Journal of Renewable Energies

Revue des Energies Renouvelables

journal home page : https://revue.cder.dz/index.php/rer

MPPT Fuzzy Logic Control of a Variable Speed Wind Turbine

Abdeldjalil Dahbi [a,b,*], Miloud Benmedjahed [a], Abderrahman Khelfaoui [a], Sara Kadi [c], Boualam Benlahbib [d], Houcine Guentri [e], Nouar Aoun [a], Abdelghani Harrag [f], Messaoud Hamouda [b], Ahmed Bouraiou [a], Abdeldjalil Slimani [a], Ammar Neçaibia [a], Djilali Chogueur [b], Boudjema Tidjar [a], Abdellatif Oudran [a], Kada Bouchouicha [a], Samir Mouhadjer [a], Tahar Touahri [a], Ahmed Yassine Kadri [g]

[a] *Unité de recherche en énergies renouvelables en milieu saharien (URER.MS) Adrar,Centre de Développement des Energies Renouvelables (CDER), Algeria;*

[b] *Laboratory of sustainable Development and computing, (L.D.D.I), University of Adrar;*

[c] *Laboratory of Power Equipment Characterization and Diagnosis, University of Science and Technology Houari Boumediene, Algiers, Algeria.*

[d] *Unité de Recherche Appliquée en Energies Renouvelables, URAER, Centre de Développement des Energies Renouvelables, CDER, 47133, Ghardaia, Algeria;*

[e] *Department of Science and Technics, Institute of Science and Technologies, Abdelhafid Boussouf University centre, Mila, Algeria.*

[f] *Renewable Energies Team, Mechatronics Laboratory, Optics and Precision Mechanics Institute, Ferhat Abbas, University, 19000, Setif, Algeria;*

[g] *Department of electrical engineering, University of Biskra, Algeria.*

* *Corresponding author, E-mail address: Dahbi_j@yahoo.fr*
Tel.: + ___ ____________

Abstract

This work is focused on the control of a wind turbine system based on (PMSG). In order to enhance the efficiency of the wind turbine system, the maximum power point tracking (MPPT) control is applied to exploit the maximum power from the wind. The Fuzzy Logic controller (FLC) has been proposed and developed for the speed control. The simulation results show good performances of this control.

Keywords: Maximum Power Point Tracking (MPPT) control, Fuzzy Logic Control (FLC), modelling.

1. Introduction

Currently, the use of renewable energies is increasing, because the pollution and the environmental problems caused by fossil sources [1]. Among these renewable energies, the wind energy takes a good place which knows a high growth and used. Many researches have been done in order to increase the efficiency of the WECS, for this reason, various technologies use the Permanent magnet synchronous generators (PMSGs) in low and medium power relatively due to their special characteristics and efficiency. Moreover, the PMSG does not require a gear box, which reduces the cost, weight and volume of the system [2]. However, its rotation speed should be controlled according to variations of wind speed for extracting the maximum of power, this technics is called MPPT. MPPT control with speed controller has more efficiency, but it needs the wind speed sensor and a speed controller. Various controllers can be used in MPPT. In this work, one of the most promising controls is presented and explained based on FLC. This later can maximize the wind turbine power. This paper presents the performance evaluation of the wind turbine system using FLC, “Fig.1”.

