Regulation of Voltage in Micro grids by using Sliding Mode Control Technique

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ABSTRACT: The sliding mode controller is to achieve terminal voltage regulation while ensuring maximum power point tracking. Based on the voltage sensitivity analysis, to eliminate the possibility of interference with the other device in the micro grid development by the controller. In control systems, sliding mode control, or SMC, is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal that forces the system to "slide" along a cross-section of the system's normal behavior. The proposed methods: 1) no need to require synchronous coordinate transformation.2) to require to eliminates for decoupled proportional integral loops.3) can be implemented while in the absence of widespread communication. Dynamic models are considered for the double fed induction wind generators, converters, and internal controller along with their operational limits. Stochastic fluctuations in wind speed are modeled with NREL. Turbine while accounting for tower shadow and wind shear. Dynamic simulations are presented to access the control performance with voltage fluctuation compensation and control system robustness.

Keywords-Micro-grid, robust sliding mode control, Voltage regulation, DFIG.

1. INTRODUCTION

Doubly fed induction generator (DFIG)-based wind generation is an attractive option for sustainable energy integration in micro grids. The most noticeable one is the installation of the smart meters. Additionally, another important concept related with improving energy delivery is the micro grid concept, for whose right integration into the main grid, some challenges need to be studied. One of those is the frequency and voltage regulation in interconnected electrical systems with multiple generation sources. Many different approaches have been studied and Proposed for both grid-connected and islanded micro-grid operation. Grid-connected operation relies on main grid parameters. A micro-grid is a part of a distribution network with at least one distributed energy source which can operate independently as an island when necessary. Doubly fed induction generator (DFIG)-based wind generation is an attractive option for sustainable energy integration in micro-grids.

A suitable method of reactive power management of DFIG wind systems based on the voltage sensitivity analysis is proposed in. The method eliminates the potential for interference with other voltage regulation devices by locally adjusting the DFIG reactive power based on voltage sensitivity analysis. However, the method in is based on the classical control and performed by the decoupled PI rotor current control loops. SMC-based DTC methods are proposed in and while special consideration is spent on the wind turbine mechanical stress. The method Proposed by improves the wind system reliability, and the Method in governs the wind turbine in different operation regions.

2. SYSTEM STRUCTURE

A schematic diagram of a DFIG-based wind energy generation system is shown in Fig. 1

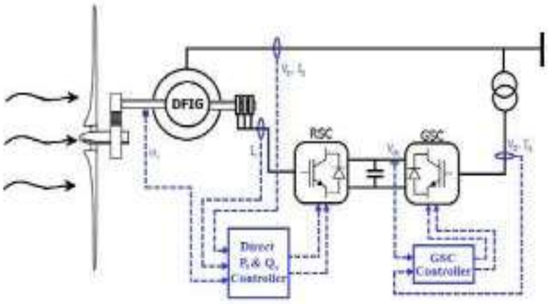

Fig.1.Schematic diagram of a DFIG

The system employs two back-to-back converters: a rotor side. Typically, these converters are rated at about 25%–30%of the generator rating. While the RSC is used to adjust the rotor current, the GSC is responsible to maintain the dc link voltage.

Together, the converters are able to control reactive power exchanges with the network converter (RSC) and a grid side converter GSC. Two DFIGs (each rated at 2.2 MW) are connected to bus 611 of the IEEE 13-bus distribution network as shown in Fig. 2. The network is connected to the bulk power system through bus 650, with a short circuit capacity of58.52 MVA and X/R ratio of 1/4. It is further assumed that:

1) The two DFIG systems at bus 611 are identical;

2) The DFIG converters employ pulse wide modulation (PWM);

3) Distribution lines include resistive and inductive characteristics;

4) Wind speed fluctuations, aerodynamics of the turbine, wind shear, and tower shadow lead to fluctuations inactive power, and consequently the voltage;

5) The system is three-phase balanced.

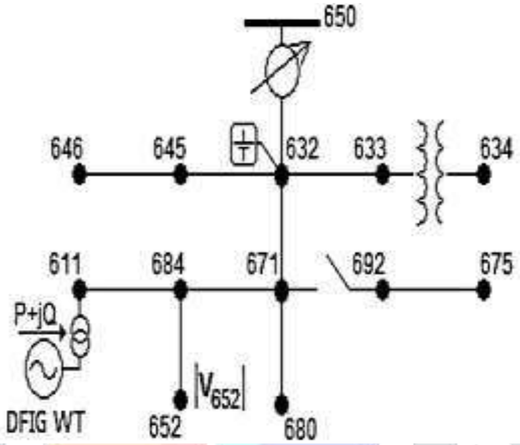

Fig.2. line diagram of the modeled IEEE 13-bus system.

