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LVRT CAPABILITY ENHANCEMENT OF WIND FARM INTERECONNECTED POWER SYSTEM BY USING PITCH CONTROLLER

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Abstract-*Wind energy, a renewable and environmental friendly, is an important source of electrical power in recent years. As the wind power penetration increases day by day, it is required that wind turbines remain connected to the grid and actively contribute to the system stability during and after grid faults. This paper focuses on a new topology, for reactive power compensation, voltage regulation and transient stability enhancement for wind turbines equipped with fixed-speed induction generators in large interconnected power systems. This study proposes an efficient control strategy to improve the low voltage ride through (LVRT) capability by using the pitch controller during successful reclosing of CBs. Besides the unsuccessful reclosing of circuit breakers, the performance of controller is also evaluated. Extensive simulations have been carried out with real wind speed data and different time durations where the effectiveness of the proposed control scheme is verified using power system simulator PSCAD/EMTDC.*

Keywords: Wind power generation, Low Voltage Ride-Through (LVRT), Capability, Pitch controller.

1. INTRODUCTION

Now a day's worldwide energy crisis is one of the great problem. Recently, the generation of electricity using wind power has received much interest and considerable attention all over the world. The important drawbacks associated with this renewable energy systems are their inability to guarantee reliability and their lean nature [1]. One of the simplest methods of operating a wind generation system is to use an induction generator connected directly to the power grid, because an induction generator is the most cost-effective and robust machine for wind energy conversion. However, the fixed-speed wind turbines equipped with the induction generators, reactive power support is needed at WECS terminals for voltage regulation and improvement of low voltage ride through (LVRT) capabilities [2].

2. LVRT REQUIREMENT

As wind speed continuously changes, the voltage at the PCC of the power system fluctuates. When fault occurs, the voltage at the WECS terminal drops. Thus the generated active power falls, while the mechanical power does not change instantly and so the induction generator accelerates. After fault clearance, the reactive power consumption increases resulting in reduced voltages near the generator unit. Thus the induction generator voltage does not recover immediately after fault, but a transient period continues. As a consequence, the generator continues to accelerate and this may lead to rotor speed instability. Then the WECS requires to be disconnected from the power system. But shutdown of a wind farm during and after a network disturbance is not acceptable and not desirable by transmission system owners (TSO). The wind generator shut down phenomenon has been reduced by adopting the low voltage ride through (LVRT) requirement.

3. SYSTEM OVERVIEW

The wind turbine and the induction generator (WTIG) are shown in figure 3.1. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding. The pitch angle is controlled in order to limit the generator output power to its nominal value for high wind speeds. In order to generate power the induction generator speed must be slightly above the synchronous speed. But the speed variation is typically so small that the WTIG is considered to be a fixed-speed wind generator. The well-known cascade control scheme with independent control of the active and reactive currents was developed as shown in Figure 3.2. The VSC converts the DC voltage across the storage device into a set of three-phase ac output voltages. These voltages are supplied to the ac system through the coupling transformer.