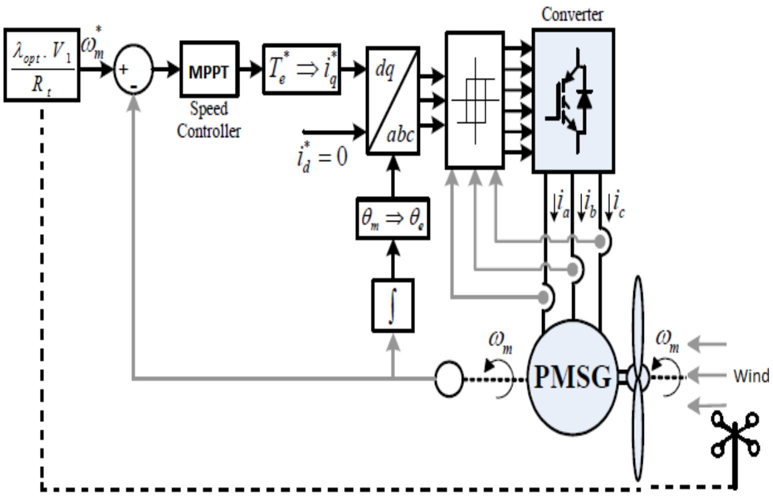

Fig1. Wind energy system using PMSG.

2. Wind turbine system

The wind turbine is defined as [3]:

$$P_m = \frac{1}{2} C_p(\lambda) \rho A V_1^3 \tag{1}$$

The tip-speed ratio may be written as [4]:

$$\lambda = \frac{\Omega_t R_t}{V_1} \tag{2}$$

where,

A : area swept by blades [m^2]

ρ : density of air [kg/m^3]

V_1 : speed of the wind [m/s]

R_t : turbine blade radius [m]

Ω_t: rotor speed [rpm]

C_p : power conversion coefficient

The value of the coefficient of power conversion C_p can be approximated by [5]:

$$C_p(\lambda,\beta)=\left(0.5-0.0167(\beta-2)\right)\sin\left[\frac{\pi(\lambda+0.1)}{18-0.3(\beta-2)}\right]-0.00184(\lambda-3)(\beta-2) \tag{3}$$

The simulation of C_p is presented in "Fig.2":

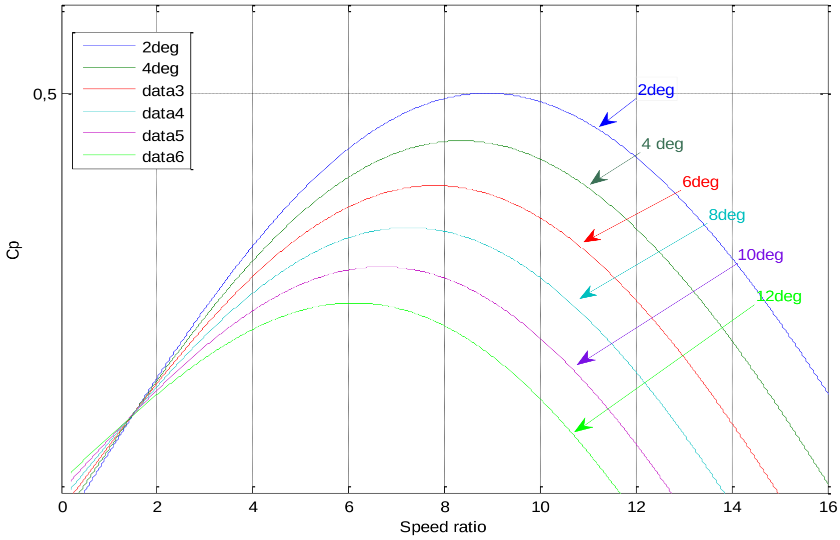

Fig.2 Characteristics of $C\,p\,(\lambda,\beta)$ for different values of β

When the wind power is less than the nominal power, β should be maintained fixe at the smallest degree; so, the power coefficient takes the maximum value corresponding to the maximum power value at the λ_{opt}. Hence, for maximizing the wind turbine energy, λ should equal λ_{opt} or Ω_t *at* Ω_{ref}.

The optimal rotor speed is expressed by [6]:

$$\Omega_{ref}=\frac{\lambda_{opt}\,.\,V_1}{R_t} \tag{4}$$

3. MPPT control using Fuzzy Logic

Fuzzy logic control (FLC) has the advantage of solving the non-linearity of the system and it doesn't need its mathematical model parameters. FLC imposes the reference torque on PMSG to obtain the optimal speed rotation which leads to optimal torque and then the optimal power, "Fig.3".

