Journal of Electrical Power System Engineering & Technology
Volume 7, Issue 1, January-April, 2022

Using the Grid to Produce Wind Power

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Abstract

Power has become increasingly important for everyone as a result of the rise of industries and an ever-increasing global population, and as a result, energy consumption has increased dramatically in recent decades. The unease with which we used traditional resources alerted us and drove us to utilise alternative resources. In terms of electricity output, wind is outperforming other non-conventional energy sources. Despite the fact that wind energy is still a relatively new source of electricity, it has benefited enormously from ongoing technological advances in grid integration, electrical machines, power converters, and control capability. The main focus in the modelling of DFIG-based wind power generating schemes is DFIG modelling. The input power to the propeller is expected to be variable when modelling a wind turbine rotor. The DFIG created model in this section is simply a basic and realistic reduced model that is utilised to do minor signal analysis. The output of the Wind Turbine is almost similar to the output power of the DFIG when the regulator is used, resulting in improved and satisfying small signal stability of the power system.

***Keywords:** Simulation, DFIG modelling, Power control technique, Small signal stability*

INTRODUCTION

Continuous consumption of fossil fuel resources exacerbates environmental issues such as greenhouse gas emissions and global warming. Due to these issues, we must rely on renewable energy sources to generate electricity. One of the most common systems is the doubly-fed induction generator (DFIG), in which the power interface modulates the rotor currents to obtain the variable speed required for maximum energy capture in different winds. Because the power electronics only process the rotor power, which is typically less than 25% of the overall output power, the DFIG provides the benefits of speed control with lower costs and power losses. When a wind energy farm is added to the existing main conventional power grid, the additional single wind generators connected in parallel are simulated as an equivalent aggregate model to study the effects on the steady state small signal stability of the current main power system (PS). The rotor-side converter (RSC), the grid-side converter (GSC), the dc linkage capacitor, and the regulating circuitry for the converters are all part of the frequency converting scheme model, which is used to convert the power frequency to the rotor frequency. The grid-side converter should be flawless, and the voltage of the dc link between the converters should be constant. GSC and RSC can be addressed separately or simply described as decoupled when the above assumptions are taken into account.

SYSTEM ARCHITECTURE

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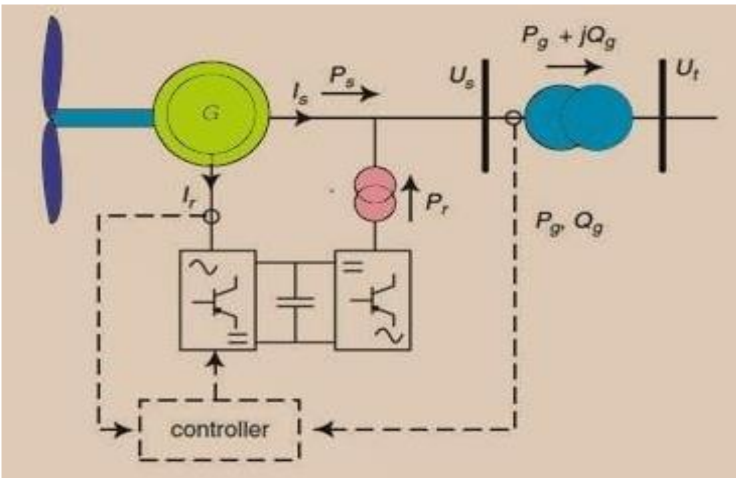
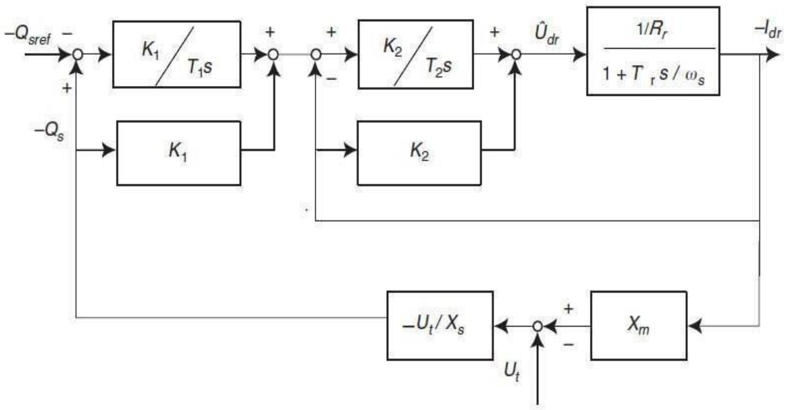


Fig. 1: Configuration of DFIG.

