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Active and Reactive Power Management for Wind Turbine by using A Fuzzy Logic Controller and Vector Controlled Technique in the Doubly-Fed Induction Generator (DFIG)

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***Abstract*: Active and reactive power control is proposed for Doubly-fed induction generator (DFIG) that uses the constant output voltage is must and to optimize the power flow in the wind turbine and stability. This paper has focussed on several issues related to the stability, active and reactive power control and rotor side and grid side operational control of power flow.**

This model design to show DFIG utility and control power utility. Here are the designed rotor and converter side. The rotor side converter is modelled as a controlled voltage source and grid side converter is neglected as the machine is basically controlled by the rotor side converter and most of the active and reactive power is supplied by the machine. The vector control technique is introduced for controlling the doubly-fed induction generator. Here model manages the active and reactive power of the system. The power flow in the turbine has been studied with varying wind speed. An improved hysteresis control strategy has been proposed to minimize the activated time of the crowbar. Moreover, This control strategy of the reactive power has been implemented to cut down the oscillations of the transient current during the voltage and after the clearance of the fault in the machine.

We had introduced the fuzzy controller in the doubly-fed induction generator using a software Matlab-Simulink where at the rotor side converter for reactive control with voltage regulation and active power of wind turbine. The available mechanical power from a wind turbine is a function of its shafts speed. The objective was to follow the optimal torque for given maximum power the rotor side converter (RSC) is controlled and the simulation results clearly shows the outstanding performance of the fuzzy control unit as improving power quality and stability of the wind turbine.

Key words – Doubly fed induction generator (DFIG), Fuzzy logic controller, Active and Reactive power control, Vector control technique.

I. INTRODUCTION

Among the renewable energy sources, wind energy wind turbine is one of the fastest growing and the most important promising source because it is non-polluting, cost-effective and safe when compared to other sources such as fossil fuels and nuclear power. The advantage of using DFIG in wind turbines is the four-quadrant control of real and reactive power flow, variable speed operation, low converter cost and reduced power loss compared to other methods.

A fuzzy logic controller is designed for in the control unit of the vector control induction generator. To control the motor flux in order to provide the direct axis current and speed control loop is managed by the introduced fuzzy logic controller. The proposed vector control technique is deliberate to control the rotor/stator side voltage and current that allows the active and reactive power to be controlled along with the rotor speed.

This paper describes a variable – speed wind generation system, where fuzzy logic based intelligent control has been used to enhance the performance of a DFIG wind turbine. The conventional DFIG system uses the PI controller. As compared to other research papers is paper the PI controller is replaced with fuzzy logic control technique used for triggering the back-to-back connected IGBT decoupled circuits. The stator and rotor side controllers are developed separately to regulate the voltage of the DC bus capacitor and also used partly to control the flow of reactive and active power from the turbine system to the grid. Here this paper is fully focussed on achieving the active and reactive power control.

An overall control scheme can be implemented in the MATLAB Simulink platform. The controllers of DFIG perform the operation of the rotor side and the grid side back-to-back converters. The rotor side controller will control the real and reactive power flow, track the optimum power point and limit the power during high wind speed. The grid side controller keeps a constant DC voltage to the system and injects reactive power to the

The fuzzy logic controller used for controlling the real and reactive power flow can be improved while using a cross-coupled controller to adjust the speed and power of the system and also the voltage stability problem in power network and wind turbines provide a very fast dynamic VAR injection by reducing controller system losses to ensure the stability in output active and reactive power.

II. VECTOR CONTROL TECHNIQUE IN THE PROPOSED MODEL

vector controller was proposed to improve the system performance under unbalanced grid condition. These techniques improve the dynamic behaviour of the DFIG

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(induction generator) and to reduce the noise at low wind speeds.

