Study on PMSG Based Grid Connected Wind Energy Conversion System using Vector Control Strategy

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Abstract:

This work introduces modeling of wind energy systems using MATLAB Simulink. Due to the non-linear characteristic of the model wind turbine, the MPPT (maximum power point tracking) technology is considered to track the maximum power extractable from wind power. Models include wind production models, converter Back to Back models (AC-DC-AC converter), and MPPT controllers. The main contribution of our work is in the Back to Back converter (Dual converter) model which has been developed rather than the description, which adjusts the voltage input of the MPPT controller output (Maximum power point) pconverter to track the maximum power point wind Generator The results of simulations show that the developed model complies with the theoretical one. Apart from this, MPPT control shows a high power output compared to the system without MPPT.

Keywords: MPPT controllers, Direct Current, Grid Side Converter, Permanent Magnet Alternating Current

1. INTRODUCTION

India is facing 'energy crisis' with the world. There is a significant difference in demand and supply for electricity. As our country progresses in the direction of development, the gap is rising and it is very important to continue the ascending path of our country to solve this situation. In order to fulfil this situation, many options are being considered with great focus on renewable energy research and development. The options considered are solar energy, biogas, wind energy, geothermal energy. Out of all the available options, solar thermal power generation is one of the most promising options. However, availability of technology, adaptation of traditional electric chakras to adapt to traditional solar cycles, there are many challenges, such as the availability of industrial and technical capacity and issues related to indigenous development of technology.

With the issue of the lack of experience in the solar thermal plants associated with the operating grid, the Ministry of New and Renewable Energy, Government of India has given a policy to provide grid on electricity generated from solar energy and fed to the grid.

To support this background, it is necessary that we obtain indigenous capacity to design, develop and install solar thermal plants. For this, establishing a display-cum-research facility that will help indigenous development prove to be a basis for future growth and expansion.

2. LITERATURE SURVEY

Wind power contributes a significant proportion of the growing power of consumers to electricity demands. In the last few years, wind energy production has increased at a hazardous rate and will continue to do so as the electricity electronic technology isgrowing. Several power converter techniques have been developed to integrate with anelectric grid.

The use of electrical electronic converters allows for variable speed operation of windturbine. A wide range of control plans, variations in cost and complexity, are integrated with power electronic converter to maximize power generation at all possible windspeeds.

Based on possible combinations of converter and generator topologies for various drivesystems such as permanent magnet generator, caged rotorfade induction generator, a review is conducted and so far the potential control strategiesare affected.

To regain optimum energy capture, thiristor-based inverter is used in [21] to allow theconstant control of the turbine speed through the DC-link voltage, to allow continuouscontrol of the inverter firing angle. The benefits of this plan include higher availablepower ratings than hard-switch costs and hard-switched inverters. This inverter requires alarge reduction of reactive power and active compensation to create harmonic distortion.To allow continuous control of the hail of the speed of the turbine through the DC-linkvoltage, the inverter firing angle. [21]. A voltage source converter (VSC) is used forcompensation and error signal between reference and actual compensation flows is usedto run pulse width modulated (PWM) control.

Different control strategies applied to the converter [23]. A proposed control involves the manipulation of the modulation index of the reference sinusoidal signal applied to thePWM generator. It is achieved by determining the DCtechnique that has maximum power versus DC voltfurther improved using the derived control on the stator frequency, as it changes with thechange in the DC-link voltage.

This control is compared to maximum power point tracking (MPPT), which includes ananemometer, a wind prediction control plan and a fixed voltage plan. Anemometermeasures the wind speed and accessories to provide the wind energy reference to theMPPT controller. The reference power is compared to the actual DC power in which theresult is used to determine the new operating voltage DC. The current control loop of theinverter receives the new operating DC voltage and outputs an instantaneous drivingsignal for PWM. Under fixed voltage control, the inverter voltage is fixed at a targetedoptimum wind speed. Compared to the four control methods, the fixed voltage schemewas used as reference because it was least efficient. MPPT proved to be better withanemometer setup, 56-63% energy is available. However, the proposed method usingThyristor based inverter [23]. A proposed control involves theDC-link voltage with a power mappingvoltage attribute.