MANTECH Publications
Journal of Electrical Power System Engineering & Technology
Volume 7, Issue 1, January-April, 2022

The rotor-side converter (RSC) can be described as a voltage-controlled current source based on the aforementioned assumption (VCCS). A system known as stator flux oriented control scheme is used for decoupled control of the DFIG's actual and reactive power outputs. The overall controlling system is made up of two cascaded control loops: the inner vector control loop and the outer power control loop. RSC is depicted in a block diagram with its inner and outer control loops, which are represented by the d- and q-reference axes, respectively. The true power is controlled by the outside control loop. While the terminal voltage Ut is kept constant during the tiny signal analysis, the true and reactive powers may be desperately regulated by modifying the rotor currents.



$$\frac{T_r}{\omega_s}\frac{dI_{dr}}{dt} = -I_{dr} - \frac{\hat{U}_{dr}}{R_r}$$

$$Q_s = -\frac{\psi_s}{X_s}(\psi_s + X_m I_{dr})$$

$$I_1 \frac{\text{[illegible]}}{dt} - K_1 I_1 \left(\frac{\text{[illegible]}}{dt} - \frac{\text{[illegible]}}{dt} \right) = K_1 (Q_s - Q_{sref})$$

$$T_2 \frac{d\hat{U}_{dr}}{dt} + K_2 T_2 \left(\frac{dI_{dr}}{dt} - \frac{dI_{dref}}{dt} \right) = K (I_{dr} - I_{dref})$$

Fig. 2: Rotor-Side Converter (RSC) Reactive Power Control Scheme with Equations

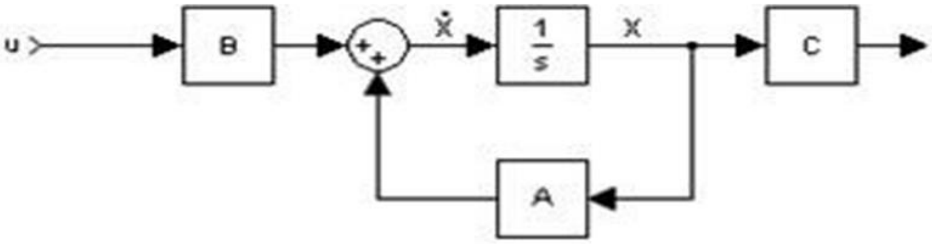


Fig. 3: LQR Controller Design.

