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Comparison of Pi, Fuzzy Logic and Neural Networks Based Control of Doubly Fed Induction Generator in Wind Energy Generation

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Abstract

Among the various renewable energy sources available, the WECS is gaining more importance due to its numerous advantages. In this paper a study and a comparison of various control methodologies like PI, FUZZY and NEURAL NETWORKS of DFIG used in a Wind Energy Conversion/Generation Systems is detailed. In a DFIG, the stator is directly connected to the grid whereas the rotor is connected to the grid through different power electronic converters at the rotor and grid side. In this paper the various control techniques of grid side and rotor side converter is analyzed as different cases and the response of each method is detailed using MATLAB/SIMULINK output.

Keywords: *Wind Energy Conversion, Generation, Comparison, PI, Fuzzy, Neural Networks.*

1. Introduction

Over the past few decades, the WEC is rapidly growing due to its renewable nature and eco-friendliness. Also various advanced controls strategies developed during these years increased the energy production from wind source. Compared to the fixed/constant speed wind power generation, the variable speed wing generation is of greater advantageous. In the wind energy conversion system excited from an AC supply, the stator and the grid are directly connected and the rotor is connected with the grid with some intermediate power electronic converters used for the regulation of frequency, rotor current and speed control.

Recent researches concentrate on the above mentioned rotor current and speed control. Different controllers are developed for this purpose. In DFIG, there are two converters namely the rotor side converters(RSC) and the grid side converters(GSC). The different controllers for these converters are

(i) PI controllers
(ii) Fuzzy Logic controllers (FLC)
(iii)Artificial Neural Networks based controllers (ANN)

In this, the PI controller can be used only at the time of normal operating conditions. Its performance gets reduced at the time of any disturbances and results in either voltage sag or voltage swell. Compared to the PI controllers, the advanced one is the Fuzzy logic based controller and the ANN based controllers. In this paper, two different cases of comparison of controllers for DFIG is analyzed. They are

Case 1 : FLC for the RSC and PI controllers for the GSC.
Case 2 : ANN based controllers for both RSC and GSC.

2. FLC for the RSC and PI controllers for the GSC

For the analyses we assume that both the stator and rotor variables are referred to their corresponding reference frames in the developed model of [1].The voltage and the current components of the stator side is referred to the stationary reference frame whereas the voltage and the current components of the rotor side is referred to the rotating reference frame which is rotating at rotor electrical speed [2].In this case the RSC is controlled based on the stator flux-oriented control and the rotor is controlled based on the voltage-oriented control [1].

From the various voltage and flux equations of [1], the electromagnetic torque given by $T_e=(\frac{\frac{3}{2}pM}{Ls}\Psi s\ i_{qr})$ can be controlled using i_{qr} current. Hence the reference current obtained is $I_{qr(ref)}=(\frac{2Ls\omega_s T_{cmd}}{3pMus})$. Similarly it is clear from [1] that the stator reactive power controlled using i_{dr} current and hence the i_{dr} reference current obtained is $i_{drref}=(\frac{u_s}{M\omega_s})$. The basic fuzzy logic controller diagram is shown below in Fig 2. The inputs of the fuzzy controller is the error $e=(N_{gref} - N_g)$ and the change in error $\Delta_e=(1- Z^{-1})$ given below[2]. Where N_{gref} is the reference value of the generator speed and N_g is the actual generator speed, K,K_1 and K_2 are the normalization constants. The Fuzzy controller designed can provide better operation in case of any parameter variations and disturbances. The fuzzy rules required for the optimum operation and control of the rotor side converter is given below in table 1[1].

Where the fuzzy sets are given by
1.NL and PL (Negative and Positive Large respectively)
2.NM and PM(Negative and Positive medium respectively)
3.NS and PS(Negative and Positive small respectively)

The PI controller used to control the GSC gives a smooth DC voltage and nearly a sinusoidal wave in the grid side. The block diagram of the GSC controlled by a PI regulator is given below in figure 4. The input to the PI controller is the error value which is the difference between the V_{dcref} and the actual V_{dc}. The dc voltage can be controlled by the current i_{qg} as per [3]. The reference value of the direct axis current is taken as zero in order to obtain the unity power factor.

3. ANN based controllers for both RSC and GSC

Here the same assumptions are made as that for the RSC in the case 1. The d axis in the dq transformation is aligned with the flux axis. The ANN controller for the rotor side converter and grid side converter is given below in figure 5 and figure 6 [4].