An advanced method using backwork has been done using this type ofin those functions is almost identical;Differences lie in control strategy. through the current [7] and [8] changes. For the rotor side, decoupled control of electrictorque and rotor stimulation flow is presented [7]. The machinesynchronous rotating reference frame, in which the Dvector, which provides maximum energy transfer. In the case of [8] the rotor was decomposed into the current Dcontrol current electromagnetic torque and the QBoth types of rotor-side converter control PI controllers. Space vector modulation (SVM)is used to obtain better modulation index [8].place of Speed Encoder [9] and [10] With a capacitor in the DC link, the battery can be13s Hard switching Inverterback-to-back converter is shown in Figure 2.4, and a lot ofconverter [7], [8], [9] and [10]. The converter usedsupply-side converter is to implementDC-link voltage continuously. This Q-axis is also responsible for reactive power controlis controlled in theD-axis is oriented with the stator [8].The supply side controller is made up of three PI controllers - for external loop powercontrol, and the D-Q-axis remains for internal control loop. Energy is storedduring high winds and is exported to the grid during low air conditions for compensation.The control algorithm is modified to control voltage for less air conditions.

Here, the rotor-side converter is gate to control the actual and reactive power of themachine. Another different option for rotor control is presented in [10], where thealgorithm detects the peak power by changing the speed of the rotor, and peak powerpoints are identified as zero slopes on the power-speed curve.

The use of induction generators (IG) is advantageousinexpensive, robust and require low maintenance. Induction generator need bi-directional power flow in the generatorside converter since it requires external reactive powersupport from the grid. The use of backthe implementation of one or more fuzzy logic controllers is a consistent convertercontrol combination [14], [15] and [16]. The advantages of fuzzy logic control areparameter insensitivity, fast convergence and acceptance of noisy and inaccurate signals. A PI type fuzzy logic controller takes in the DC voltage error and controls this error [15].The controller outputs the d-axis reference current used in real power flow control.

3. MODELING OF WIND TURBINE AND PMSG

In Fig. 3.2 shown wind turbine and the power contains in the undisturbed wind is in form of kinetic energy then the power is

$$P = \frac{1}{2}\dot{m}v_a^2$$

Where $\dot{m}$ and $v_a$are rate of flow of wind and speed of undisturbed wind respectively.

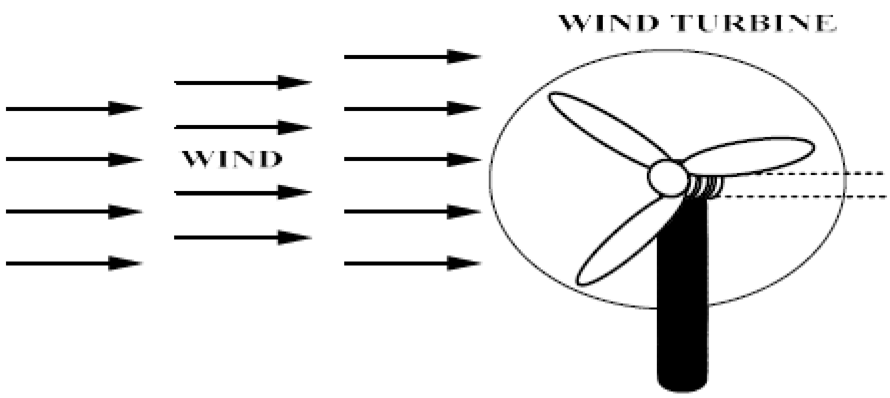

Fig 1: Wind turbine

And the rate of flow of wind is the function of air density, area through wind is passing and speed of wind then the power contains in undisturbed wind can be also written as,

$$P = \frac{1}{2}\rho A v_a^3$$

Where ρ and A are the density of wind and swept area of wind turbine respectively. Andas depicted in eq. 3.2 power is the function of wind speed and power is directly proposalto cube of wind speed hence there is slightly change in wind speed it affect more power.

