

# Contribution on modeling and control of a wind power system based on fuzzy

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**Abstract**—In this work, we study the modeling and control of a wind energy conversion chain based on a Dual Power Asynchronous Machine. First, the mathematical model of the whole system under study is developed in d-q Park coordinates. Then, the proposed control strategy is designed based on a fuzzy logic control technique that gives good results. Finally, the results of the different simulations of the whole conversion chain, performed under MATLAB/Simulink environment, are presented.

**Keywords**— wind power, double asynchronous generator power supply (GADA), fuzzy control, MPPT.

## 1 Introduction:

Nowadays, wind energy has become a viable solution for electricity generation as a complement to other energy sources. The wind power system studied converts the kinetic energy of the wind into mechanical energy, usually this energy is transformed into electrical energy by the generator which allows a variable speed production of electricity. This allows the wind resource to be better exploited for different climatic conditions (wind speed...).

In fact, the rotor captures the kinetic energy of the wind and transmits its rotation directly to the main shaft. The kinetic energy has been converted into mechanical energy. A fast motion is transmitted to the output shaft, which is connected to the generator, which converts the mechanical energy of the rotary motion into electrical energy, before injecting the produced energy into the grid [1], the generator is connected to power converters. The converter on the grid side controls the DC bus voltage and the power factor [2, 3]. In addition, the generator-side power converter controls the active and reactive power produced by the GADA [4]. This paper presents a method for controlling a Dual Power Asynchronous Generator, which provides a tool for recursive control law design based on fuzzy logic [5].

## 2 Wind turbine system :

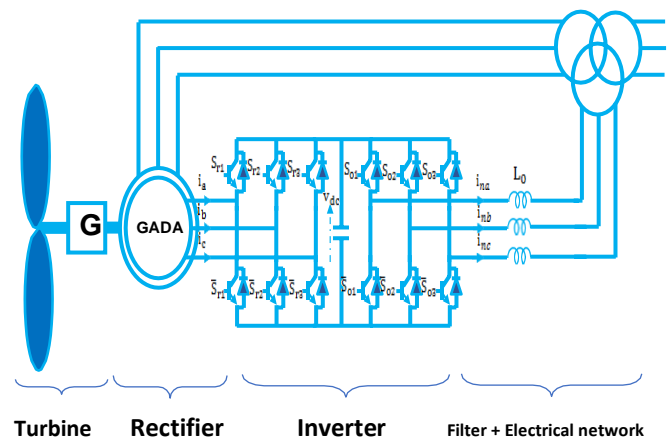


Figure 1: Architecture of a GADA-based wind power system

### A. Modelling the 'Generator - DC/AC' combination

The modeling of the Double-fed asynchronous machine has already been the subject of numerous studies, the choice of a representation model, whether formal or derived from an identification, is always made according to the type of control to be carried out. The machine is supplied with voltage: the components of the control vector of the state equation will therefore be voltages. The different quantities will initially be expressed in their respective references (a, b, c). The first change of variable will allow expressing its voltages in the reference frame (d, q) [4]. Like any machine, the GADA can be represented by three stator windings and three rotor windings.

The voltage equation is written:

$$\text{For the stator } v_s = [R_s] [i_s] + \frac{d}{dt} [\varphi_s]$$

with  $v_s = [v_{sa} \ v_{sb} \ v_{sc}]^T$  : Stator voltages  
 $i_s = [i_{sa} \ i_{sb} \ i_{sc}]^T$  : Stator currents  
 $\varphi_s = [\varphi_{sa} \ \varphi_{sb} \ \varphi_{sc}]^T$  : Stator flux

For the rotor:  $v_r = [R_r] [i_r] + \frac{d}{dt} [\varphi_r]$

with:

$v_r = [v_{ra} \ v_{rb} \ v_{rc}]^T$  : Rotor voltages

$i_r = [i_{ra} \ i_{rb} \ i_{rc}]^T$  : Rotor currents

$\varphi_r = [\varphi_{ra} \ \varphi_{rb} \ \varphi_{rc}]^T$  : Rotor flux

The most appropriate model to study the dynamic behavior of the machine and the implementation of the control laws is a model expressed in PARK coordinates [6], The park model is the replacement of the stator windings (a,b,c) by equivalent windings (d,q). We can switch from one to the other reference point using a transition matrix. The change of variable to the voltage, current, and flux equations gives :

$$\begin{aligned} [i_{rdq}] &= p(\theta)[i_{rabc}] \\ [v_{rdq}] &= p(\theta)[v_{rabc}] \\ [\varphi_{rdq}] &= p(\theta)[\varphi_{rabc}] \end{aligned}$$

