Improvement of the Performance of Doubly-Fed Induction Generator for Wind Turbines by Optimizing the Parameters of the Fuzzy Controller

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Abstract: This study investigates the improvement of wind turbine performance by giving optimal values to the fuzzy controller parameters of a doubly-fed induction generator. The results obtained from the simulation by MATLAB, especially when using the genetic algorithm, confirm that the control of this machine (Doubly Fed Induction Generator) gives very satisfactory results. In particular, the operating system gives a fast response without any disturbance. Moreover, it allows the Doubly Fed Induction Generator to perform its functions without any hindrance and without any impact on the content.

INTRODUCTION

Wind energy is one of the fastest growing uses of renewable energy sources is clean and available because of its low cost and improved technology. Using the fuzzy control, a more reliable controller can be produced due to the effect of other parameters such as noise and events caused by a wide range of control regions. In addition, an online change of the controller parameters can be considered. Moreover, without the need for a detailed mathematical model of the system and by simply using knowledge of the overall operation and behavior of the system, it is easier to adjust the parameters[1-3].

This study presents a wind turbine system its characteristics are described to estimate its dynamics and performances under different operating conditions. Then, fuzzy logic control of the DFIG used to independently control the powers is proposed and tested on a wind turbine equipped with a DFIG of 10 kW and using the optimal values of the fuzzy controller parameters of a dual-fed induction generator for wind turbines.

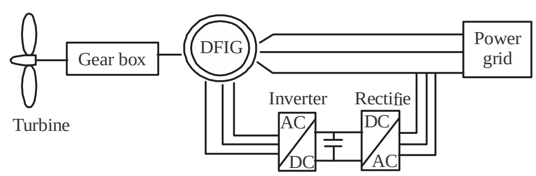

Fig. 1: Wind energy conversion system based DFIG

Wind turbine characteristics: Figure 1 shows a complete diagram of the wind energy conversion system connected to the electricity grid.

Mathematical model of the DFIG: The DFIG model is described in the d-q Park reference frame, based on Eq. 1-3[4-7]:

$$\begin{aligned}
V_{sd} &= R_s I_{sd} + \frac{d}{dt}(\phi_{sd}) - \omega_s \phi_{sd} \\
V_{sq} &= R_s I_{sq} + \frac{d}{dt}(\phi_{sq}) - \omega_s \phi_{sd} \\
V_{rd} &= R_r I_{rd} + \frac{d}{dt}(\phi_{rd}) - (\omega_s - \omega_r)\phi_{rq} \\
V_{rq} &= R_r I_{rq} + \frac{d}{dt}(\phi_{rq}) - (\omega_s - \omega_r)\phi_{rq}
\end{aligned} \tag{1}$$

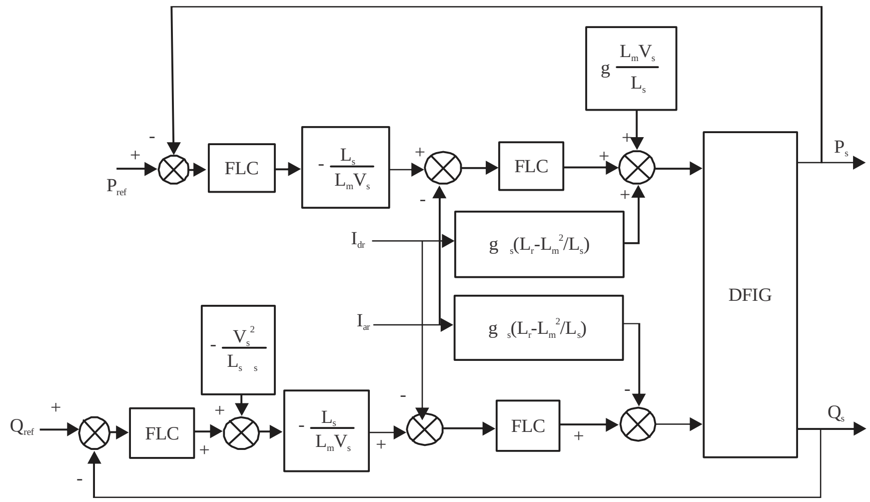

Fig. 2: Control scheme of DFIG

$$\begin{aligned} \phi_{sd} &= L_s I_{sd} + L_m I_{rd} \\ \phi_{sq} &= L_s I_{sq} + L_m I_{rq} \\ \phi_{rd} &= L_s I_{rd} + L_m I_{sd} \\ \phi_{rq} &= L_s I_{rq} + L_m I_{sq} \end{aligned} \quad (2)$$

$$\begin{cases} P_s = V_{sd} I_{sd} + V_{sq} I_{sq} \\ Q_s = V_{sq} I_{sd} - V_{sd} I_{sq} \end{cases} \quad (3)$$