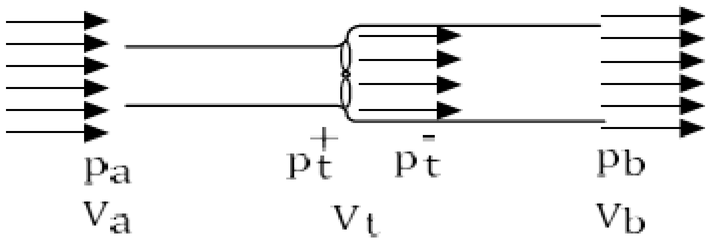

Fig. 2: Idealized model for a wind rotor (Betz)

4. THE MATHEMATICAL MODEL OF PMSM

Three phase PMSM is constructed with sinusoidal distributed phase windings, with a 120-degree angle phase shift between the three windings. In a stator reference frame coordinate system, the phase vectors abc can be seen as they are fixed in angle, but with time varying amplitudes. This three-vector representation makes calculation of machine parameters unnecessarily complex. Transformation of the system into a two-vector orthogonal system makes the necessary calculations much simpler.

Three phase machine can be described by a set of differential equations in time dependentcoefficients. By the transformation of the motor variables, the complexity of machinecalculations is reduced. As Per the definitions, the transforms give a 3rd component,zero-sequence. But since a motor is normally balanced load, the zero-sequencecomponent not of importance.

Clarke and Park transformations are mainly used in vector control architectures related topermanent magnet synchronous machines and asynchronous machines.

5. MODELING AND CONTROL OF POWER ELECTRONIC CONVERTERS

The output voltage of synchronous generator is rectified using a three- phase passive bridge rectifier. This rectifier consists of a three- phasediode bridge, comprising diodes D1 to D6 which converts ac power generated by the wind generator into dc power in an uncontrollable way.

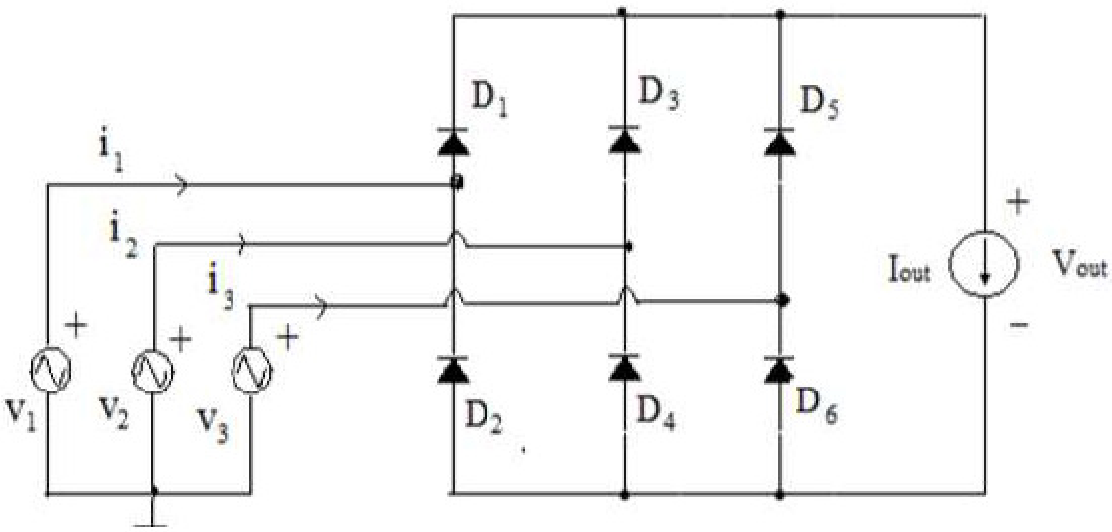

Fig. 3: Three-phase diode bridge rectifiers

Fig. 3.8 shows AC equivalent circuit of the MSVSC. L and R are inductance and equivalent resistance of the AC coupling inductor. C is the capacitance of the main DC capacitor and Vdc is the DC link voltage. Vw is the wind farm ac voltage and Ic is the converter output current.

