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Design of PI Controller for doubly-fed Induction Generator Using Static Output Feedback

Pooja Sharma, Monika Jain
Department Electrical & Electronics Engineering of OIST, Bhopal (M.P)
pujasharma1192@gmail.com, oisthodex@oriental.ac.in

Abstract— *When the wind electricity is associated with an electric grid affects power quality. Power quality issues like active power, reactive power, change in voltage, flicker, harmonics, and electric behavior of switching operations has to measure. Most of the wing power era system used the doubly-fed induction generator, due to its benefit of making sure a variable rotation and it can run above the synchronous value. DFIG prevents damage to the wind turbine mechanism whet it is used more than the rated speed. In the present work, with the help of PI controller scheme will get the enhancement behavior of a DFIG.*

Keywords— Wind turbine(WT), Doubly fed induction generator(DFIG), rotor side converter(RSC), grid side converter(GSC), PI controller, static output feedback(SOF)

I. INTRODUCTION

The thriving need for electrical energy and the need to preserve nature due to the reduction in fossil fuels and increased pollution of problems peoples are interested in sustainable development by the use of a source of renewable energy which becoming very essential for the electrical power generation system. By the comparison of all renewable energy sources, one of the most economical renewable sources is wind energy system [1]. In these days for wind power generation, the DFIG is an attractive choice because of its have many advantages [2], like it can work on different speed mode, provide almost constant frequency, also able to control the active and reactive power [3] and reduced mechanical stresses [4]. The employment of DFIG is turning into additional and additional common for power generation because it is appropriate for the implementation of advanced options needed for grid integration [5]. Most of the countries have wind energy conversion system is a very popular non-conventional power generation technology [6]. In the wind, the energy generation system previously used generators are an induction generator and a synchronous generator. Now the evolution of technology associated with wind system trade led to the development of generation of variable speed turbine that presents several benefits compares to mounted speed wind turbines. DFIG is a very good alternative for variable and unpredictable wind speed [10].

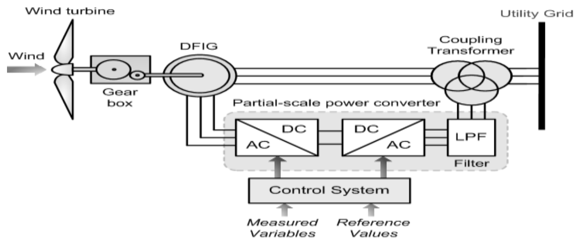

Fig.1. DFIG-based WECS scheme [2].

The doubly-fed induction generator base wing generation system is shown in fig. 1[7-8]. DFIG consisting an induction generator (wound rotor type) and a conversion system means from AC to DC or from DC to AC and PWM voltage source converter with IGBT switching. Stator winding connected directly to the grid with a constant frequency of 50 Hz. The wind turbine is a device that converts kinetic energy from wind to mechanical energy. Whenever mechanical energy is used to produce electrical energy, the device may be called a wind generator. When mechanical energy is used to drive machines, such as for grinding grain or raising water, the device is named as windmill. Due to increasing development, today's wind turbines are constructed in a range of vertical as well as horizontal axis types [4]. The smallest turbines are used for applications, for example, charging of battery otherwise auxiliary power on seafaring boats; while large grid-connected arrays of turbines are becoming gradually larger sources of profitable electric power. The basic principle of wind turbines is the conversion of aerodynamic power into electrical energy.

II. MODELING OF DFIG

It is given below [9],

$$V_{sd} = R_s i_{sd} + \frac{d\Psi_{sd}}{dt} - \omega_d \Psi_{sq} \quad (1)$$

$$V_{sq} = R_s i_{sq} + \frac{d\Psi_{sq}}{dt} + \omega_s \Psi_{sd} \quad (2)$$

$$V_{rd} = R_r i_{rd} + \frac{d\Psi_{rd}}{dt} - (\omega_s - \omega)\Psi_{rq} \quad (3)$$

$$V_{rq} = R_r i_{rq} + \frac{d\Psi_{rq}}{dt} - (\omega_s - \omega)\Psi_{rd} \quad (4)$$

Where,

$$\Psi_{sd} = L_s i_{sd} + L_m i_{rd} \quad (5)$$

$$\Psi_{sq} = L_s i_{sq} + L_m i_{rq} \quad (6)$$

$$\Psi_{rd} = L_r i_{rd} + L_m i_{sd} \quad (7)$$

$$\Psi_{rd} = L_r i_{rd} + L_m i_{sd} \quad (8)$$

$$\Psi_{rq} = L_r i_{rq} + L_m i_{sq} \quad (9)$$

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These are the voltage as well as flux equations in terms of resistance, inductance currents. ω_s represents the angular velocity at synchronous speed. Rotor angular velocity is given as (9). The torque is given as follows,

$$T_m = n(\Psi_{sq} i_{rd} - \Psi_{sd} i_{rq}) \quad (10)$$

Where n is the number of poles.