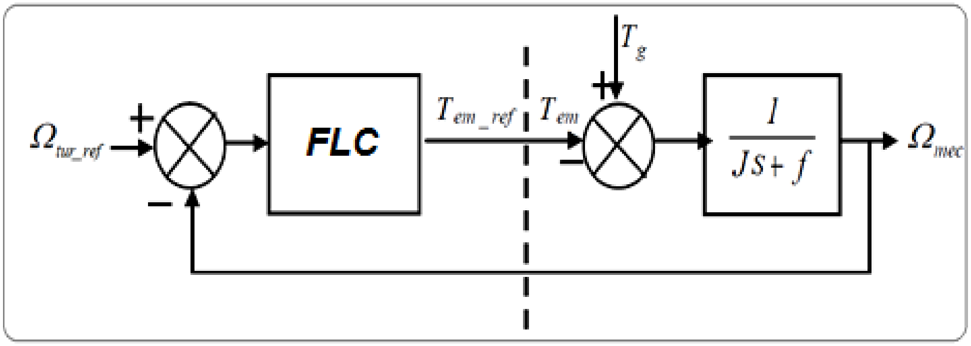

Fig.3 Diagram block of the FLC.

Two input variables are in FLC controller; speed error ‘e’ and the error speed variation ‘de/dt’ [6].

The structure of FLC is given as shown in “Fig.4”:

Generally, FLC pass by three steps:

- *Fuzzification,*
- *Reading table,*
- *Defuzzification.*

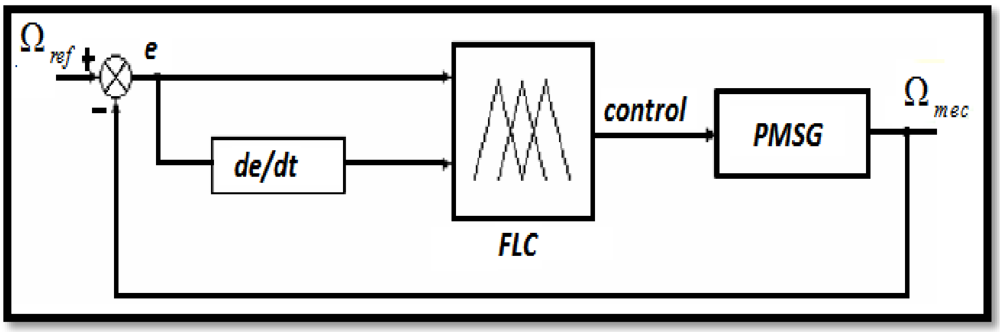

Fig. 4 Conception of FLC

At first stage, by using the triangular membership functions, the input variables should be converted into fuzzy variables ‘e’ and ‘de’. The input variables ‘e’ and ‘de’ universes of discourse are respectively (-0.5, 0.5) rad/s and (-1, 1) rad/s. The output variable discourse universe is (-1, 1). Five fuzzy sets divide each universe of discourse: **NG** : Negatif-big, - **NP** : Negatif-small, - **Z** : About Zéro, -**PP** : Positif-small, **PG** : Positif-big.

In the second stage, FLC executes the 25 control rules to obtain the output according to inputs. Table.1 shows the control rules [7]:

e \ de	NG	NP	Z	PP	PG
NG	NG	NG	NP	NP	Z
NP	NG	NP	NP	Z	PP
Z	NG	NP	Z	PP	PG
PP	NG	Z	PP	PP	PG
PG	Z	PP	PP	PG	PG

Table 1. Fuzzy control rules for speed controller.