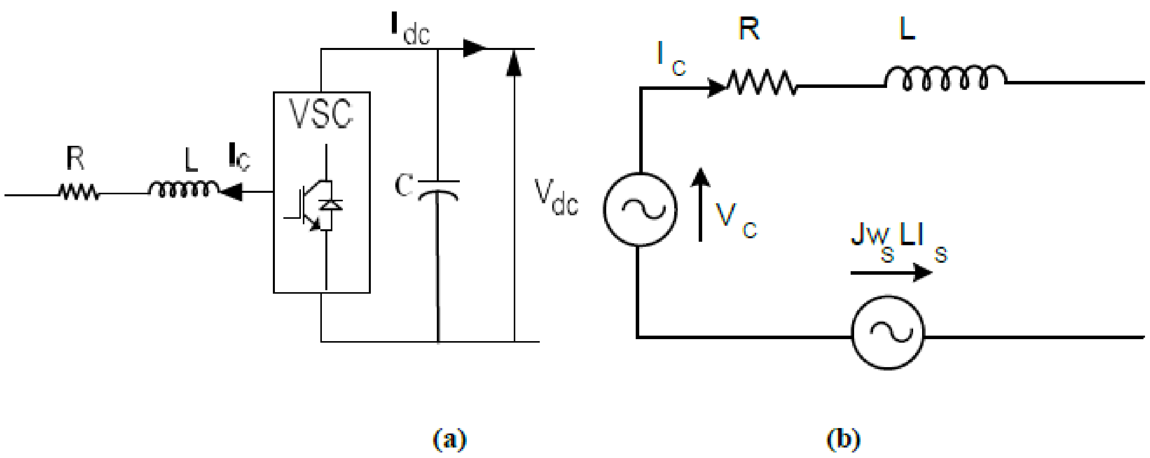

Fig. 4: equivalent circuit of the MSVSC a. Schematic diagram b. ac equivalent circuit

6. SIMULATION RESULT AND DISCUSSION

The proposed WECS have been simulated with discrete time at 10µs in R2015a. The developed WECS is examined under different condition with different wind speed and power.

6.1. WECS under Fixed wind speed and fixed power

The general execution of MSC, GSC, ESS and Pitch Angle Regulation is exhibited in Fig. 5 with constant wind speed.