In this method the stator current are identified as two mutually rectangular vector components. The vectors are torque and magnetic flux of the induction motor. In a Doubly-fed induction generator connected to power grid, closed loop vector control of active and reactive produce the reference flux and torque currents. The flux and the voltage equation for DFIG dynamic model is:

$$\frac{d}{dt}\lambda_{ds} = V_{ds} - r_s I_{ds} + \omega_s \lambda_{qs}$$

$$\frac{d}{dt}\lambda_{qs} = V_{qs} - r_s I_{qs} - \omega_s \lambda_{ds}$$

$$\frac{d}{dt}\lambda_{dr} = V_{dr} - r_s I_s + (\omega_s - p\omega_r)\lambda_{qr}$$

$$\frac{d}{dt}\lambda_{qr} = V_{qr} - r_s I_s - (\omega_s - p\omega_r)\lambda_{dr}$$

$$\lambda_{ds} = I_s I_{ds} + I_m I_{dr}$$

$$\lambda_{dr} = I_r I_{dr} + I_m I_{ds}$$

$$\lambda_{qs} = I_s I_{qs} + I_m I_{qr}$$

$$\lambda_{qr} = I_r I_{qr} + I_m I_{qs}$$

Here, I_s and I_r are stator and rotor inductance while I_m represents the mutual inductance ω_s.

V_s – is a stator voltage, I_s – is a stator current, λ_s – is a stator flux.

V_r – is a rotor voltage, I_r – is a rotor current, λ_r – is a rotor flux.

The controller has been implemented for the DFIG model, where the Rotor side control (RSC) and Grid side control (GSC) are required only for voltage orientation due to simpler control design for DFIG. The RSC improves the performance of the DFIG and the real power of the induction generator is controlled with the rotor voltage to improve the overall efficiency of the generator. Due to the introduction of control technique and controller enhance the performance of a wind turbine system with stability. The feedback linearization technique is used to control the real power of the DFIG along with the stator voltage and current control.

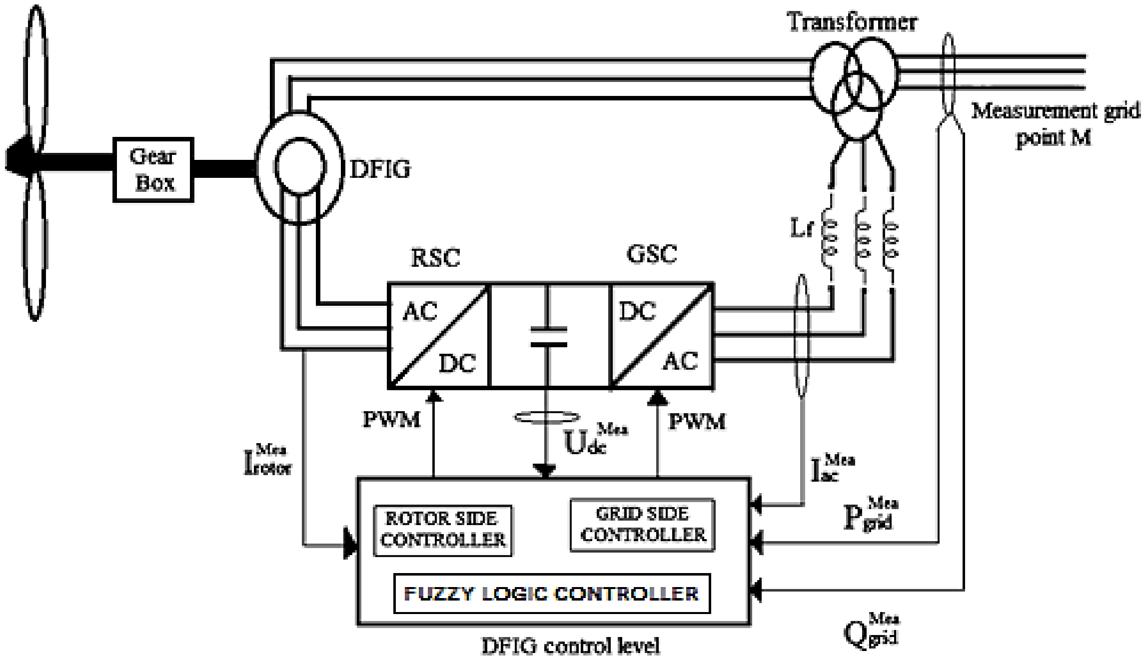

Figure 1. Vector control of DFIG

Figure 1 shows the overall vector control scheme of the Rotor side converter (RSC), in which the independent control of the rotor active power (Ps) and reactive power (Qs) is gained with support of rotor current regulation. The control of the rotor side converter consists of adaptability of the stator active power (Ps) and reactive power (Qs) independently. In this paper, we assume that both the frequency and voltage of the grid are constant.