Hence, the stator and rotor voltage equations of the MADA are written:

$$\begin{aligned} v_{sd} &= R_s i_{sd} + \frac{d}{dt} \varphi_{sd} - \varphi_{sq} \omega_s \\ v_{sq} &= R_s i_{sq} + \frac{d}{dt} \varphi_{sq} - \varphi_{sd} \omega_s \\ v_{rd} &= R_r i_{rd} + \frac{d}{dt} \varphi_{rd} - \varphi_{rq} \omega_r \\ v_{rq} &= R_r i_{rq} + \frac{d}{dt} \varphi_{rq} - \varphi_{rd} \omega_r \end{aligned}$$

In the following, we consider the vector  $[i_{rd} \ i_{rq} \ \varphi_{sd} \ \varphi_{sq} \ \omega]^T$  as the state vector and  $[v_{rd} \ v_{rq}]$  as the control variables, hence the model of the overall system in state space is expressed in d-q coordinates as follows:

$$\begin{aligned} \frac{d i_{rd}}{dt} &= -\mu i_{rd} + \omega_r i_{rq} \alpha \frac{R_s}{L_s} \varphi_{sd} + \frac{1}{L_r \sigma} v_{rd} \\ &\quad - \alpha v_{sd} \\ \frac{d i_{rq}}{dt} &= -\mu i_{rq} - \omega_r i_{rd} \alpha p \omega \varphi_{sq} + \frac{1}{L_r \sigma} v_{rq} \\ &\quad - \alpha v_{sq} \end{aligned}$$

with:

$$\mu = \frac{R_s}{L_r \sigma} + \frac{R_s M_{sr}^2}{L_r L_s^2 \sigma} \quad \text{and} \quad \alpha = \frac{M_{sr}}{L_r L_s \sigma}$$

We have expressed the equations of the machine but there is also the electromagnetic torque. The latter can be derived from the expression of the co-energy obtained using a power balance

$$C_{em} = \frac{p M_{sr}}{L_s} (\varphi_{sq} i_{rd} - \varphi_{sd} i_{rq})$$

And the relationship between torque and speed is written :

$$j \frac{d\omega}{dt} = C_{em} - C_r - f\omega$$

### 3 Application of fuzzy logic to MADA active and reactive power control

In this section, we will follow the steps shown in the Main Steps diagram when designing an RLF to design two Mamdani type fuzzy logic controllers for the current and power control loop, to improve the control performance, both controllers are of the same type, and have the same membership functions. The difference is only in the normalization gains. The general block diagram of the fuzzy logic control of MADA is given in fig (2).

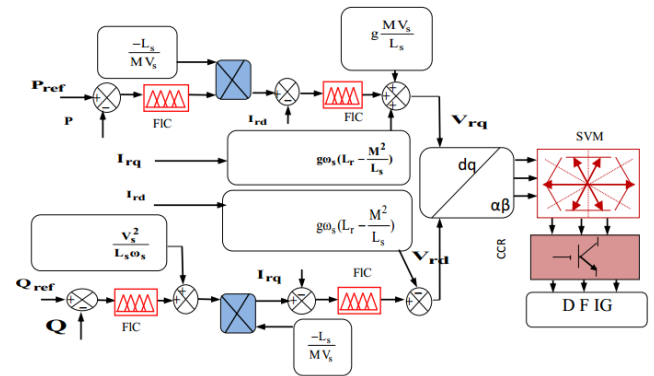


Figure 2: Block diagram for fuzzy logic control of MADA

### 4 Robustness study:

The simulation results reported in the following figures concern the control of the wind power conversion chain based on a double-fed variable-speed asynchronous machine, with the application of reference steps of active and reactive powers.

From the following figures, we can see that the measured active and reactive power quantities follow their reference values, and from these results, better tracking of the fuzzy controllers than the PI controllers.

For the robustness tests of the fuzzy controller control, we studied the influence of the variation of

the rotor resistance  $R_r$  and the inductance  $L_r$  on the control performance.

We simulated the system for a gradual increase of 150% in resistance and rotor inductance at time  $t=0.25$ , and a return to their initial values at  $t=0.35$ . The following figures show the results of the simulation test.

The simulation results show respectively that these parametric variations introduced at time  $t=0.25$  have a slight influence on the performance of the control; in contrast to the PI controller which is influenced leading to destabilization.