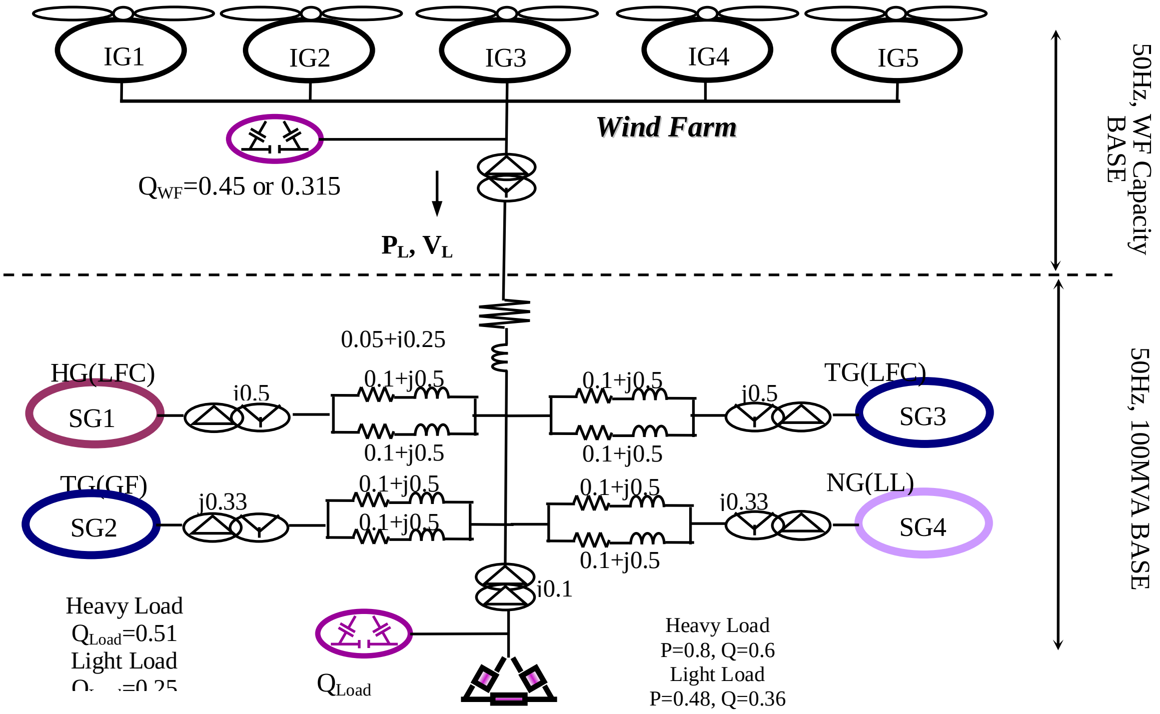

Fig. 3.1: Model System

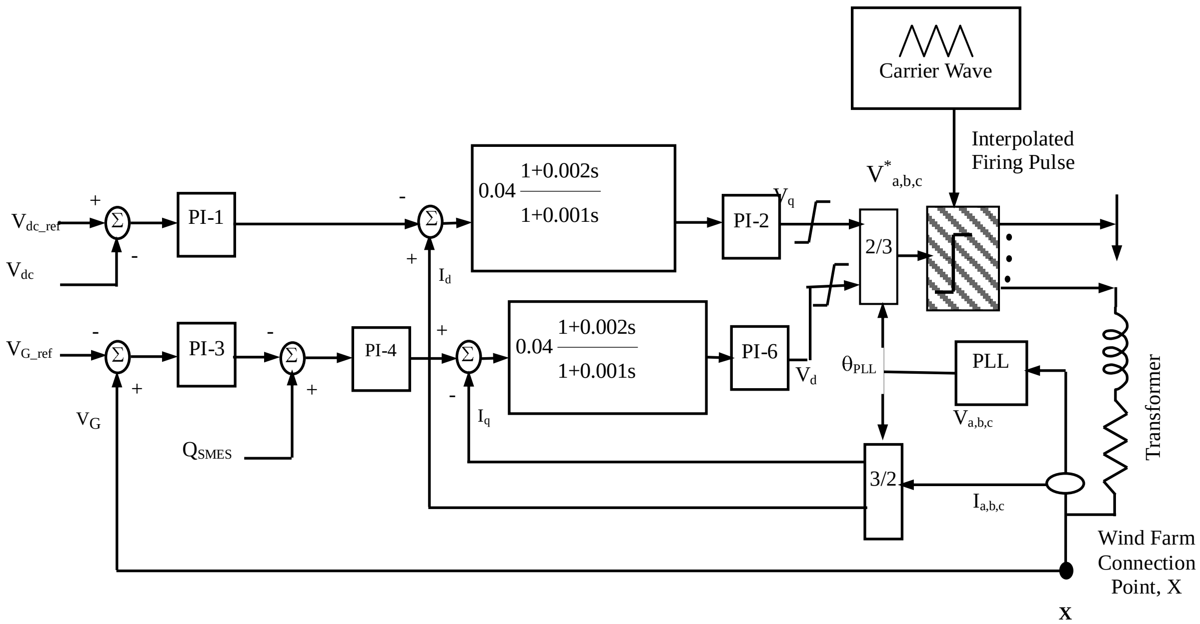

Fig. 3.2: Control system of the VSC

3.1 PI Controller

A Proportional-Integral (PI) controller is used to control the blade pitch angle in order to limit the electric output power to the nominal mechanical power []. The pitch angle is kept constant at zero degree when the measured electric output power is under its nominal value. When it increases above its nominal value the PI controller increases the pitch angle to bring back the measured power to its nominal value. Parameters of the PI Controller and generator are shown in Table 3.1 and Table 3.2.

