STABILITY ANALYSIS OF DFIG WIND POWER SYSTEM USING PI CONTROLLER WITH STATIC FEEDBACK

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Abstract: *When wind electricity is associated with an electric grid affects power quality. The consequences of the power quality like active & reactive power, change in voltage, flicker, harmonics, and electric behaviour of switching operations has to measure. The doubly-fed induction generator (DFIG) is used in most wind energy conversion systems (WECS) due to its advantage of ensuring a variable speed and running above the synchronous speed. This characteristic avoids damage to the wind turbine mechanism, especially when the measured wind speed is above the rated speed. In this paper, we present the enhancement behaviour of a DFIG by the PI regulator.*

Keywords: *Power quality, wind generator, double fed induction generator, PI controller*

1. INTRODUCTION

With the thriving need for electrical energy and the need to preserve nature due to the reduction in fossil fuels and increased pollution of problems, many research teams are interested in sustainable development by using renewable energy sources becoming essential for electrical power generation systems. By comparing all renewable energy sources, one of the most economical renewable sources is the wind energy system [1]. These days for wind power generation, the DFIG is an attractive choice because of their various advantages [2], such as variable speed, constant frequency, active/reactive power controllability [3] and reduced mechanical stresses [4]. DFIG is becoming more and more common for power generation as it is suitable for implementing advanced features required for grid integration [5]. Most countries have wind energy conversion systems, a very popular non-conventional power generation technology [6]. In the wind energy generation system, previously used generators are induction and synchronous generators. The evolution of technology related to the wind system industry led to the development of variable speed wind turbine generators that presents many advantages compared to fixed speed wind turbines. DFIG is an excellent alternative for variable and unpredictable wind speeds [10]. The DFIG-based wind energy conversion system is the most accepted due to its flexible power control, small converter size and simple structure.

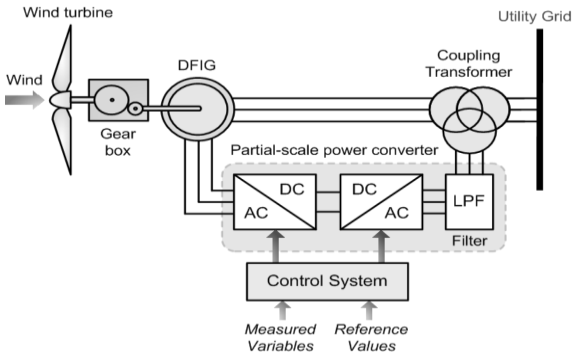

Figure:1 shows the schematic diagram of a doubly fed induction generator based on WECS [7-8].

DFIG consisting a wound rotor induction generator and AC/DC/AC IGBT-based PWM voltage source converter. Stator winding is connected directly to the grid at 50 Hz.

2. MATHEMATICAL MODELLING OF DFIG

The DFIG model in the synchronous (d–q) [12] reference frame can be described as follows

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

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

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

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

Where,

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

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

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

$$\Psi_{rq} = L_r i_{rq} + L_m i_{sq} \quad (8)$$

These are the voltage and flux equations of stator and rotor in terms of inductance, resistance and currents. The ω_s represent the angular velocity at synchronous speed. Rotor angular velocity is given as in equation 9.

$$\omega_r = \omega_s - \omega \quad (9)$$

The torque is given as follows,

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

Where n is the number of poles.

The active power is given as

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

The reactive power is given as

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

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

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

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

So active and reactive power in terms of stator current is given as

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

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

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

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

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

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

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

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

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

By using the equations (15), (16), (19) and (20), obtain the simplified model of the DFIG as shown in Fig. 2.