Where:
s/r = The stator/rotor subscript; voltage/current
φ = Flux
R = Resistance
L_m = Mutual inductance

Fuzzy control: Figure 2 shows the schematic diagram in which fuzzy controllers are integrated in the rotor-side converter to control the DFIG. The main objective of this step is the control of the active and reactive power. As shown OU?, the rotor-side converter can separately track the reference active and reactive power using fuzzy controllers.

FLC design: The rule base of the FLC contains nine rules based on the IF-THEN structure summarized in Table 1.

DESIGN OF A FUZZY LOGIC CONTROLLER (RLF)

Figure 3 illustrates the main steps in designing an FLC. First, the system to be regulated (process) must be studied and adequately described.

There is no analysis to establish a mathematical model. Instead, the measurable quantities must be determined and the dynamic behavior of the process compared with the control quantity variation must be analyzed. The description may use linguistic variables that canbe incorporated into the command theory knowledge and/or operation experiments.

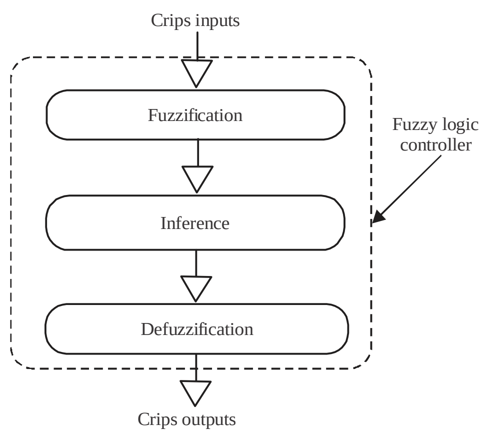

Fig. 3: Main steps when designing an FLC

Table 1: Rules bases

	Δe		
Δu	N	Z	P
e			
N	N	N	Z
Z	N	Z	P
P	Z	P	P

The databases and rules necessary to determine the control strategy can then be established. The next step is to design the FLC which includes fuzzification, inference and defuzzification. It is usually necessary to modify membership functions and fuzzy rules interactively in several passages to find an acceptable behavior.

Genetic algorithm

Program used for the simulation: Two files are considered to find the optimal gains:

- File “pid_ga15.m”
- File “indirect command inverter.mdl”

```
function [y]=pid_ga15(p)
assignin ('base','kp1',p(1));
assignin ('base','ki1',p(2));
assignin ('base','kz1',p(3));
assignin ('base','kz2',p(4));
%assignin ('base','kd',p(3));
[t,x,y]=sim('commande_indirecte_onduleur',[0,1.5]);
y=y(end,2);
```

Fig. 4: “Gatool” window under MATLAB (Genetic algorithm)

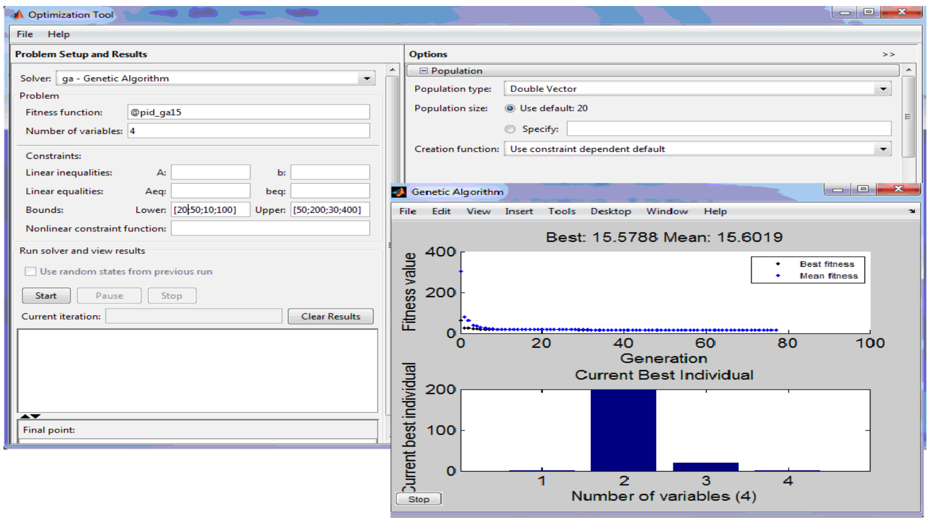

Fig. 5: “Gatool” window under MATLAB

Moreover, four variables are used in this simulation:

- K_p, K_i, K_Z gain parameters for power control
- K_{pc}, K_{ic}, K_{Zc} gain settings for current control

$$\begin{cases} k_p = k_{pc} = k_{p1} \\ k_i = k_{ic} = k_{p2} \\ k_z = k_{z1} \\ k_{zc} = k_{z2} \end{cases} \quad (4)$$

Then the Mistletoe Gatool is called, all the necessary information is filled in and GATOOL is started. After several iterations the genetic algorithm converges. Figure 4 represents the “Gatool” window developed under MATLAB. The simulation is made to illustrate the performance of the fuzzy control applied to the DFIG. Figure 5 shows a block diagram to control the whole system. Results shown in Fig. 6 indicate the powers generated when reference signals are applied.

SYSTEM RESPONSES

The system responses with the GA-optimized fuzzy controller are:

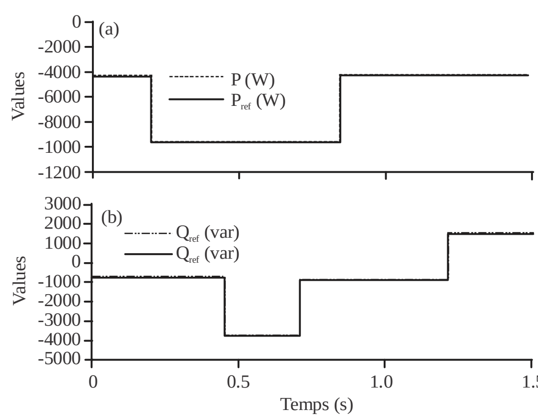

Fig. 6(a, b): Simulation results obtained by the fuzzy controller optimized by GA (Genetic Algorithm)

- The decrease in fluctuations around their optimum values
- Quick response at startup

Based on the simulation results obtained, it has been observed that this technique allowed to reduce the effort of trial-and-error design and to have powerful power controllers available quickly.

CONCLUSION

This study examined the enhancement of wind turbine efficiency using optimal values for the fuzzy controller parameters of a doubly-fed induction generator. MATLAB'S simulation results, especially when using the genetic algorithm, showed that the control of this machine (Dual-Fed Induction Generator) gives very good results.

Improvement of the performance of the doubly-fed induction generator for wind turbines by optimizing the parameters of the fuzzy regulator allows its functions to be carried out without any disturbance or fluctuation of the active and reactive power level.

REFERENCES

01. Jabr, H.M., D. Lu and N.C. Kar, 2011. Design and implementation of neuro-fuzzy vector control for wind-driven doubly-fed induction generator. IEEE. Trans. Sustainable Energy, 2: 404-413.
02. Mamdani, E.H. and S. Assilian, 1975. Experiment in linguistic synthesis with a FL controller. Int. J. Man-Mach. Stud., 7: 1-13.
03. Chaiba, A., R. Abdessemed, M.L. Bendaas and A. Dendouga, 2005. Performances of torque tracking control for doubly fed asynchronous motor using PI and fuzzy logic controllers. J. Electr. Eng., 5: 25-30.
04. Bekka, H., S. Taraft, D. Rekioua and S. Bacha, 2013. Power control of a wind generator connected to the grid in front of strong winds. J. Electr. Syst., 9: 267-278.
05. Rekioua, D., 2014. Wind Power Electric Systems: Modeling, Simulation and Control. 1st Edn., Springer, London, UK., Pages: 202.
06. Boyette, A., S. Saadate and P. Poure, 2006. Direct and indirect control of a doubly fed induction generator wind turbine including a storage unit. Proceedings of the IECON 2006-32nd Annual Conference on IEEE Industrial Electronics, November 6-10, 2006, IEEE, Paris, France, pp: 2517-2522.
07. Poitiers, F., T. Bouaouiche and M. Machmoum, 2009. Advanced control of a doubly-fed induction generator for wind energy conversion. Electric Power Syst. Res., 79: 1085-1096.