The active power is given as

$$P_s = V_{sd} i_{sd} + V_{sq} i_{sq} \quad (11)$$

The reactive power is given as

$$P_s = V_{sq} i_{sq} - V_{sd} i_{sd} \quad (12)$$

Using the equation (5) & (6), we get stator currents for d-q axis, as follows

$$i_{sd} = -\frac{L_m}{L_s} i_{rd} + \frac{V_{sq}}{L_s \omega_s} \quad (13)$$

$$i_{sq} = -\frac{L_m}{L_s} i_{rq} \quad (14)$$

So power of d-q axis in terms of stator current is given as

$$P_s = -\frac{L_m}{L_s} i_{rq} V_{sq} \quad (15)$$

$$Q_s = -\frac{L_m}{L_s} i_{rd} V_{sq} + \frac{V_{sq}^2}{L_s \omega_s} \quad (16)$$

Now by using equations (7) & (8), we can obtain the value of flux, as given below

$$\Psi_{rd} = L_r.\sigma.i_{rd} + L_m \frac{V_{sq}}{L_s \omega_s} \quad (17)$$

$$\Psi_{rq} = L_r.\sigma.i_{rq} \quad (18)$$

Now substituting the value of equation (17) & (18) on equation (3) & (4) we get

$$V_{rd} = R_r i_{rd} + L_r.\sigma \frac{di_{rd}}{dt} - \omega_r.L_r.\sigma.i_{rq} \quad (19)$$

$$V_{rq} = R_r i_{rq} + L_r.\sigma \frac{di_{rq}}{dt} + \omega_r.L_r.\sigma.i_{rd} + \omega_r L_m \frac{V_{sq}}{L_s \omega_s} \quad (20)$$

$$\sigma = 1 - \frac{L_m^2}{L_s L_r} \quad (21)$$

By using the equations (15), (16), (19) and (20),

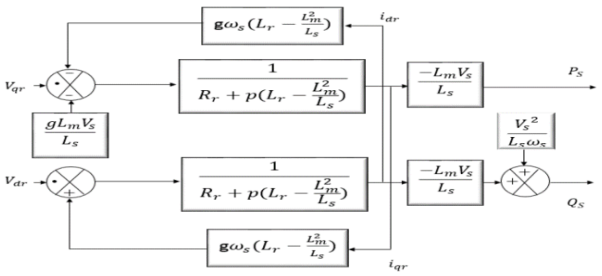

Fig. 2 Simplified model of DFIG

III. DESCRIPTION OF CONTROL SYSTEM

Various techniques are out there up to speed systems to style PI controller. Among these techniques, Static Output Feedback is that the one that may be applied to the controller to form the system globally stable. Fig.3. shows that the input to the PI controller is that the error between the point y_o price and also the measured price y from the plant [11].

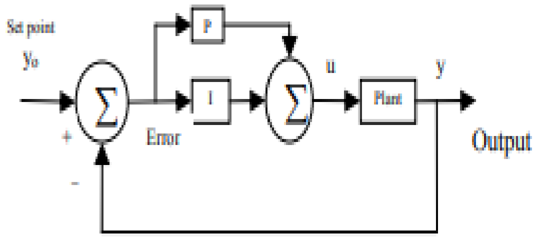

Fig. 3 PI controller with closed-loop system

Output of the controller is given as

$$u = K_p Y_o + K_I \int Y_0 dt \quad (22)$$

Where K_p is the proportional constant and K_I is Integral constant. Also, equation (22) can be written as