4. Results and discussion

The simulation results are presented below:

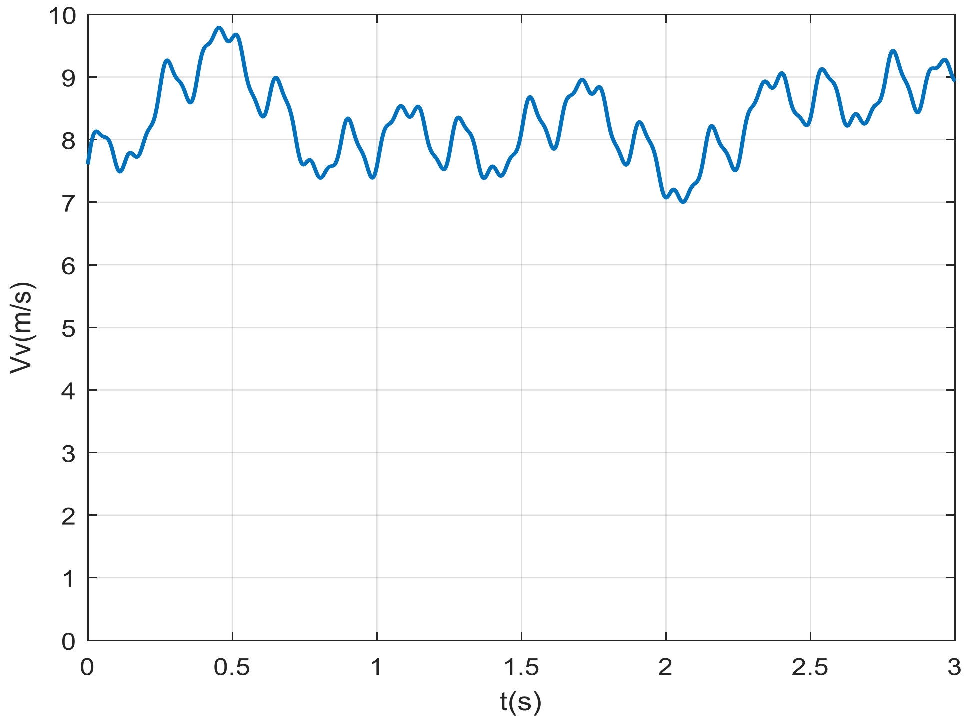

Fig. 5 Wind speed

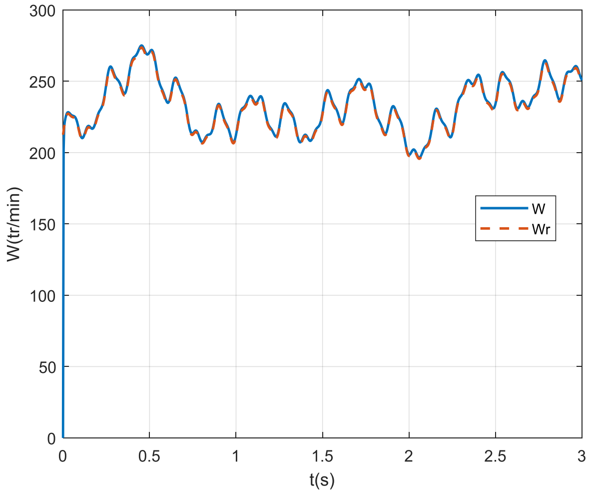

Fig. 6 Rotor speed (tr/min)

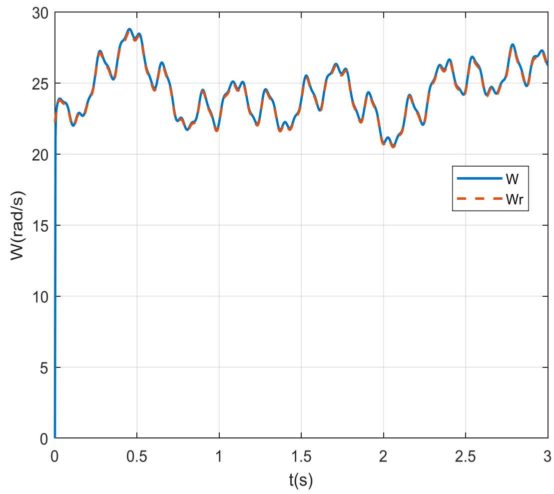

Fig. 7 Rotor speed(rad/s)