Fuzzy logic current controllers are used to generate the base signals of the direct and quadratic axis current components. The controls of the DFIG are based on the feedback technique by using the suitable vector control on the rotor side as well as in the grid side. The current harmonics at the grid side are controlled using an appropriate fuzzy controller.

III. FUZZY LOGIC CONTROL IN FEEDBACK SYSTEM OF DFIG

The common control technique for active and reactive power decoupled by using the PI control to improve the dynamic behaviour of the DFIG. But during the operation, many factors such as unpredictable wind speed, wind turbine, temperature etc are the main problem in the PI control method. Fuzzy logic controller outputs are more reliable because the effect of the aspects like noise, change in control parameter. Without knowing about the mathematical modelling just by the knowledge of the total operation and behaviour of the wind turbine system can be done more easily. The fuzzy logic controller works on the set of the fuzzy rules which can be

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designed for controlling the system and make the system to work in a more stabilized manner. For the development of the rule the selection of input and output variable is must and their quantization in fuzzy sets. Also, the membership function should be defined associated with the input variables for desired output responses.
In the model, the fuzzification interface alters input data into suitable linguistic values,

• A Knowledge Base which comprises of a database along with the essential linguistic definitions and control rule set.
• The fuzzy logic control have the information form the set control rules and the linguistic variable descriptions for decision making in wind turbine system.
• Along with fuzzy control the Defuzzification interface is connected which provides the non-fuzzy control action from an conditional fuzzy control action

IV. METHODOLOGY

The asynchronous machine DFIG is chosen in a discreate solver model with the trapezoidal non-iterative mode in MATLAB with an initial pitch angle of $\theta = 0^o$, mechanical power (load flow) = 1.49 x 10^6. The control scheme of the rotor-side converter is planned in a generic way with two series of two PI controllers. The electromagnetic torque, rotor speed and rotor angle are controlled by a feedback system by using a fuzzy logic controller, the fuzzy logic controller only be compatible with the discreate mode in DFIG.
The reference q-axis rotor current i_r from an outer speed control loop or from a reference torque imposed on the machine. The flow of real and reactive power is controlled by the grid-side converter, through the grid interfacing inductance.

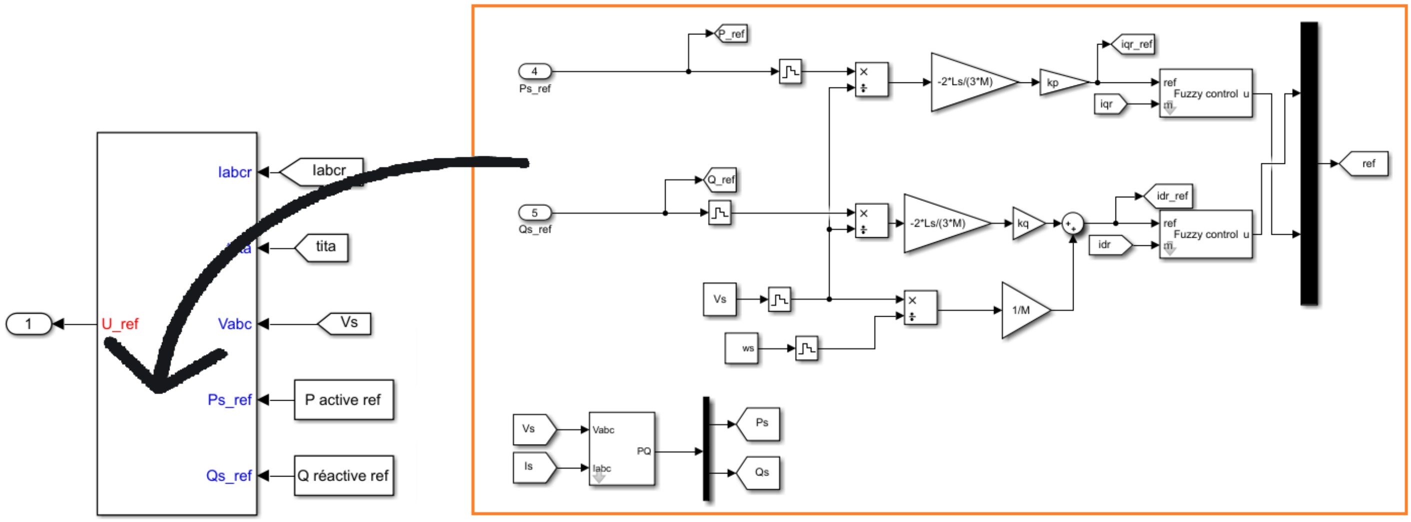

Figure 2: RSC control structure using fuzzy control approach for active and reactive power control.

