ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A New Control Scheme for Voltage Regulation in Micro Grids to Ensure Maximum Power Point Tracking (MPPT)

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ABSTRACT:

MICROGRID 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 based wind generation is an attractive option for microgrids because of its own advantages with significant wind energy penetration; a wind speed variation translates to fluctuations in electrical variables and contributes towards power quality issues such as variations in bus voltages. Such fluctuations can disrupt the normal operation of voltage regulation devices.

Conventional PI controllers for DFIG based microgrids are incapable of obtaining good dynamical performance. The method eliminates the potential for interference with other voltage regulation devices by locally adjusting the DFIG reactive power based on voltage sensitivity analysis. The coupling of a controllable reactive power source with the wind energy system is used to flatten out the voltage variations. Since direct voltage regulation by wind energy systems may interfere with other voltage regulation devices.

The classical control with decoupled PI rotor current control loops is used for reactive power management of DFIG based on voltage sensitivity analysis but this controller highly depends on PI controller parameters which leads to un-avoidable errors since inaccurate tuning of parameters degrades the performance of the controller. To improve the voltage regulation, the sliding mode control is proposed to realize the objective of terminal voltage regulation in DFIG based microgrids. This principle is based on voltage sensitivity, it does not require synchronous coordinate transformation, it eliminates the need for decoupled proportional-integral (PI) loops and the performance of the proposed controller may not depend on the system parameters. The performance of this control scheme is illustrated on the IEEE 13-bus distribution network.

The proposed work carried on MATLAB environment and different comparisons are made. The results proved that the proposed system with Sliding Mode controller have better performance as compared to the performance of system with conventional controller.

INTRODUCTION:

Wind power has become one of the most important and promising sources of renewable energy that can partially solve the energy crisis. Wind energy generation equipment is most often installed in remote, rural areas. These remote areas usually have weak grids, often with voltage unbalances and under voltage conditions. When the stator phase voltages supplied by the grid are unbalanced, the torque produced by the induction generator is not constant. Instead, the torque has periodic pulsations at twice the grid frequency, which can result in acoustic noise at low levels and at high levels can damage the rotor shaft, gearbox, or blade assembly. Also an induction generator connected to an unbalanced grid will draw unbalanced current. These unbalanced current tend to magnify the grid voltage unbalance and cause over current problems as well.

Wind energy has been the subject of much recent research and development. In order to overcome the problems associated with fixed speed wind turbine system and to maximize the wind energy capture, many new wind farms will employ variable speed wind turbine. DFIG (Double Fed Induction Generator) is one of the components of Variable speed wind turbine system. DFIG offers several advantages when compared with fixed speed generators including speed control. These merits are primarily achieved via control of the rotor side converter. Many works have been proposed for studying the behavior of DFIG based wind turbine system connected to the grid. Most existing models widely use vector control Double Fed Induction Generator. The stator is directly connected to the grid and the rotor is fed to magnetize the machine.

Wind electrical power system are recently getting lot of attention, because they are cost competitive, environmental clean and safe renewable power sources, as compared fossil fuel and nuclear power generation. The reason for the world wide interest in developing wind generation plants is the rapidly increasing demand for electrical energy and the consequent depletion reserves of fossil fuels, namely, oil and coal. Many places also do not have the potential for generating hydel power. Nuclear power generation was once treated with great optimism, but with the knowledge of the environmental hazard with the possible leakage from nuclear power plants, most countries have decided not to install them anymore.

SLIDING MODE CONTROLLER:

Introduction :

In control theory, 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 state-feedback control law is not a continuous function of time. Instead, it can switch from one continuous structure to another based on the current position in the state space. Hence, sliding mode control is a variable structure control method. The multiple control structures are designed so that trajectories always move toward an adjacent region with a different control structure, and so the ultimate trajectory will not exist entirely within one control structure.

Instead, it will slide along the boundaries of the control structures. The motion of the system as it slides along these boundaries is called a sliding mode and the geometrical locus consisting of the boundaries is called the sliding (hyper) surface. In the context of modern control theory, any variable structure system, like a system under SMC, may be viewed as a special case of a hybrid dynamical system as the system both flows through a continuous state space but also moves through different discrete control modes.Essentially, sliding mode control utilizes discontinuous feedback control laws to force the system state to reach, and subsequently to remain on, a specified surface within the state space (the so called sliding or switching surface).The system dynamic when confined to the sliding surface is described as an ideal sliding motion and represent the controlled system behavior.The advantages of obtaining such a motion are twofold: firstly the system behaves as a system of reduced order with respect to the original plant; and secondly the movement on the sliding surface of the system is insensitive to a particular kind of perturbation and model uncertainties. This latter property of invariance towards so called matched uncertainties is the most distinguish feature of sliding mode control and makes this methodology particular suitable to deal with uncertain nonlinear systems.