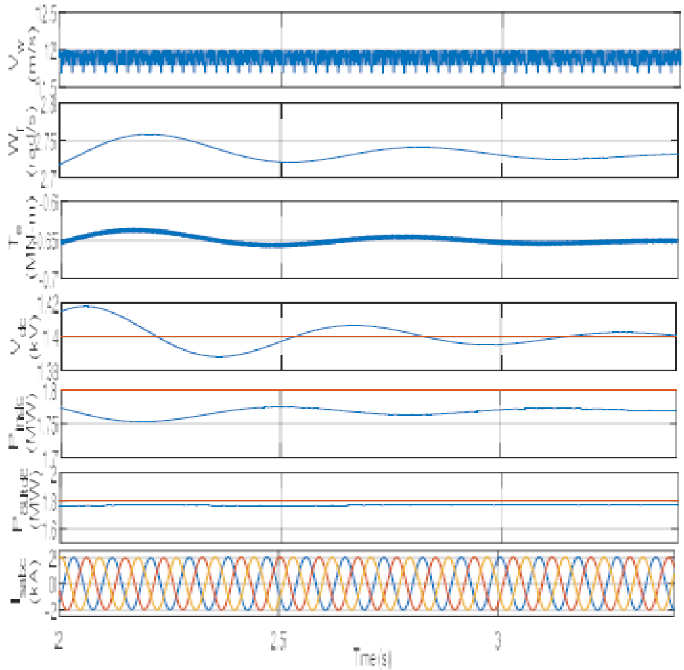

Fig. 5: (a) Performance of MSC with fixed speed and fixed power

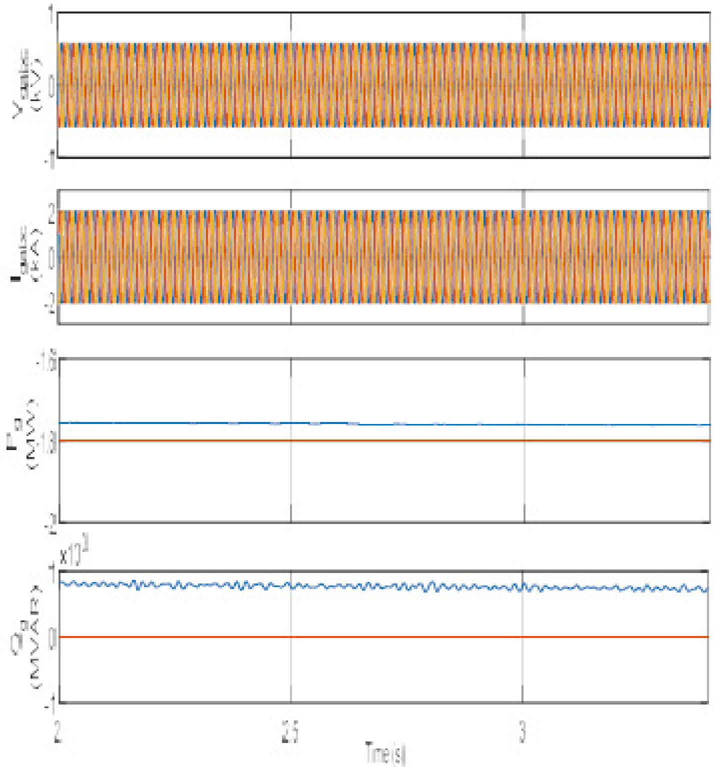

Fig. 5 (b) Performance of GSC with fixed speed and fixed power

Demonstrating the performance of proposed system under normal conditions where wind speed is fixed at 12 m/s with disturbance. When PMSG operated near rated condition, machine side converter maintained DC link voltage at 1400V. As shown in figure 5 (a) input power to DC link and power output from DC link is equal. The speed of the generator and the generator's electromagnetic torque is constant and each phase of the current generated form generator is fully sinusoidal and has been shifted from 120 degrees.

According to the grid code, the behavior of the grid side converter is sterling, as shown in Figure 5 (b) the voltages and currents of the grid are exactly out of phase, which means the active power is injected to the grid and the system operated on unity power factor. The execution of control technology is excellent because the power generated from the generator is fully injected to the grid and the system only injected the active powers with only a few watt reactive powers, with the fact that some value of inductance is always exist in practical system.

6.2. WECS under Variable wind speed and fixed power

The general execution of MSC, GSC, ESS and Pitch Angle Regulation is exhibited in Fig. 6 with variable wind speed.