Turbine is a precise wind model developed by the National Renewable Energy Laboratory (NREL). It is a stochastic, full field, turbulent wind simulator that has been developed for simulation of a full- field flow for turbulence structures. An example of wind speed produced by Turbine for 100 s is shown in Fig.3.

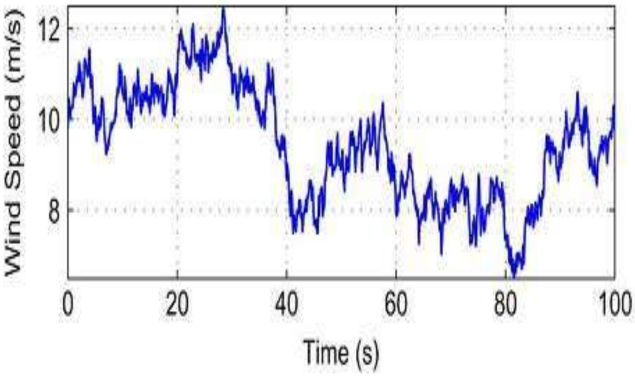

Fig.3. wind speed produced by Turbine

The term wind shear is used to describe the variation of wind speed with height, and the term tower shadow describes the redirection of wind due to the tower structure. In three-bladed turbines, power pulsations occur at what is known as 3p frequency, and it is the same frequency at which blades pass by the tower.

The model computes torque variations for a three- bladed turbine including the effects of wind shear and tower shadow. The output torque computed with this model (turbine parameters in Appendix) is shown in Fig. 4 from which one can note the drop in output torque three times per revolution.

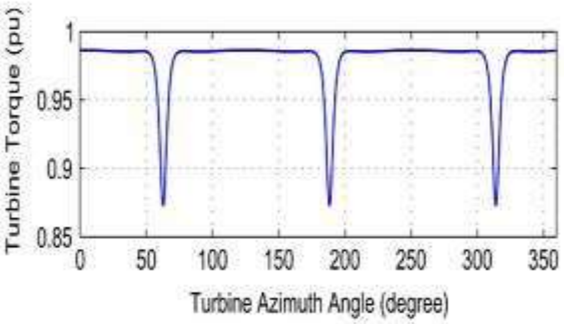

Fig.4. wind shear effects on the turbine torque.

3. VOLTAGE REGULATION BASED ON THEVOLTAGESENSITIVITYAN ALYSIS

The control concept for voltage regulation based on voltage sensitivity analysis appears in [7]. However, it is briefly described here to make the presentation Self-contained. The power flow equations for the system considering both inductive and resistive characteristics of the power lines are

$$Pk = \sum_{n-1}^{N} |\mathrm{Vk}|.|\mathrm{Vn}||\mathrm{Ykn}|.\cos(\theta\mathrm{kn} + \delta\mathrm{n} - \delta\mathrm{k})$$

$$Pk = \sum_{n-1}^{N} |\mathrm{Vk}|.|\mathrm{Vn}||\mathrm{Ykn}|.\sin(\theta\mathrm{kn} + \delta\mathrm{n} - \delta\mathrm{k}) \ldots 1$$

WhereP_k and $Q_k$are the active and reactive powers of busY_{kn}, is the admittance of the line from bus to bus, $V_k$is the voltage at bus.

4. DYNAMIC BEHAVIOR OF DFIG IN THE STATOR STATIONARY REFERENCE FRAME

Fig. 5 displays the equivalent circuit of a DFIG in the stator stationary reference frame where the flux linkage vectors are given by

$$\Psi^{s}_{s\alpha\beta} = L_s I^{s}_{s\alpha\beta} + L_m I^{s}_{r\alpha\beta}$$

$$= \qquad + L_r I^{s}_{r\alpha\beta} \qquad \Psi^{s}_{r\alpha\beta} \qquad L_m I^{s}_{s\alpha\beta} \qquad \ldots.2$$

Fig.5. Equivalent circuit of a DFIG in the stator stationary reference frame.

5. SLIDING MODE CONTROL DESIGN

The basic idea in sliding mode control (SMC) is to steer the system's state trajectory into a user defined surface and maintain the state on that surface for subsequent time. Therefore, two sliding variables are defined namely:

a) MPPT sliding variable; and
b) Reactive power control sliding variable.