One application of sliding mode controllers is the control of electric drives operated by switching power converters because of the discontinuous operating mode of those converters, a discontinuous sliding mode controller is a natural implementation choice over continuous controllers that may need to be applied by means of pulse-width modulation or a similar technique of applying a continuous signal to an output that can only take discrete states.

Sliding mode control must be applied with more care than other forms of nonlinear control that have more moderate control action. In particular, because actuators have delays and other imperfections, the hard sliding-mode-control action can lead to chatter, energy loss, plant damage, and excitation of unmodeled dynamics. Continuous control design methods are not as susceptible to these problems and can be made to mimic sliding-mode controllers.

Robust MIMO Sliding Mode Controller:

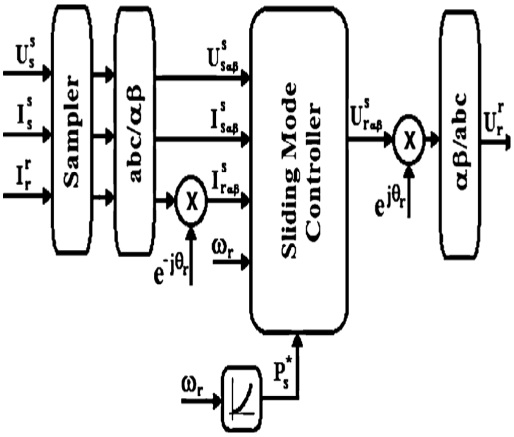

Fig.1 Schematic diagram of the robust MIMO controller.

A control system based on the defined sliding manifold ($S = [s_1, s_2]^t$) should enforce the states of the system to reach the manifold intersection ($S = 0$) and keeps them there. With $W = (1/2)S.S^t$ as a Lyapunov function candidate, the control design includes three steps:

a) System dynamic drift cancellation,

b) Manifold intersection reaching, and

c) Control system robustness as follows

u(x) = ua(x) + ub(x) + uc(x)
It should be noted that the final output of the controller is limited by a saturation function to keep it within the acceptable range. A schematic diagram of the controller is shown in Fig. 1.

SIMULATION RESULTS:

Introduction to Simulation:

Simulation is an effective tool by which we can experience the practical results through the software. There are number of simulation software available and the most efficient tool is the MATLAB. There are number ways in which MATLAB software can be used for simulation of electrical circuits. We employ the Simulink part of the MATLAB for the simulation of three-phase VSI operating in 150° conduction mode.

Results:

Simulation results 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 (low, medium, high) conditions across different buses in the system.

Different Modes of Operation:

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 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 IEEE 13-bus distribution network;
3) Heavy load condition—150% of nominal loading.

Simulink Model of SMC:

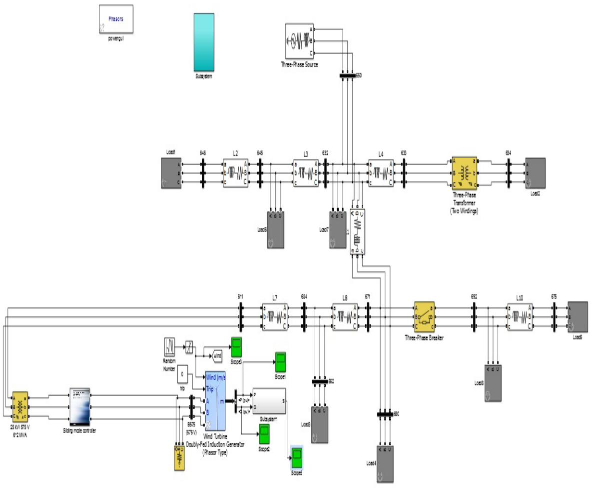

Fig. 2 Simulink diagram of modeled SMC based voltage regulation in Microgrids

Under normal conditions, the active power which is measured locally, serves as the input to the reactive power controller. The local nature of this scheme thus obviates the need for remote measurements and minimizes the potential for interference with other voltage regulation devices. In order to regulate the voltage at the target bus by modulating the DFIG reactive power in response to active power variations.