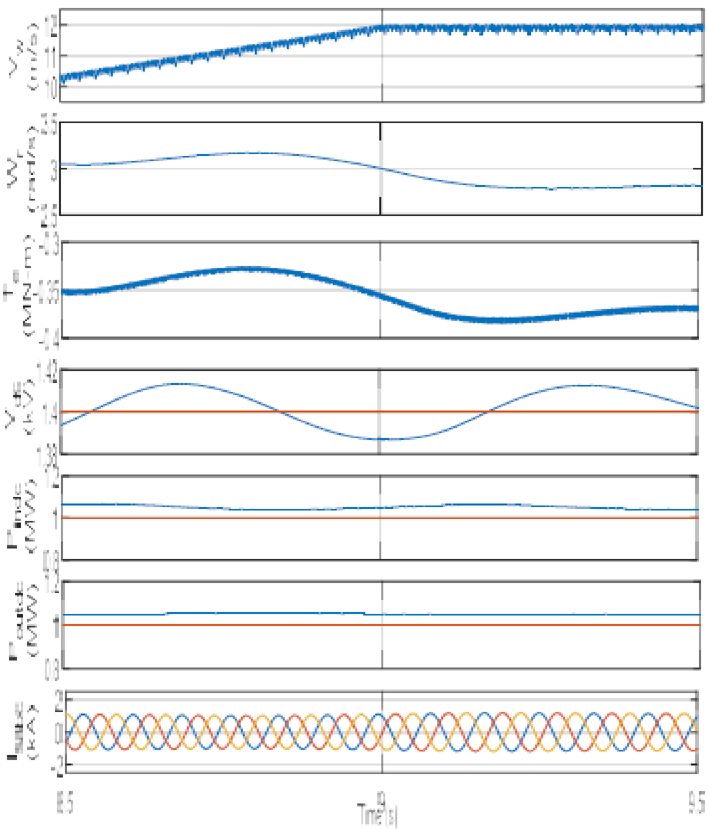

Fig. 6: (a) Performance of MSC with variable wind speed and fixed power

Demonstrating the performance of machine side converter under normal conditions is shown in figure 6 (a) where wind speed is varied from 10m/s to 12 m/s with disturbance. When PMSG operated lower than rated condition, machine side converter maintained DC link voltage at 1400V (±0.143%). The generated currents from generator are fully sinusoidal, equal in magnitude during variable wind speed and each phase of currents is shifted from 120 degrees.

As the wind speed of increases there is slight change in speed of generator's speed and electromagnetic torque. These outcomes are demonstrated that execution of machine side tactic is prominent.

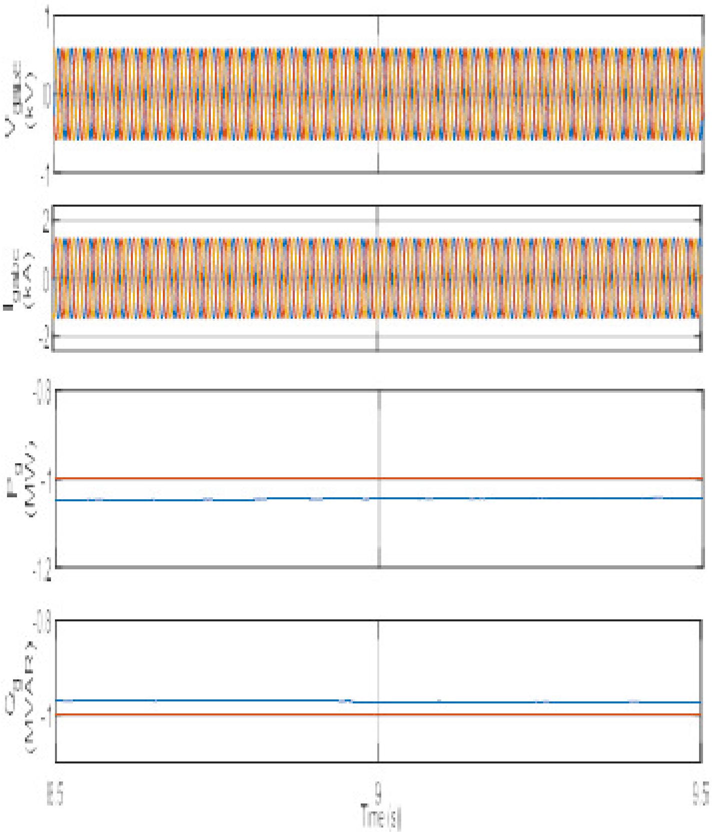

Fig. 6 (b) Performance of GSC with variable wind speed and fixed power

As appeared in Figure 6 (b) the voltages and currents of the grid are not exactly out of phase, which implies the active power and reactive power are injected to the grid and the system operated at less than unity power factor. The execution of control technology is excellent since there is no transient in injected current to the grid.

As shown in figure 6 (a), there is a slight variation in the power output and power input from the DC link because the generator increases the electromagnetic torque slightly but no change in the power (active and reactive power) to inject the grid resulting DC link voltage is slightly oscillate.

6.3. WECS under Variable wind speed and variable power

The general execution of MSC, GSC, ESS and Pitch Angle Regulation is exhibited in Figure 4.3 with variable wind speed and variable power (active and reactive). In figure 7 wind speed, active power and reactive power is varied from 12 m/s to 10 m/s, -2 MW to -1 MW and 0 MVAR to -1 MVAR respectively (negative sign indicate that power is injected to grid) at time 7 second.