3. Tables, Figures

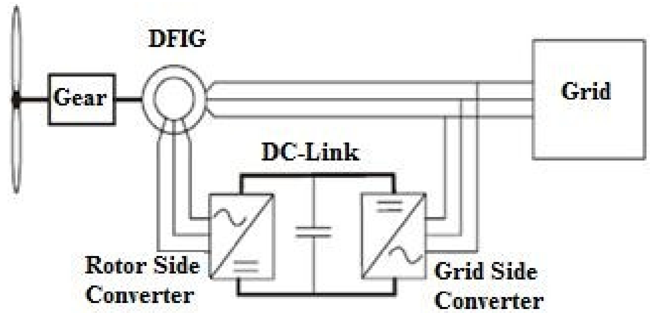

Fig 1: Scheme of Wind System

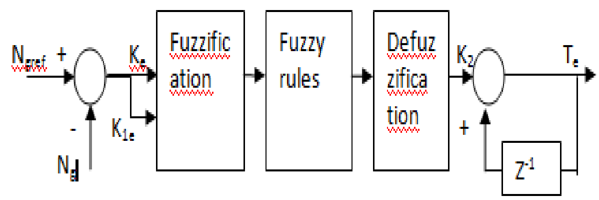

Fig 2: Basic Fuzzy logic controller

Table 1: Fuzzy Rules for optimum operation

Δ_e \ e	NB	NS	EZ	PS	PB
NB	NB	NB	NS	NS	EZ
NS	NB	NS	NS	EZ	PS
EZ	NB	NS	EZ	PS	PS
PS	NS	EZ	PS	PS	PB
PB	EZ	PS	PS	PB	PB

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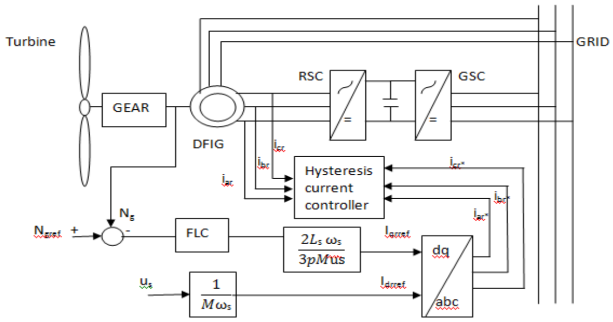

Fig 3: Rotor side converter with FLC

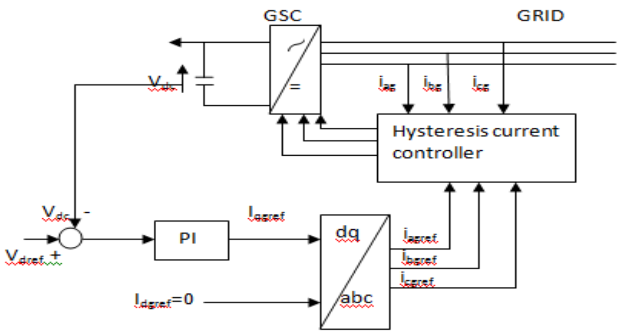

Fig 4: GSC controlled by a PI Controller

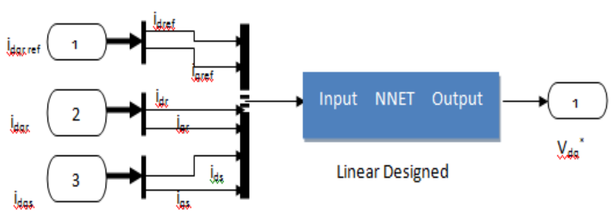

Fig 5: RSC ANN Controller

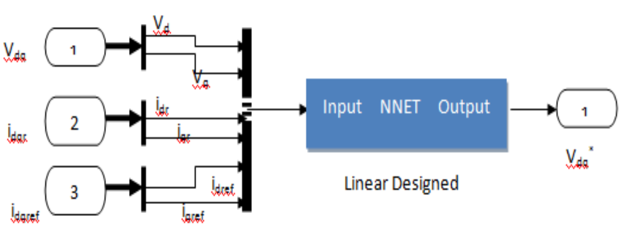

Fig 5: GSC ANN Controller

4.Simulation Results

The following results were obtained from the implementation of different controllers in MATLAB/SIMULINK[1][4]. Figure 6 shows the real and reactive power output of PI controller, Figure 7 shows the real and reactive power output of Fuzzy controller and Figure 8 represents the response output of ANN controller.

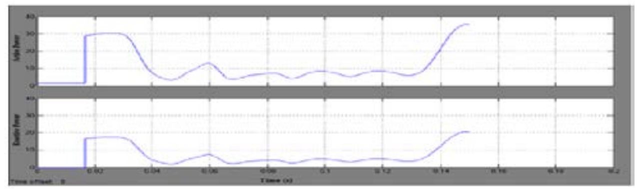

Fig 6:Response of PI Controller based DFIG

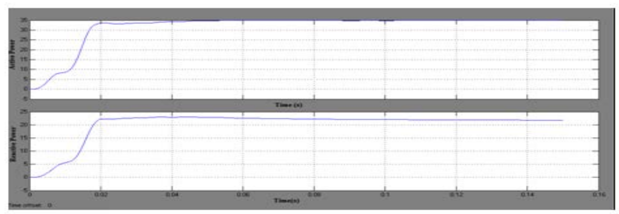

Fig 7: Response of Fuzzy controller based DFIG

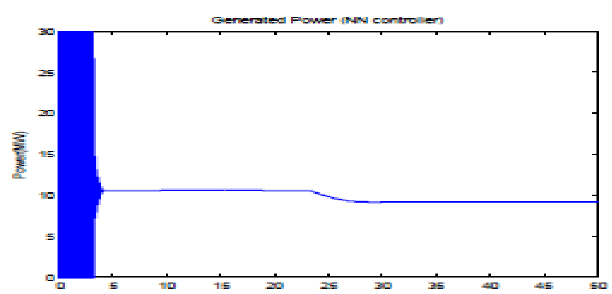

Fig 8: Response of ANN Controller based DFIG

4. Conclusions

From the analyzes of three controllers and the response output from the simulation results reveal that the ANN controllers are very effective and efficient compared to the PI and Fuzzy controllers, because the steady state error in case of ANN control is less and the stabilization if the system is better n it. Also in the ANN methodology the time taken for computation is less since there is no mathematical model .

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