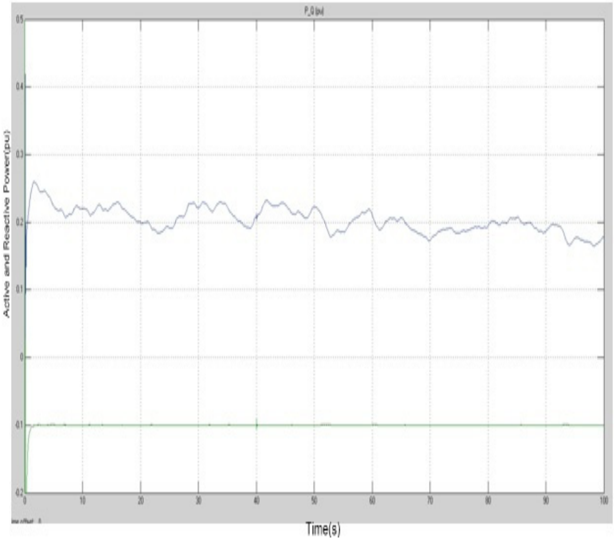

Fig 3 Active and reactive powers of the DFIG wind system.

The active and reactive powers produced by DFIG as shown in Fig. 3. The maximum voltage variation (in %) experienced at each of the buses, with various wind speed series, under three loading conditions and with each of the control modes is noted in Table I.

Bus Number	Load Condition		
	Low	Med.	High
	UPF	UPF	UPF
632	3.02	3.25	3.91
633	3.02	3.25	3.91
634	3.22	3.46	4.01
645	3.03	3.25	3.91
646	3.01	3.25	3.91
671	3.01	3.91	4.22
680	3.22	3.91	4.52
675	3.91	3.91	4.72
684	3.88	4.52	4.94
652	**3.88**	**4.91**	**5.23**
611	3.91	5.11	5.15
	PCM	PCM	PCM
632	0.05	0.06	0.72
633	0.05	0.06	0.72
634	0.05	0.06	0.92
645	0.05	0.06	0.72
646	0.05	0.06	0.72
671	0.05	0.06	0.76
680	0.05	0.06	0.86
675	0.05	0.36	0.66
684	0.05	0.55	0.85
652	**0.14**	**0.05**	**0.85**
611	0.06	0.79	1.11

Table I. Maximum Voltage Variations in Different Control Modes (%)

Light Load Condition of Microgrid:

Voltage variations of bus 652 under light load conditions of the microgrid as shown in Fig.4. The minimum and maximum voltages experienced at each bus with different wind speed series. The method decreases the voltage variation at bus 652 from 3.88% at UPF to 0.14%. Also, the method effectively reduces the voltage variations on the other buses.

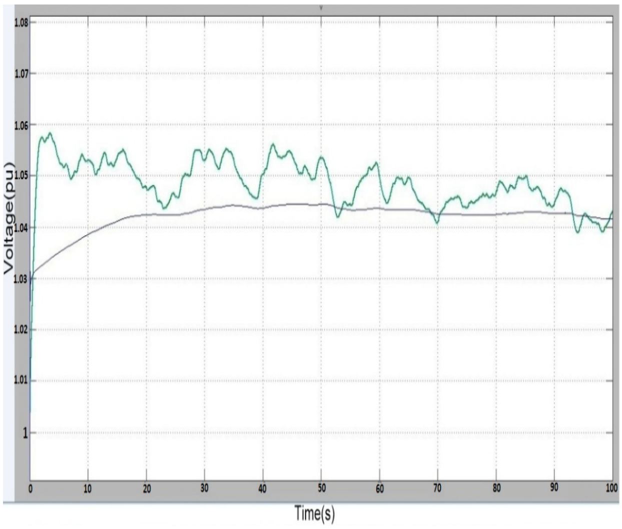

Fig. 4 Voltage at sensitive bus (652) in the grid connected mode under Light load conditions.

Medium Load Condition of Microgrid:

Voltage variations of bus 652 under medium load conditions of the microgrid are displayed in Fig. 5.4. Sensitivity factors are calculated for the medium load condition; therefore, not surprisingly, control performance is excellent in decreasing voltage variations of bus 652 from 4.95% in UPF to 0.05%. Also the method effectively reduces voltage variations of other buses.

