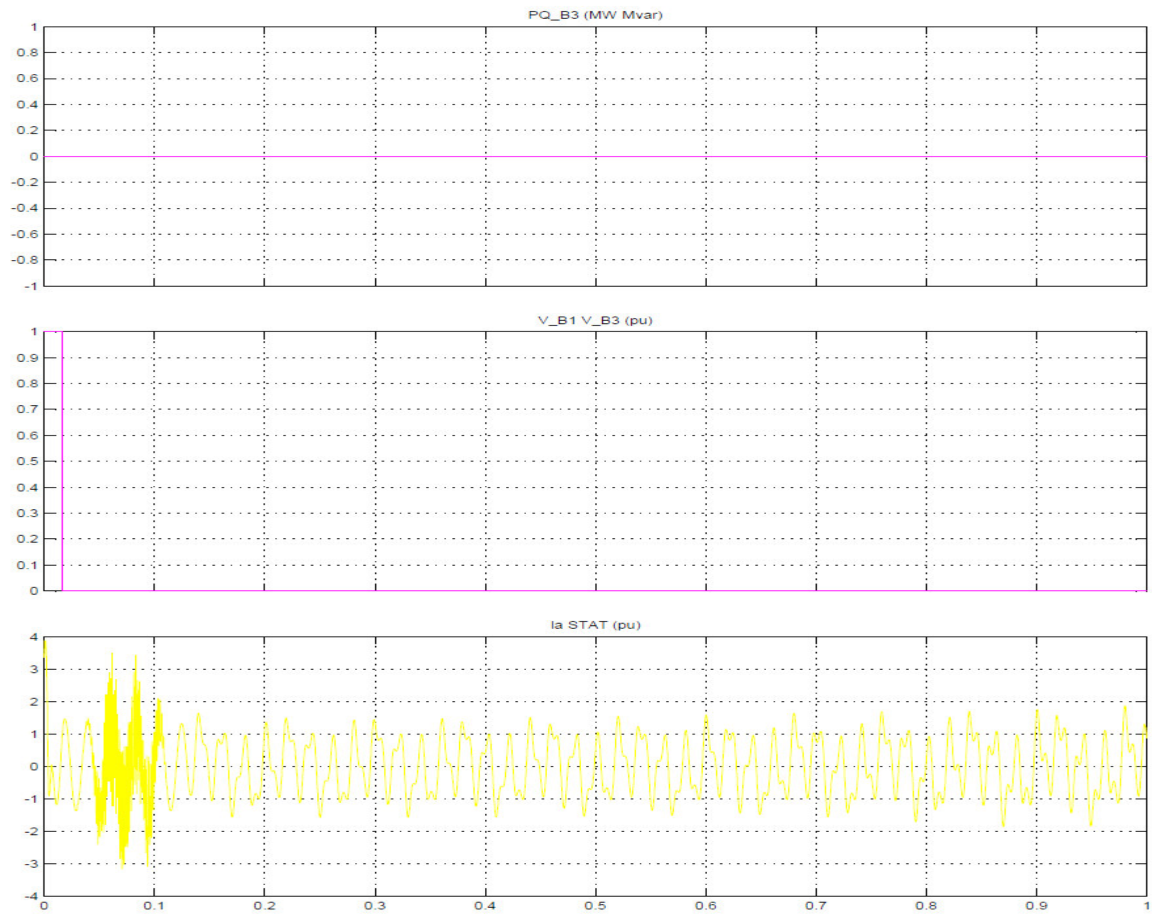

MATLAB diagram type-4 wind turbine

## 4. SIMULATION RESULTS




Iq,Iqref (pu)
P,Q (MVA)
Vdc (V)
modulation index


PQ_B3 (MW Mvar)
V_B1 V_B3 (pu)
Ia STAT (pu)

## 5. CONCLUSION

This paper presents model aspects of a DSTATCOM controller in wind power system. A proposal is made of a detailed fully realistic model of the DSTATCOM in the electric system with wind generation was studied, and its behavior analyzed. From the results obtained, it can be concluded that with the power fluctuations coming from a WG are effectively compensated. It is shown that the WG-DSTATCOM system can deliver a constant active power in a time range of seconds or more, depending on the storage capacity. For the reactive power control, it was shown that the system proposed is able to obtain a dynamic control of the voltage in the connection point. The voltage control operates satisfactorily in case of power disturbances in the WG and also for fluctuations in the system such as sudden variations in the load. Therefore, the incorporation of DSTATCOM has shown that it can improve the power quality in wind power systems.

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## BIBILOGRAPHY

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