A. MPPT Sliding Variable

The primary objective of the control system is performing the MPPT to capture the most possible energy from wind.

Temporarily neglecting tower shadow and wind shear effects, the turbine optimal torque T_{opt} and turbine optimum angular speed are given by

$$\omega_{opt}$$

$$Topt \approx \rho A V^2 R^{\frac{Cpmax}{\lambda opt}} \ldots\ldots.3$$

$$Wopt = \frac{\lambda_{opt} V}{R}$$

Where λ_{opt} the optimum tip is speed ratio and C_{pmax} is the maximum turbine power efficiency. Using (15), the turbine mechanical reference power is as follows:

$$P_m = T_{opt} w_{opt} \dots\dots .4$$

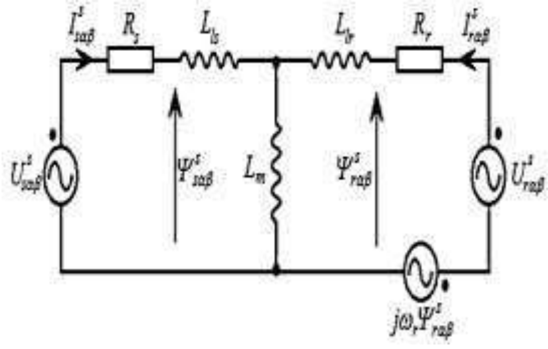

Fig 5: Equivalent Circuit

B. Reactive Power Control Sliding Variable

To ensure the minimum effect of the wind power on the target bus voltage, the second sliding variable is expressed as follows:

$$S_2(x) = K_Q.(P_s - Q_s) \dots\dots .5$$

Where K is calculated based on the sensitivity analysis in (8). The sliding variable defined by (18) modulates the reactive power in response to variations in the active power to achieve the voltage regulation of the target buses in the micro-grid. If a non-zero power set- point is selected, the second sliding variable should be expressed as follows

$$S_2(x) - K_Q.(P_s - P_o) - Q_s \dots\dots .6$$

6. SIMULATION RESULTS

Simulations are carried out for two DFIG reactive power control modes of:

1) UPF: unity power factor operation;

2) PCM (proposed control method): based on (6)— voltage regulation at bus 652.

For each of the control modes, three different loading conditions are considered:

1) Light load condition—50% of the nominal loading;

2) Medium load condition—with nominal loads of the IEEE13-bus distribution network;

3) Heavy load condition—150% of nominal loading.