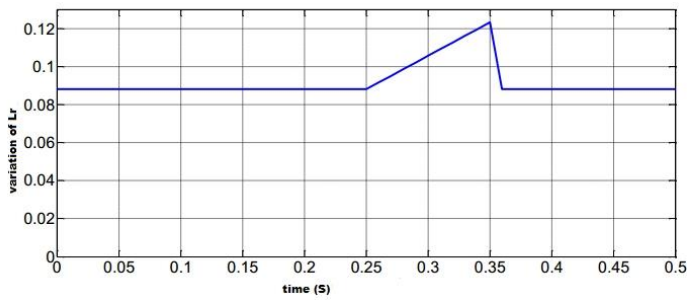


Figure 3 : Variation of rotor inductance

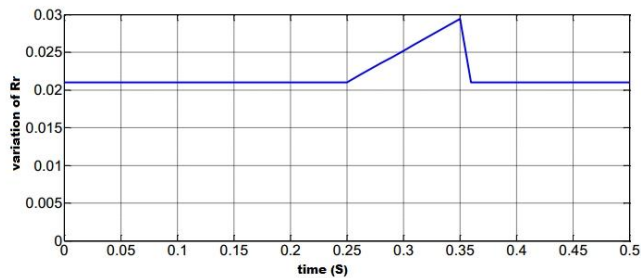


Figure 4: The disappearance of the rotor resistance

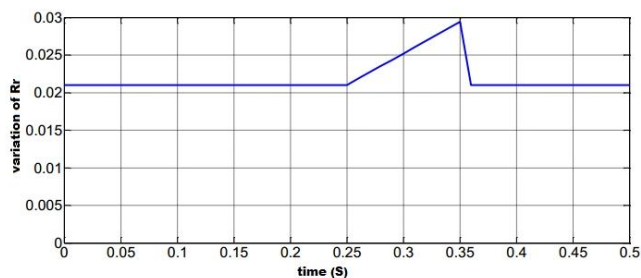


Figure 5: Active power with a fuzzy controller

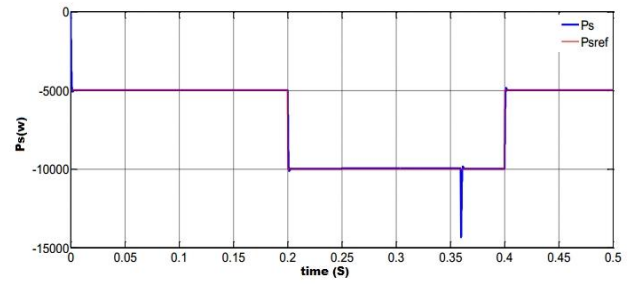


Figure 6: Active power with a fuzzy controller

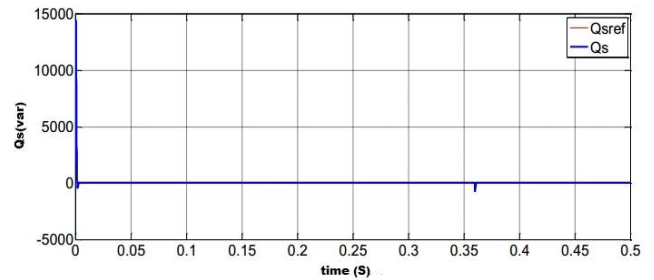


fig.6: Reactive power with a fuzzy controller

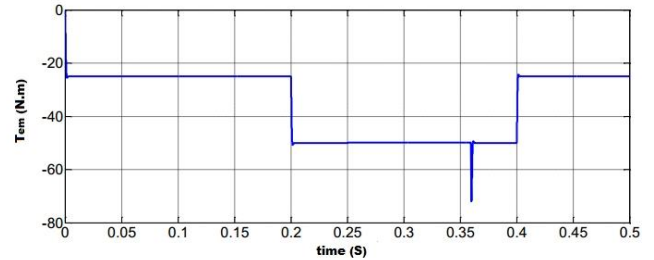


Figure 7: Electromagnetic torque with a fuzzy controller

## 5 Conclusion:

In this paper, the technique and basic notions of fuzzy logic were presented, and aspects of fuzzy logic control (FLC), as well as the design of a fuzzy controller, were introduced while justifying our choice of this type of control which lies in its ability to deal with the imprecise, the uncertain and the vague of its simplicity of design. A fuzzy controller-based simulation was carried out to perform speed control in place of the PI controller of a dual-fed asynchronous machine.

The simulation results obtained show that the FLC has a very satisfactory tracking performance, and has proven its efficiency, especially in parametric variations. The major problem in the design of the FLC is the choice of membership functions for the input and output variables.