Table 3.1 Parameters of PI Controllers

	PI-1	PI-2	PI-3	PI-4	PI-5	PI-6
K_P	3.00	2.00	2.00	0.04	1.0	0.10
T_i	0.10	0.01	0.10	0.10	0.12	0.01

Table 3.2 Parameters of Generators

Wind Generator (Induction Generator)				
	Squirrel cage type (IGn,n=1,2,,,5)			
MVA	2 (each)			
R_1 [pu]	0.01			
X_1 [pu]	0.10			
X_m [pu]	3.50			
R_{21} [pu]	0.035			
X_{21} [pu]	0.03			
R_{22} [pu]	0.014			
X_{22} [pu]	0.098			
H_e [sec]	0.30			
H_t [sec]	3.00			
K_s[pu]	90			
Synchronous Generators				
	Salient pole type (SG1)	Cylindrical type		
		SG2	SG3	SG4
MVA	20	30	20	30
Xd [pu]	1.2	2.11		
Xq [pu]	0.7	2.02		
H [sec]	2.5	2.32		

3.2 Two Mass Drive Train Model

This In case of conventional WECS model, accurate results are obtained by increasing the number of masses with spring and damping components which are used to represent the physical characteristics of the actual system. It has been proved that the two-mass model for WECS representation is fairly accurate. The wind turbine and the generator rotor are modeled as two masses and the wind mill shafts as spring element. The dynamic equations of the two-mass representation are given [3].

$$\frac{d\omega_t}{dt} = \frac{T_t - K_S\delta}{2H_t} \tag{3.1}$$

$$\frac{d\omega_e}{dt} = \frac{K_S\delta - T_e}{2H_e} \tag{3.2}$$

$$\frac{d\delta}{dt} = 2\pi f(\omega_t - \omega_e) \tag{3.3}$$

where T is the torque, δ is the angular displacement between the two ends of the shaft, ω is the angular speed, H is the inertia constant and K_s is shaft stiffness. The indexes t and e stand for wind turbine and generator parameters, respectively.

3.3 Simulation Results

This work shows a control methodology to overcome the voltage dip of wind farm during a network disturbance in power system [5]. To obtain the realistic responses, the two-mass shaft model of WTGS is considered in this study. In this case the performances of the conventional pitch controller have been evaluated. Figures 3.3 through Figure 3.7 show the simulation results for this case.

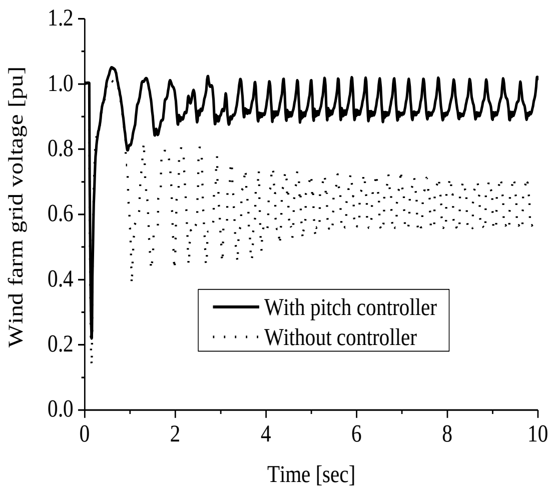

Fig. 3.3: Responses of wind farm terminal voltages

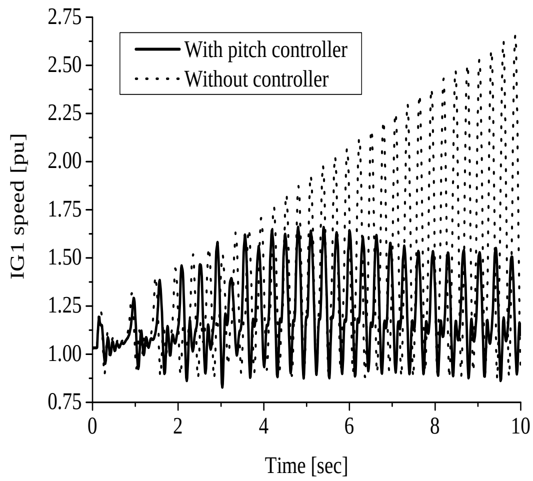

Fig. 3.4: Responses of IG1 speed [3LG]