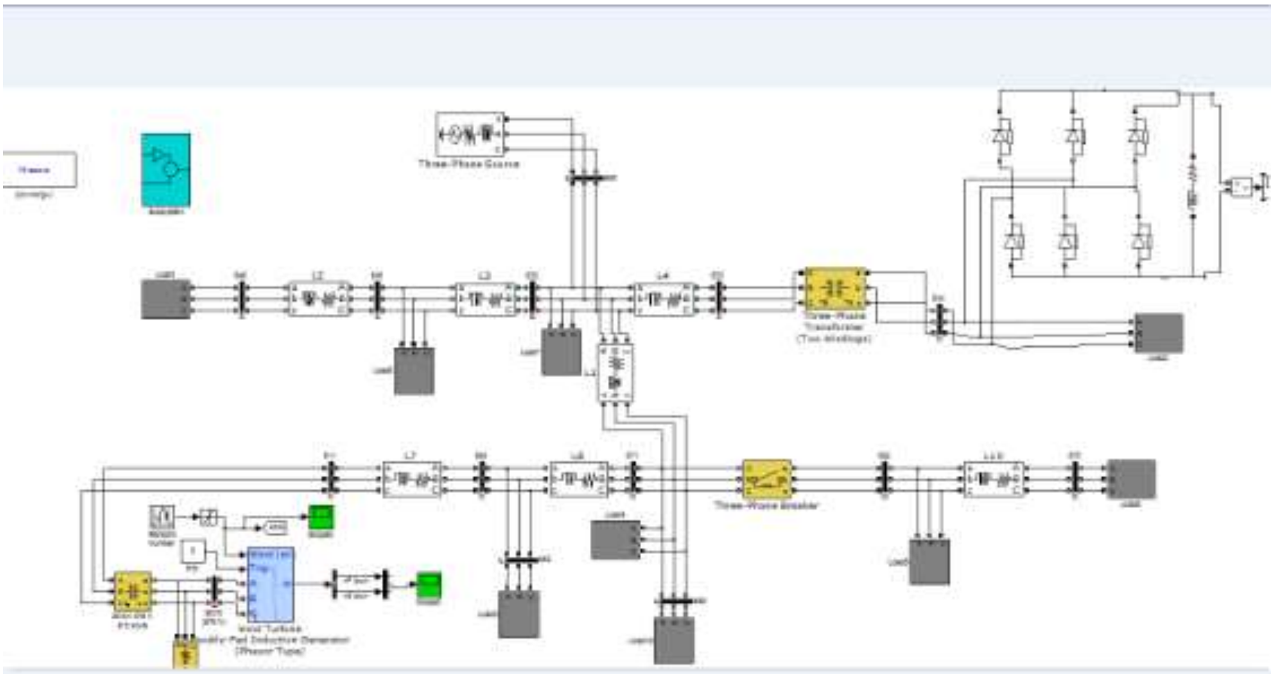

Fig 6. Mat lab diagram control strategy with no linear load

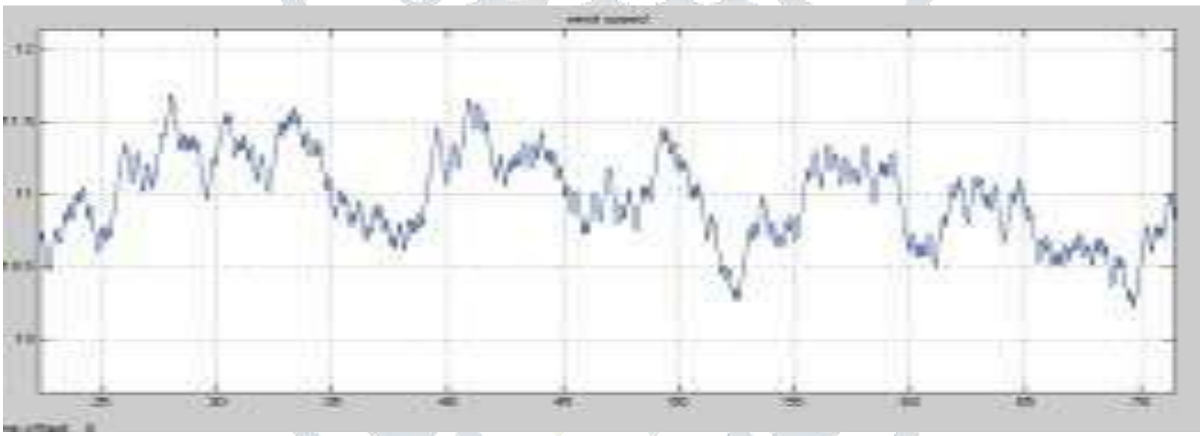

Fig .7 wind speed

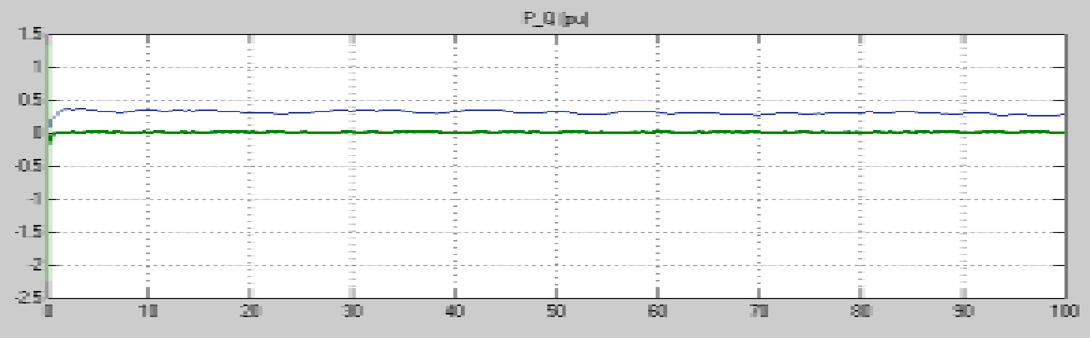

Fig .8 Voltages at sensitive bus in the grid connected mode under light load conditions and unity power factor operation