There is decreases in active power from 2 MW to 1MW at 7 second in figure 7 from power system operator (PSO) consequently generator's current decreases vice versa at 10 second increases in power from 2MW to 1MW resultant generator's current increases.

In figure 7 large fluctuation occurs in DC link voltage during 7 second to 7.5second because of there is imbalance in power input to DC link and power outputfrom DC link. The injection power from the DC link varied immediately from 2MW to 1 MW, but the power inject to the DC link is not immediately changedbecause the inertia of the wind turbine is large, hence the pitch angle regulationshould not be applied immediately. Consequently can't applied pitch angle.

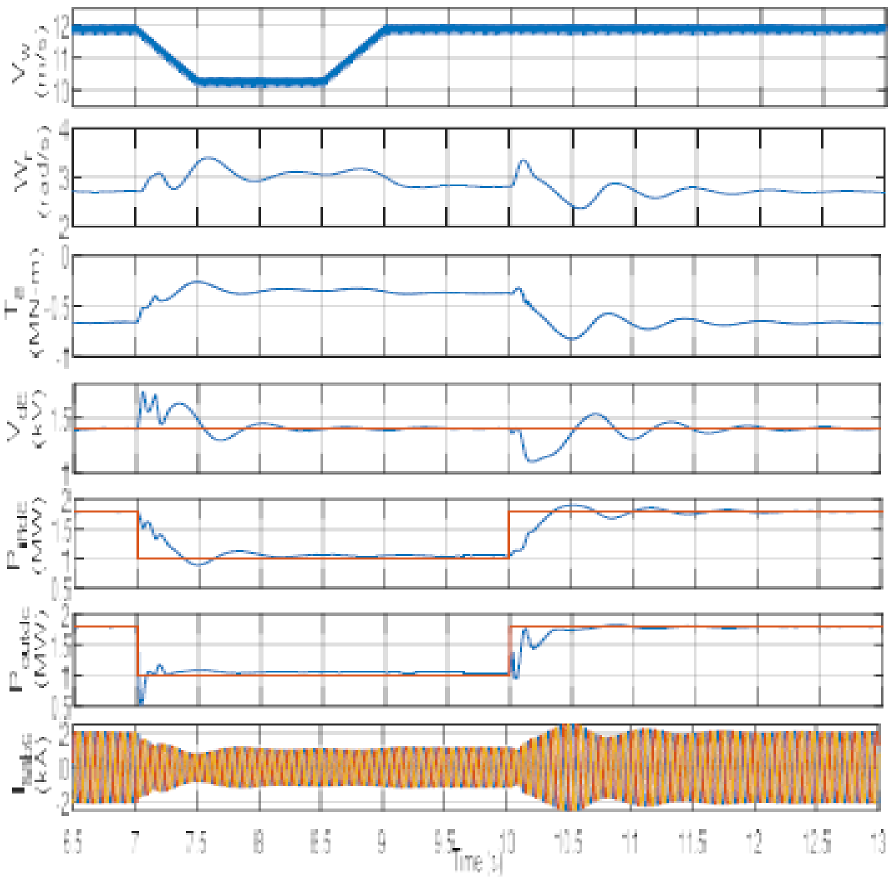

Fig. 7: Performance of MSC with variable wind speed and variable power

7. CONCLUSIONS

The behaviour of permanent magnet synchronous generator (PMSG) based wind energy conversion system (WECS) has been investigated under normal operating and grid fault conditions. The proposed configuration of PMSG based WECS is useful for electricity generation in countries with high population density. The proposed control strategy has competency of inherent damping from torsion oscillation cause of drive train and satisfied grid code necessity.

The conclusions are as follows,

I. System configuration of grid coupled PMSG based WECS has been introduced.

II. A novel control strategy of PMSG based WECS has been presented with fault ride through capability.

III. Developed WECS has been performed satisfactory under wide change in wind speed and grid fault conditions.

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