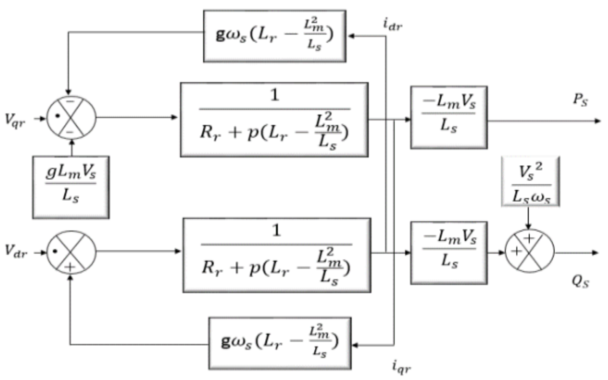

Fig.2. DFIG model

3. PI CONTROLLER DESIGN

Various techniques are available in control systems to design PI controllers. Among these techniques, Static Output Feedback is the one that can be applied to the controller to make the system globally stable. Fig.3. shows that the input to the PI controller is the error between the set point y_o value and the measured value y from the plant[11].

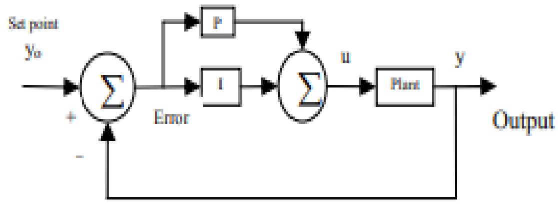

Fig. 3 PI controller with a close loop system

The controller's output (u) can be written as

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

Where Kp and K_I are the proportional and Integral constant, respectively. Also, equation (22) can be written as

$$u = [K_p \;\; K_I][Y_0 \int Y_0]^T \qquad (23)$$

Output is given as

$$Y = [Y_0 \;\; \int Y_0]^T \qquad (24)$$

PI controller is described as

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

Table 1: The PI parameters

Parameters	K_P	K_I
Gains	0.724	4.675

1. Simulation & Results

A simulation model of the wind turbine is shown in fig. 4. The front-end converter and mechanical system are shown in fig.5 and 6, respectively.

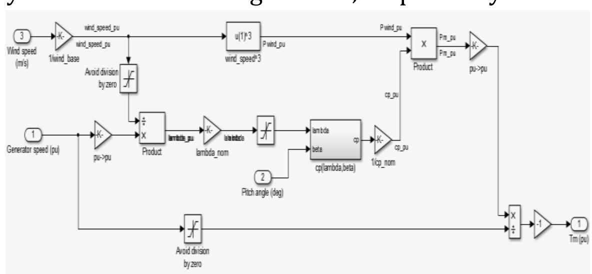

Fig.4 Wind turbine

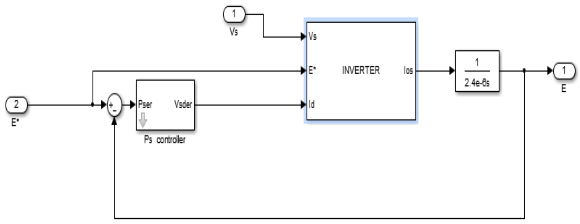

Fig.5. Front End converter

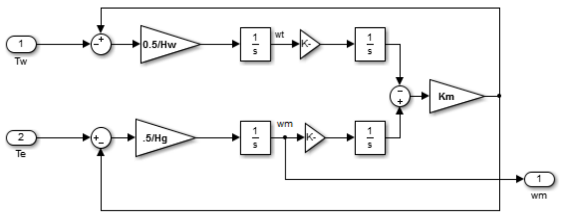

Fig. 6 Mechanical system

DFIG model with stator and rotor parameters is shown in figure 7. The complete simulation model of DFIG with active and reactive power controlled by the PI controller is shown in figure 8.