The objective of the grid- side converter (GSC) is to keep the dc-link voltage constant irrespective of the magnitude and direction of the rotor power. The used vector control method, enabling independent control of the reactive and active power transmission between the grid and the converter.
Here the stator active power be:

Ps = $\frac{3}{2}\,(V_{sx}\,.\,i_{sx} + V_{sy}\,.\,i_{sy})$

and the reactive power be:

Qs = $\frac{3}{2}\,(V_{sy}\,.\,i_{sx} + V_{sx}\,.\,i_{sx})$

Vsy – Stator Voltage ; y means Vertical axis and
x means Horizontal axis.
Stator Active and reactive power:
The stator power and quality factor be

Ps = $-\frac{3}{2}\,|V_{sx}|\,\left(\frac{L_m}{L_s}\right)\,i_{ry}$

Qs = $-\frac{3}{3}\,|V_s|\,\left(\frac{L_m}{L_s}\right)\,(i_{ms} - i_{rx})$

Grid connected converter, this simplifies the power equations

P = $\frac{3}{2}\,(V_{ds}\,.\,i_{ds})$

Q = $\frac{3}{2}\,(V_{ds}\,.\,i_{ds})$

The PWM generator used to regulate the dc-link voltage and current component to regulate the reactive power.

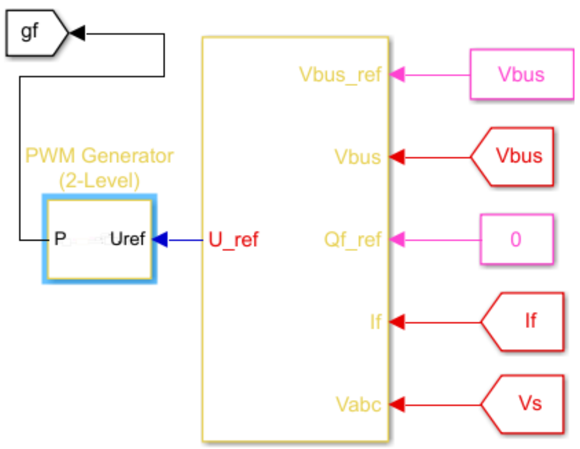

Figure 3: Simulink model of PWM generator connected with scope.

Figure 3 shows the proposed RSC control structure, using the fuzzy logic control approach. Here the speed reference is generated based on the reactive power reference based on a

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wind plant reactive power demand as well as the co-ordination of the reactive power control with the GSC. The reactive power reference is transferred to rotor d-axis current reference i_{rd}^{*} through a reactive-power controller. The torque reference generated by the speed controller is transferred to rotor q-axis. Both the GSC and RSC can contribute to reactive power control. For co-coordinating the reactive power control mechanism under fuzzy logic control approach, the following strategies are adopted.

(i) The GSC contributed a part of the reactive power control demand and the rest will deal with RSC.

(ii) The control objective of the GSC is to maintain a constant reactive power production while the RSC assures that the overall reactive power production of the wind turbine meets the grid reactive power demand.

(iii) If the GSC reaches its physical constraints due to high power transferred from DFIG rotor to the grid, the converter is operated by maintaining the DC –link voltage constant as the first priority and next is reactive power control demand.

The GSC may absorb reactive power so that the RSC must generate the reactive power to meet the demand of both the GSC and wind plant reactive power. This method cannot be applied to the conventional GSC control mechanism.