BLOCK DIAGRAM REPRESENTATION OF STATE SPACE EQUATION

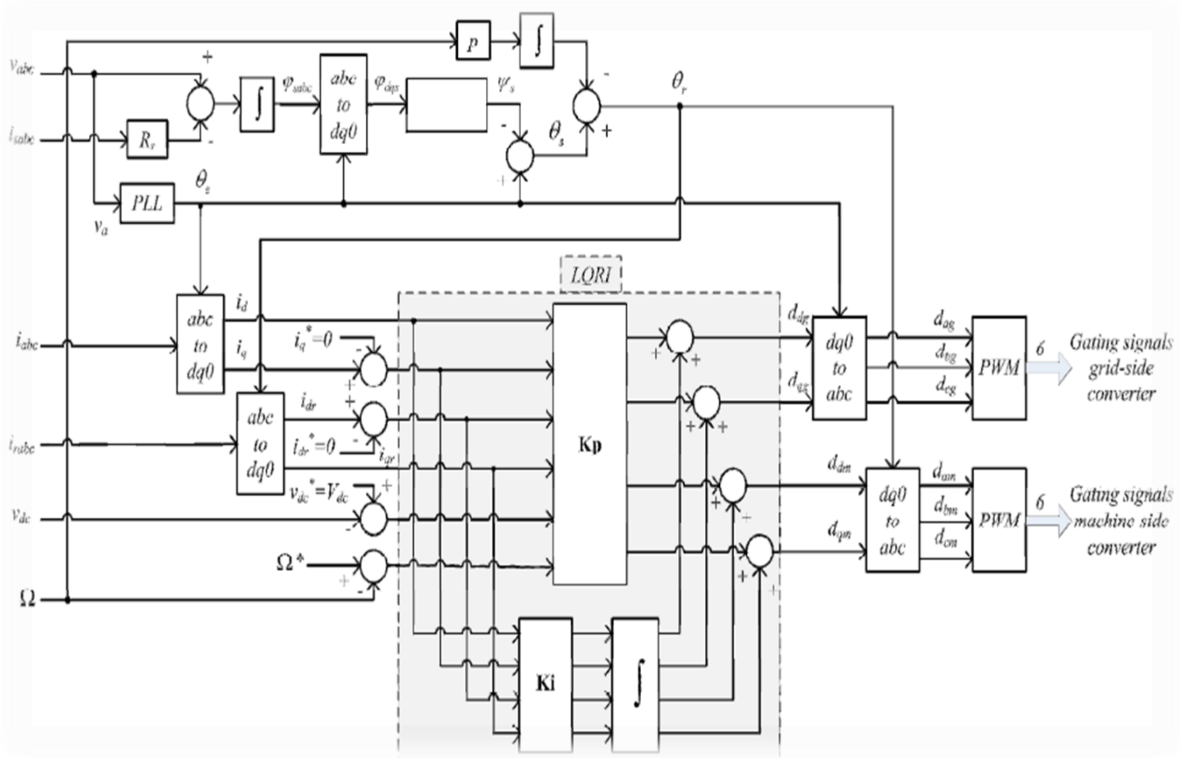


Fig. 4: Block Diagram of LQRI Controller.

The goal of optimal control is to operate any dynamic system at the lowest possible cost. The dynamics of the system are defined by a collection of LDE, and the cost by a quadratic function in the LQR problem. The feedback controller used by LQR is described in the equations below. The parameters of LQR-designed controllers are optimised by minimising a cost function using a mathematical technique.

Any control system should be able to deliver the appropriate system performance while using the least amount of control energy possible. To acquire the optimal control system response, we must consider the transient energy as the total energy in order to meet the transient response. Any control system is considered successful if its transient energy decays to zero in the shortest possible period. To improve the system's transient response, the transient energy of the system must be included in the goal function.

Control energy should be included in the objective function to reduce the cost of the control system. A multivariable proportional regulator has been built using LQR. Integral control action is introduced to the system, and four new states are added to the DFIG wind turbine model, in order to negate steady state mistakes. The integral of id, iq, idr, and for the integral control action are these four new states. This results in the LQRI controller controller action.

MATLAB SIMULATION

We must keep the output power on bus 3 at the rated level. Because the DFIG and the generator G3 are linked in parallel, the cumulative power generated by both should be equal to the rated power of the bus 3. For example, if G3 generates half of the rated power of bus 3, the DFIG must generate the remaining power. There will be issues with the system's tiny signal stability if DFIG is unable to generate electricity on its own capacity. Furthermore, because the incoming wind power is intermittent, the output of the DFIG will vary at different times.