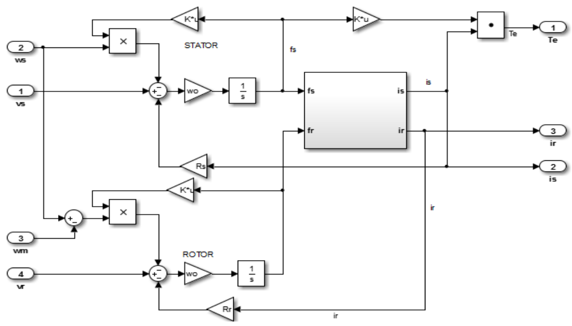

Fig. 7 DFIG Simulink model

The results of DFIG for the parameters of PI are shown in table 1 shown in fig. 9

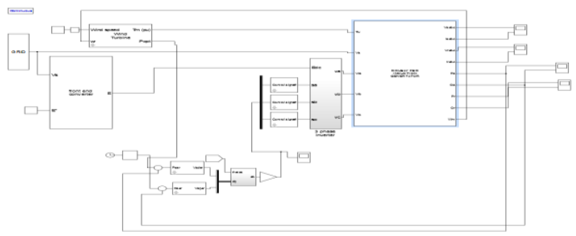

Fig. 8 DFIG with PI controller

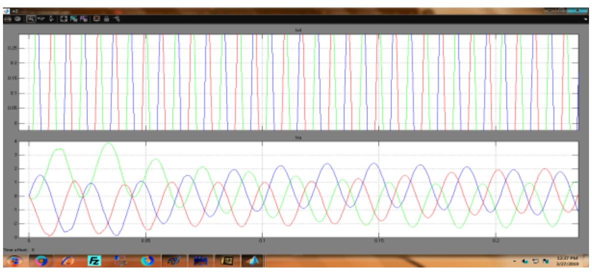

Fig. 9 Stator current for the d-q axis

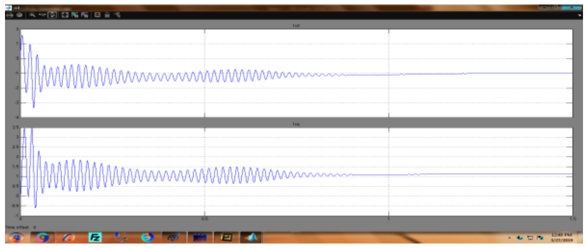

Fig.10 active and reactive power

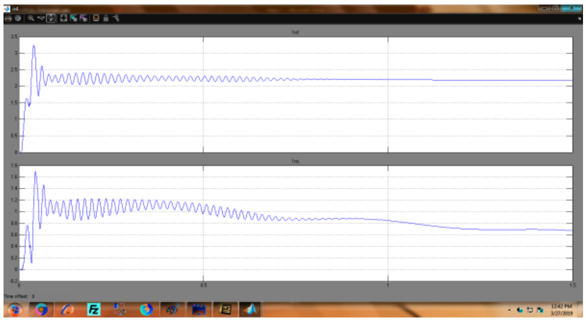

Fig. 11 Rotor currents for the d-q axis

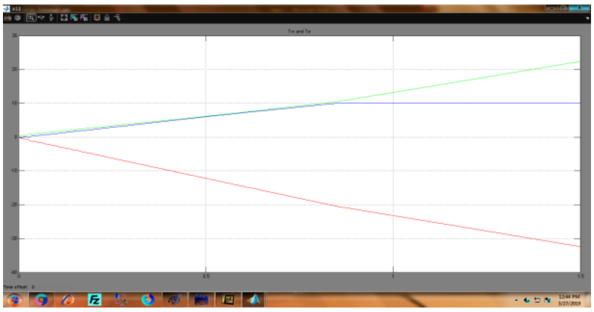

Fig.12. Torque characteristic

5. CONCLUSIONS

The supervisory PID controller used in many works improves the system response compared to the open-loop system; however, the number of oscillations is not removed entirely. The proposed PI-controller designed using the Static output feedback technique not only amends the system response but also reduces the percentage overshoot to zero. At the same time, the PI controller utilizing the Static output feedback technique depicts that the system settles down in a shorter time than when we use a supervisory PID controller. Hence, it is concluded that the static output feedback control technique provides another option for the design of the controller to be implemented in the Doubly Fed Induction Generator.

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