$$u = [K_p \ \ K_I][Y_0 \int Y_0] \quad (23)$$

Output is given as

$$Y = [Y_0 \int Y_0] \quad (24)$$

PI controller is described as

$$G_C = [K_P \quad K_I] \quad (25)$$

Table 1: The PI parameters

Parameters	K_P	K_I
Gains	0.724	4.675

The DFIG control system connected to the grid through the AC/DC/AC converter, which can be termed as the rotor side converter (RSC) and the grid side converter (GSC). It is an electrical way to decouple 2 frequencies. In acceleration mode, it works as a converter and inverter. The control system of RSC is shown in Fig. 4. Its objective is to independently regulate the stator active and reactive power, P_s and Q_s, respectively. In order to achieve decoupled control of Ps and Q_s, the rotor current is transformed to d-q axis components, i_{dr} and i_{qr} using a reference frame oriented to the stator-flux. The q-axis current component i_{qr} is used to control the stator active power. The measured value of P_s is subtracted from P_{ref} and the error is driven to PI controller. The output of this controller is the reference value of the q-axis rotor current, $i_{qr\,ref}$. This signal is compared to the actual value of i_q and the error is passed through the current controller whose output is the reference voltage for the q-axis component V_{qr}. The actual voltage at the generator terminals V_s is compared to its reference value V_{ref} and the error is passed through the PI controller to generate the reference signal for the d–axis current $i_{dr\,ref}$. This signal is compared to the d-axis current value and the error is sent to the current controller which determines the reference voltage for the d-axis component V_{dr} . The signals V_{dr} and V_{qr} are transformed back to a-b-c quantities which are used to generate the IGBT gate

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control signals to drive the RSC(3 Phase Inverter). The objective of the GSC control system is mainly to keep the dc-link voltage constant. The actual value i_{dgc} is compared with $i_{dgc\ ref}$=0 and the error signal is given to PI controller. The actual value of grid voltage V_{dc} is compared with the Vdc_{ref}. and the error signal is given to the voltage controller to generate reference value for d-axis component id ref. The actual value of id is compared with id ref. which determines the reference voltage for V_{dgc}. The signal V_{dgc} and V_{qgc} are transformed back to a-b-c quantities which are used to generate the IGBT gate control signal to drive the GSC(Front end converter).

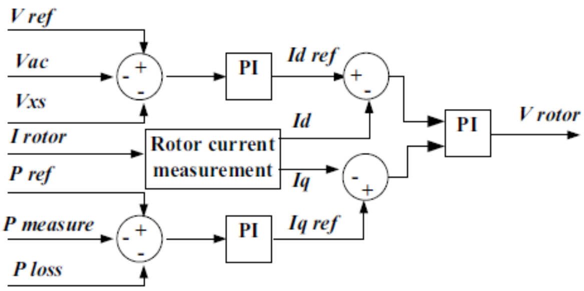

Fig. 4 RSC control system

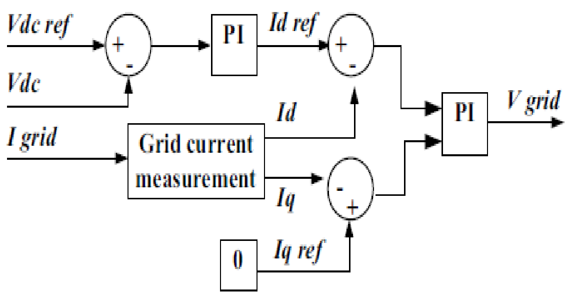

Fig. 5 GSC Control system

IV. SIMULATION AND RESULTS OF DFIG

The simulation model of DFIG with PI controller using SOF technique shows that at the starting of power generation it provides fluctuating power output due to variable wind speed which may cause damage to pieces of equipment. With the use of PI controller with DFIG the error signal is minimized and it settles down to constant value after some time providing constant value at the output.

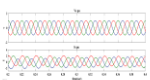

Fig. 6 Stator voltage and current characteristics before setting time

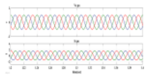

Fig. 7 Stator voltage and current characteristics after setting time

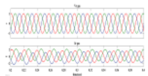

Fig. 8 Rotor voltage and current characteristics before setting time

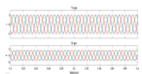

Fig. 9 Rotor voltage and current characteristics before setting time

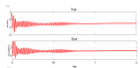

Fig. 8 Stator active and reactive power characteristics

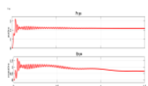

Fig. 9 Rotor active and reactive power characteristics

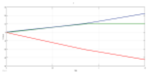

Fig. 10 Torque Characteristics

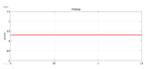

Fig. 11 Wind speed characteristics

V. CONCLUSION

In this work, we consider the doubly-fed induction generator for the constant operation of the wind power plant. As we know that obtaining the stable response of wind power plants is a very difficult task. DFIG help us to obtain stable operation but most of the cases required some controlling action for generating constant output power. Here consider the PI controller for the support of the DFIG constant and stable operation. A result of the Simulink model of wind generator with a PI controller shows the constant operation of the plant. Hence, it's finished that the PI controller with static feedback fed doubly-fed induction generator provides stable operation and gives constant output power.

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