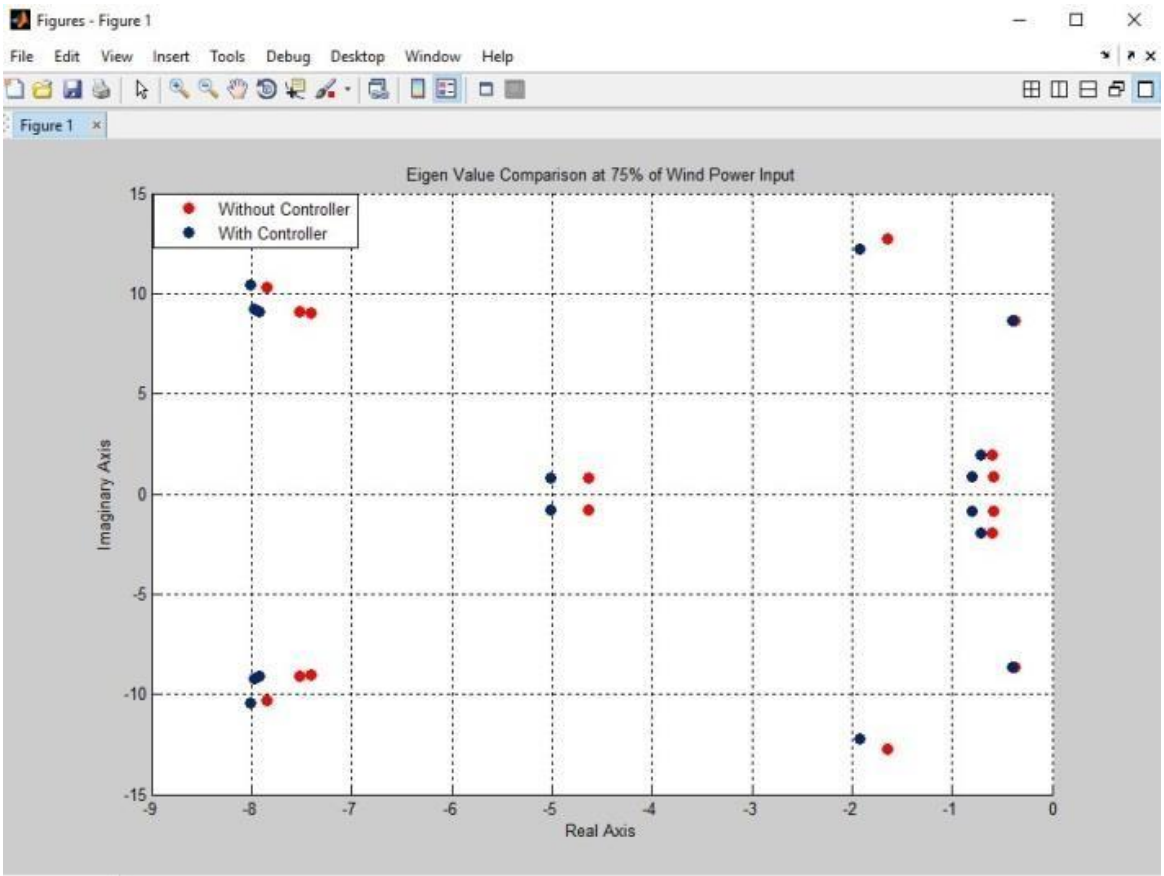


Fig. 5: Eigen Value Comparison at 75%of Wind Input Power.

RESULTS

Following the study, it is clear that when the output power of the wind farm increases, the Eigen values of the linearized power system model move away from the imaginary axis, as do the damping ratios of the system, implying that the power system's small-signal stability increases. It can be seen that when the wind farm output is at rated power output, the system is the most stable. As the difference between the output power and the rated power grows, the system's stability decreases.

The converter's firing angle is controlled by the specified controller. The flow of power from the DFIG is thus controlled by changing the firing angle, which indirectly regulates the power system's stability. The use of a LQRI controller compensates for changes in wind power input, improving the system's stability.

CONCLUSION

The significant effects of the DFIG regulators can be seen as affecting the system's stability. The parameters of the DFIG controllers are optimised using the Linear Quadratic Regulator Integral controller algorithm in this dissertation, resulting in the greatest achievable value. The major purpose of the MATLAB/Simulink programmes and simulations is to validate the improvement in the stability of the DFIG regulators while also ensuring that these regulators have the best available parameter values.

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