## References

- [1] Karim Noussi, Abdelmajid Abouloifa, Hanane Katir, Ibtissam Lachkar, Fouad Giri, "Nonlinear control of grid-connected wind energy conversion system without mechanical variables measurements" *ijpeds.v12.i2.pp1139-1149*
- [2] Ankamreddi Venkataramana, K.Narendrababu and D Ravi Kishore "Quasi Power Factor Correction for High Efficient AC/DC Converter" *International Journal for Modern Trends in Science and Technology, Learn. Syst., 7(05): 206-211, 2021*
- [3] Kangaji, Ladislav and Abo-Al-Ez, Khaled M. and Orumwense, E.F., "Modelling and Performance Analysis of Grid Connected PMSG Based Tidal Generation System (July 26, 2021)". *AIUE Proceedings of the 2nd Energy and Human Habitat Conference 2021*.
- [4] Khojet El Khil. S, 2006. Vector control of a doubly powered asynchronous machine (DPM). PhD thesis, Institut National Polytechnique de Toulouse.
- [5] K. Noussi, A. Abouloifa, H. Katir and I. Lachkar, "Modeling and Control of a Wind Turbine Based On a Doubly Fed Induction Generator," 4th World Conference on Complex Systems (WCCS), 2019, pp. 1-5,
- [6] Alireza Rezvani, Majid Gandomkar, "Modeling and control of grid connected intelligent hybrid photovoltaic system using new hybrid fuzzy-neural method" *Solar Energy, Volume 127, 2016, Pages 1-18*.
- [7] S. Boersma *and al.*, "A tutorial on control-oriented modeling and control of wind farms," *2017 American Control Conference (ACC)*, 2017, pp. 1-18.
- [8] Dana-Alexandra Ciupageanu, Linda Barelli and Gheorghe Lazaroiu "Real-time stochastic power management strategies in hybrid renewable energy systems: A review of key applications and perspectives" *Electric Power Systems Research, Volume 187,2020*,
- [9] Christian Klemm and Peter Vennemann "Modeling and optimization of multi-energy systems in mixed-use districts: A review of existing methods and approaches" *Renewable and Sustainable Energy Reviews, Volume 135,2021*.
- [10] Rushdi, Mostafa A. and Rushdi, Ahmad A. and Dief, Tarek N. and Halawa, Amr M. and Yoshida, Shigeo and Schmehl, Roland "Power Prediction of Airborne Wind Energy Systems Using Multivariate Machine Learning" *Energies,13,2020*.
- [11] Mosavi, Amir and all "State of the Art of Machine Learning Models in Energy Systems, a Systematic Review" *Energies,12,2019* .
- [12] Yanfeng Liu, Sisi Yu, Ying Zhu, Dengjia Wang, Jiaping Liu "Modeling, planning, application and management of energy systems for isolated areas: A review" *Renewable and Sustainable Energy Reviews, Volume 82, Part 1, 2018, Pages 460-470*.
- [13] Beibei Xu and all "Modeling a pumped storage hydropower integrated to a hybrid power system with solar-wind power and its stability analysis" *Applied Energy, Volume 248, 2019, Pages 446-462*.
- [14] Chengshan Wang and all "Modeling and optimal operation of community integrated energy systems: A case study from China" *Applied Energy, Volume 230, 2018, Pages 1242-1254*
- [15] X. Li and S. Wang, "A review on energy management, operation control and application methods for grid battery energy storage systems," in *CSEE Journal of Power and Energy Systems, 2019*.
- [16] X. Li and S. Wang, "A review on energy management, operation control and application methods for grid battery energy storage systems," in *CSEE Journal of Power and Energy Systems, 2019*.
- [17] K. Kumar, N. Ramesh Babu and K. R. Prabhu, "Design and Analysis of RBFN-Based Single MPPT Controller for Hybrid Solar and Wind Energy System," in *IEEE Access, vol. 5, pp. 15308-15317, 2017*.
- [18] R. Anilkumar, G. Devriese and A. K. Srivastava, "Voltage and Reactive Power Control to Maximize the Energy Savings in Power Distribution System With Wind Energy," in *IEEE Transactions on Industry Applications, vol. 54, no. 1, pp. 656-664, Jan.-Feb. 2018*.
- [19] Mohammad Mohammadi, Younes Noorollahi, "Behnam Mohammadi-ivatloo, Fuzzy-based scheduling of wind integrated multi-energy systems under multiple uncertainties" *Sustainable Energy Technologies and Assessments, Volume 37, 2020*.
- [20] Prabodh Bajpai, Vaishalee Dash, "Hybrid renewable energy systems for power generation in stand-alone applications: A review" *Renewable and Sustainable Energy Reviews, Volume 16, Issue 5, 2012, Pages 2926-2939*.
- [21] Aqeel Ahmed Bazmi, Gholamreza Zahedi "Sustainable energy systems: Role of optimization modeling techniques in power generation and supply—A review" *Renewable and Sustainable Energy Reviews, Volume 15, Issue 8, 2011, Pages 3480-3500*
- [22] M. Aly, E. M. Ahmed and M. Shoyama, "Thermal and Reliability Assessment for Wind Energy Systems With DSTATCOM Functionality in Resilient Microgrids," in *IEEE Transactions on Sustainable Energy*, vol. 8, no. 3, pp. 953-965, July 2017.
- [23] B. K. Bose, "Power Electronics, Smart Grid, and Renewable Energy Systems," in *Proceedings of the IEEE*.