V. RESULTS

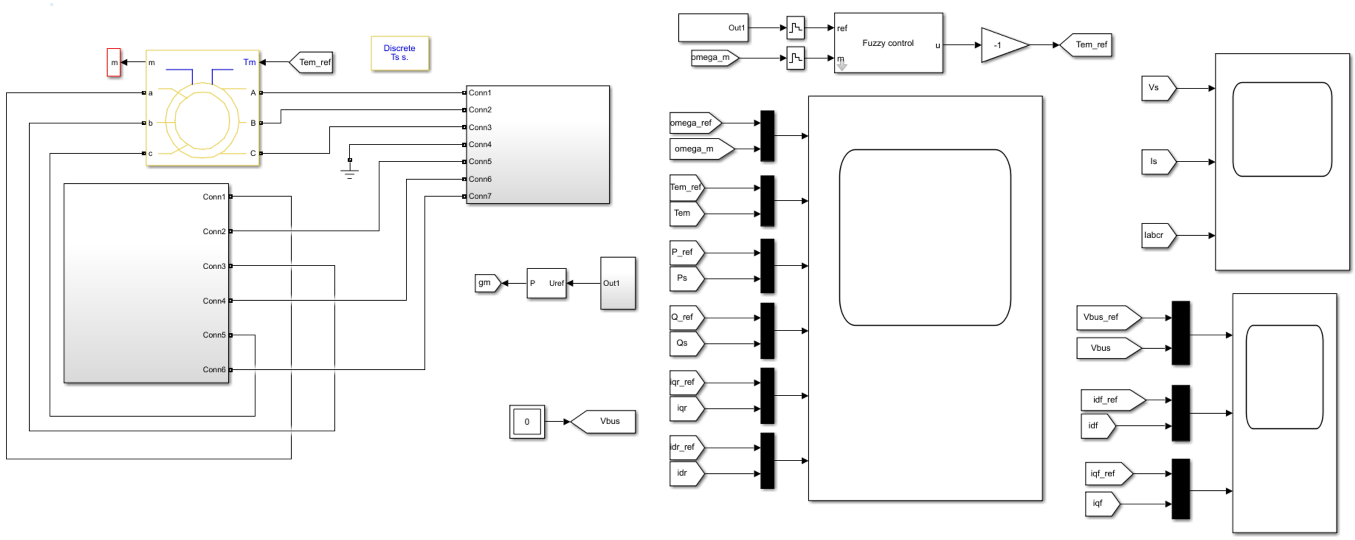

Figure 4: Detailed Proposed MATLAB Model

Output responses:

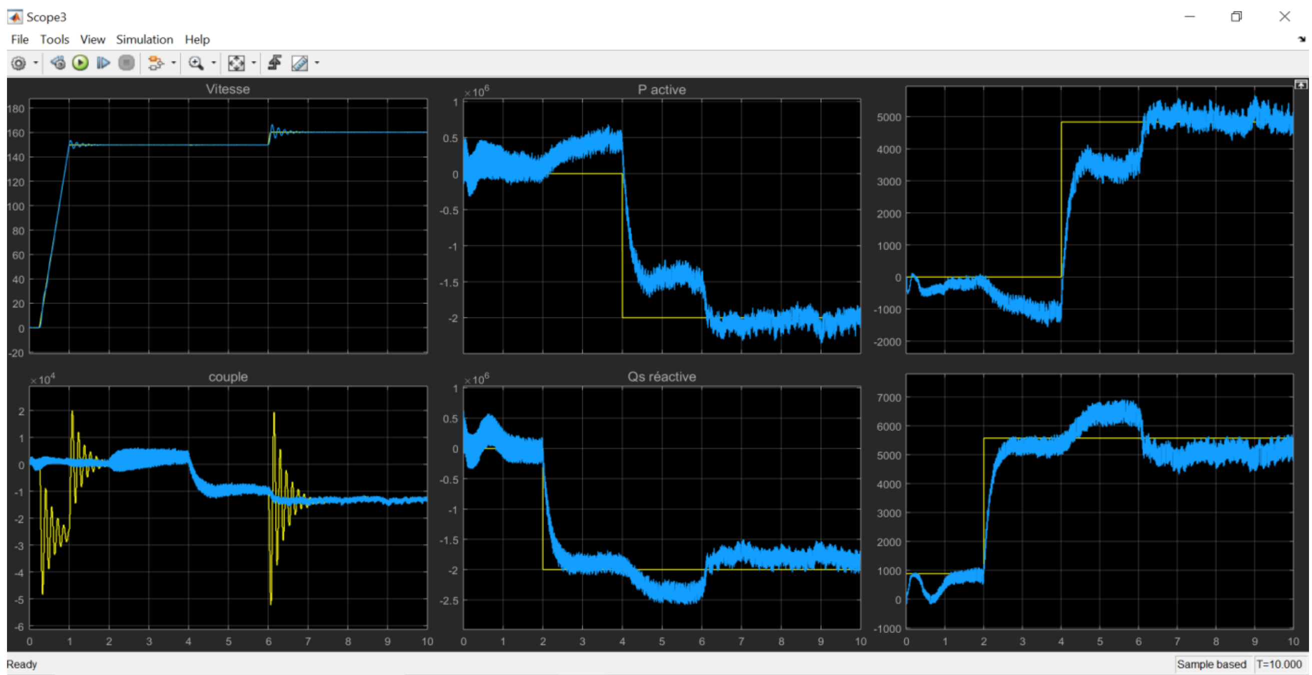

Figure 5: Active and Reactive Power response DFIG

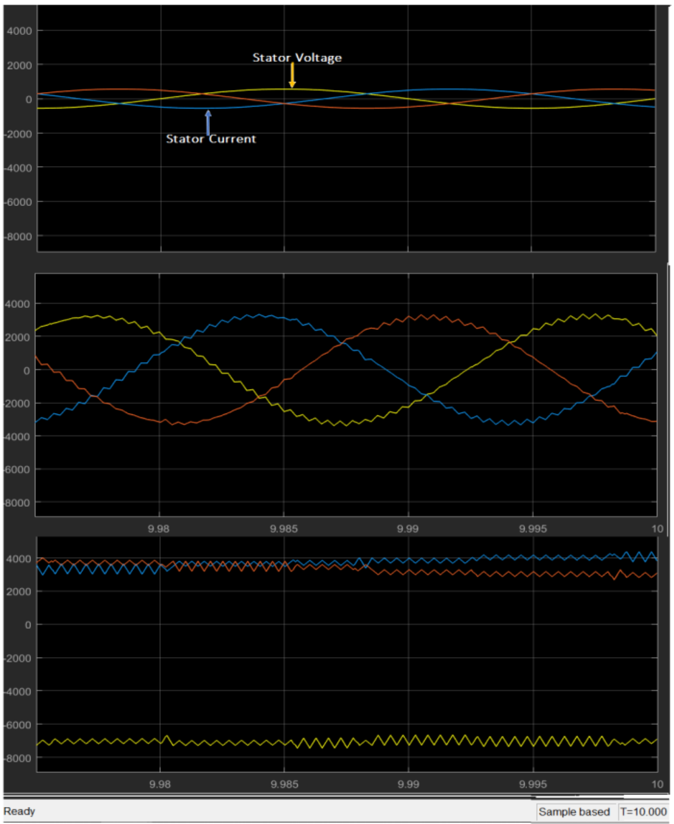

Figure 6: Output Stator Voltage and Stator current response

VI. CONCLUSIONS

In this paper, a doubly fed induction generator (which is an asynchronous machine) for the better control of the active and reactive power in the grid the power conversion systems in wind turbine are analysed by using the vector-controlled method. The proposed vector control of DFIG is capable of a simultaneous capturing maximum power of wind energy with fluctuating wind speed and improving quality factor and output power.

In this model, the overall control scheme of DFIG machine is simulated using MATLAB Simulink environment.

Determining the relative difference between rotor position and stator flux is achieved for resolving the rotor currents. In all simulations, the very fine stator output voltage and current are found, with very small negligible harmonics. It is observed after 4 sec. the constant active power is received and after 2 sec the constant reactive power in the order of 2×10^6 VAR. In Figure 6, differences between stator and rotor flux of DFIG is shown and, Figure 5 shows active and reactive and reference speed of DFIG. At time 4 sec, the reference speed changed and consequently the estimated speed changes. Also, to get the maximum torque or couple action the vector control synchronises well and changes the active and reactive power accordingly. The performance of a moving turbine can be seen clearly in the couple graph (figure 5).

It also shows that the DFIG system has superior performance under the fuzzy logic controlled direct current vector control approach. This paper has presented the fuzzy logic-based control of real and reactive power of wind turbine-driven doubly fed induction generator which feeds the power to the utility grid. DFIG model has been described based on the direct current vector control approach. The equations derived are used in the MATLAB Simulink environment.

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