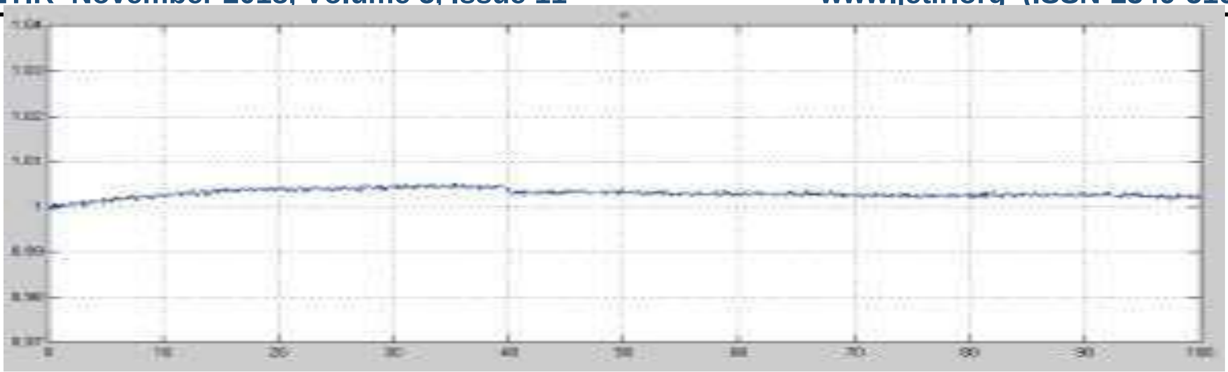

Fig.9 Voltage at sensitive bus in the grid connected mode under light load conditions. DFIG reactive power regulated by PCM

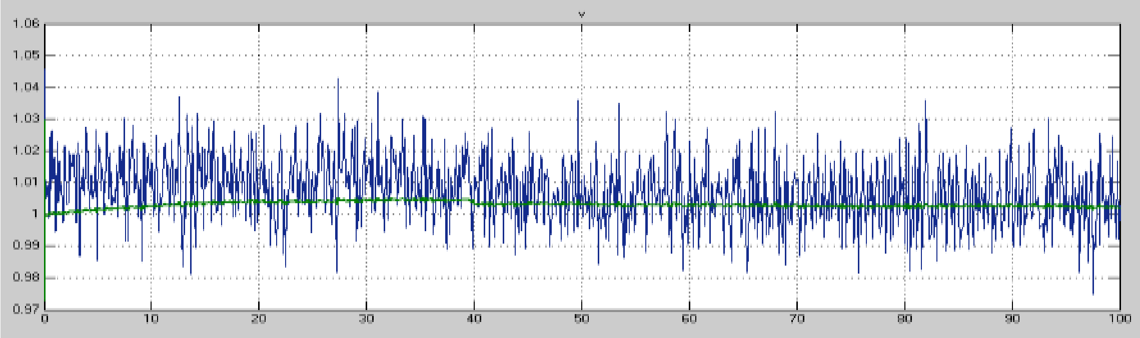

Fig. 10 Powers produced by one of the DFIG wind systems with the applied wind speed

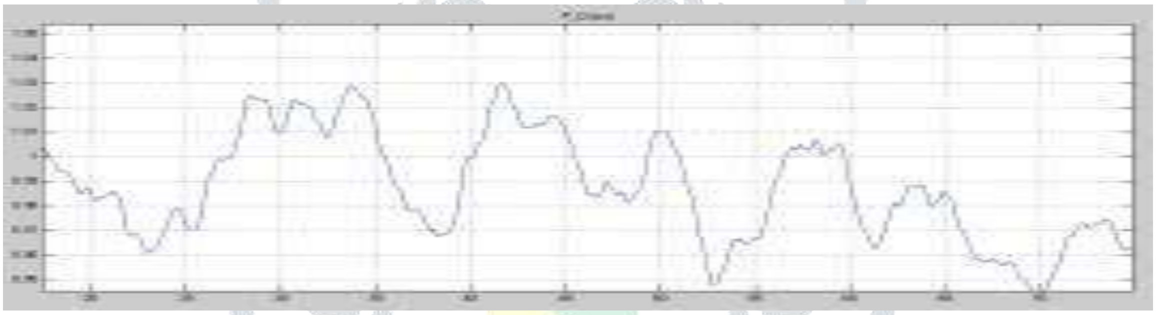

Fig. 11 DFIG wind systems with the applied wind speed

7. CONCLUSION

The sliding mode control scheme and directly controls the active and reactive powers of a DFIG wind system without involving any synchronous coordinate transformation. The method eliminates the need for decoupled proportional-integral (PI) loops; additionally, the control performance is not degraded by errors in system parameters. Simulations show that the proposed control methods are effective at restricting the voltage swings experienced at different buses compared to the UPF method. The results are consistent for different loading conditions (low, medium, high) across different buses in the system.

8. REFERENCES

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