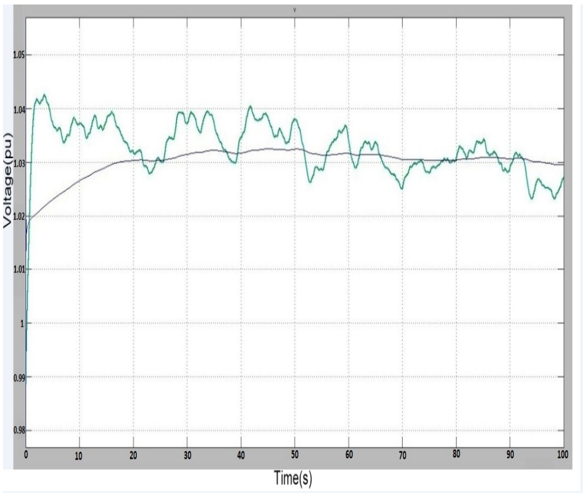

Fig. 5 Voltage at sensitive bus (652) in the grid connected mode under medium load conditions.

Heavy Load Condition of Microgrid:

Voltage variations of bus 652 under the heavy load condition of the microgrid as shown in Fig. 4 are considered. The proposed method decreases bus 652 voltage variations from 5.23% in the UPF to 0.85%. Also the method effectively reduces voltage variations of other buses.

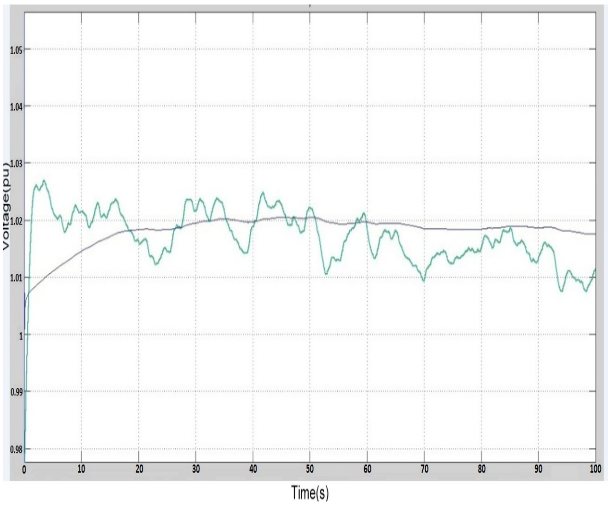

Fig. 6 Voltage at sensitive bus (652) in the grid connected mode under Heavy load conditions.

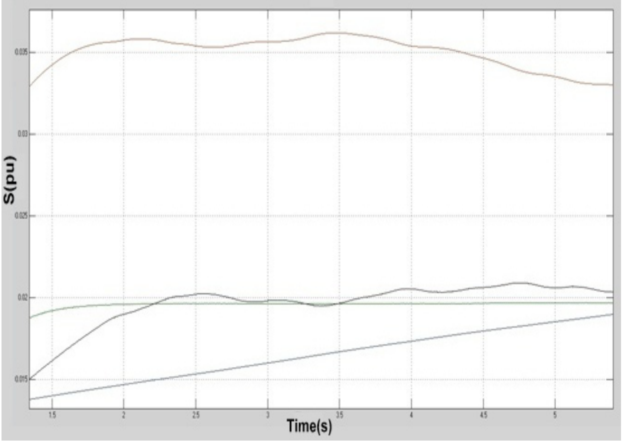

Fig. 7 Active and reactive power

The reactive power coordination between the GSC and RSC is achieved. This reactive power coordination between the GSC and RSC to ensure that stator current requirements of the RSC for reactive power production are minimal, thus avoiding associated losses. In this method, the reactive power primarily is produced by the GSC. The capacity of the GSC is limited and the priority belongs to the active power.

During a high reactive power demand, the GSC is blocked by the maximum current limiter, and cannot produce/absorb required reactive power completely. Therefore, the reactive power coordinator block shares the non produced part to the RSC by changing the reactive power reference signal of the DFIG controller. In this way, the RSC helps the GSC in reactive power production.

Conclusion:

Generally, the stochastic nature of wind can lead to significant voltage variations in microgrids. Based on voltage sensitivity analysis, this paper proposed a reactive power control method which can regulate the voltage at one or a group of the target buses in a microgrid while ensuring MPPT. The proposed method employs a 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. Also disturbances and uncertainties are effectively tolerated by the control system during the simulations.

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