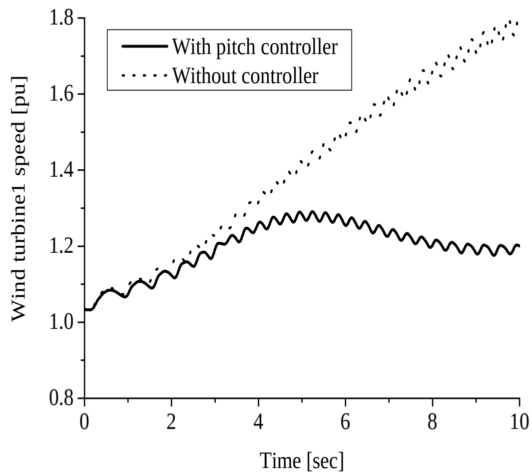

Fig. 3.5: Responses of wind turbine1 speed [3LG]

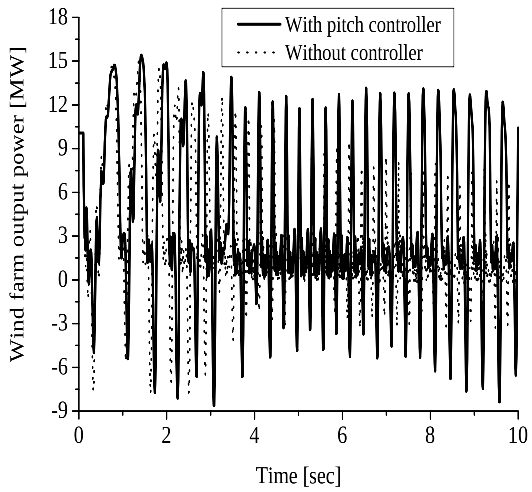

Fig. 3.6: Responses of wind farm output power [3LG]

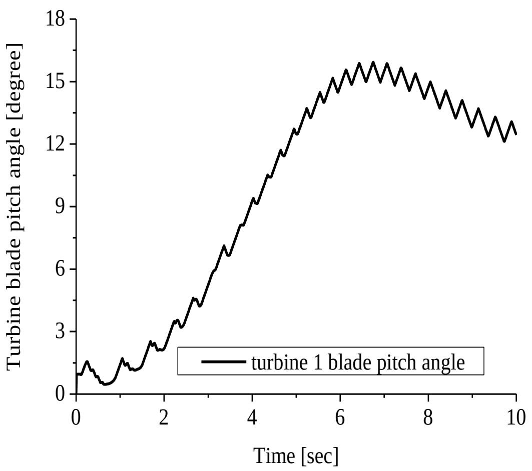

Fig. 3.7: Response of turbine blade pitch angle [3LG]

4. CONCLUSIONS

It is seen from Figure. 3.3 to Figure 3.7 that, because of the use of the pitch controller, system performances is comparatively better than without controller. However, IG rotor speed cannot return back to the stable state. It is also seen from Figure 3.3 that wind farm terminal voltage cannot return back to 90 percent of the nominal voltage by using the pitch controller. This fact also indicates that the pitch controller cannot recover the terminal voltage to the nominal value. Figure 3.6 and Figures 3.7 show the responses of wind farm real power and turbine blade pitch angle respectively. Therefore, it can be concluded that though the performances of the conventional pitch controller are somewhat better but it cannot improve the LVRT capability.

5. REFERENCES

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8. NOMENCLATURE

Symbol	Meaning	Unit
T	Torque	N-m
δ	Angular displacement	(degree)
ω	Angular speed	(rad/s)
H	Inertia constant	(MJ/MVA)
X_d	Direct axis ractance	(pu)
X_q	Quadrature axis reactance	(pu)