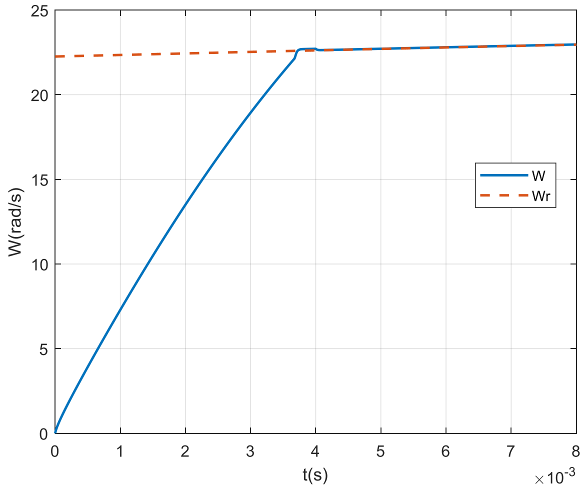

Fig. 8 Zoom of rotor speed(rad/s)

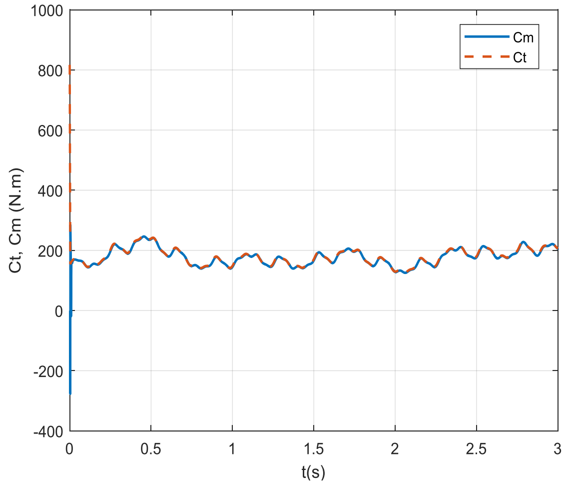

Fig. 9 Torques (wind turbine and generator)

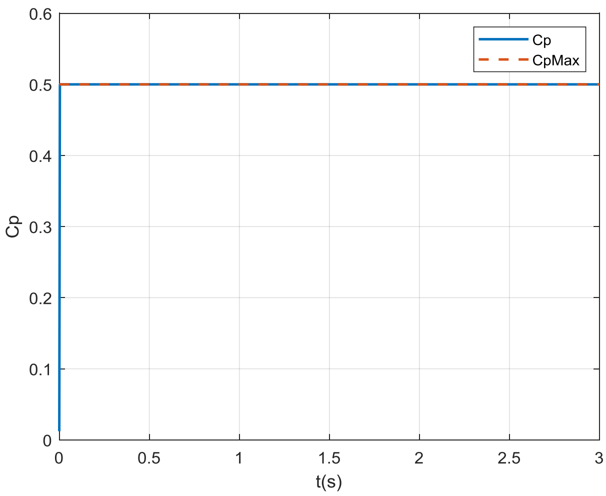

Fig. 10 Power coefficient

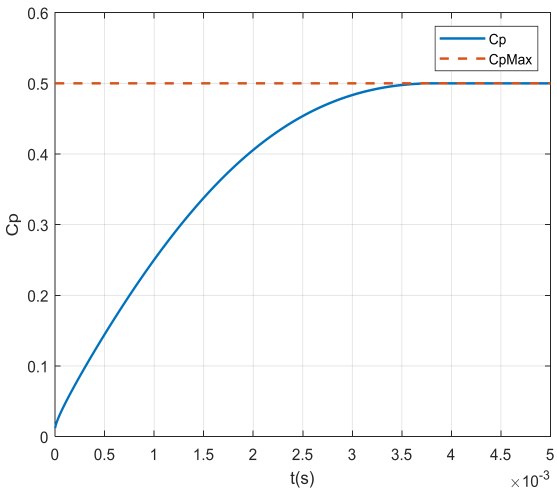

Fig. 11 Zoom of the power coefficient

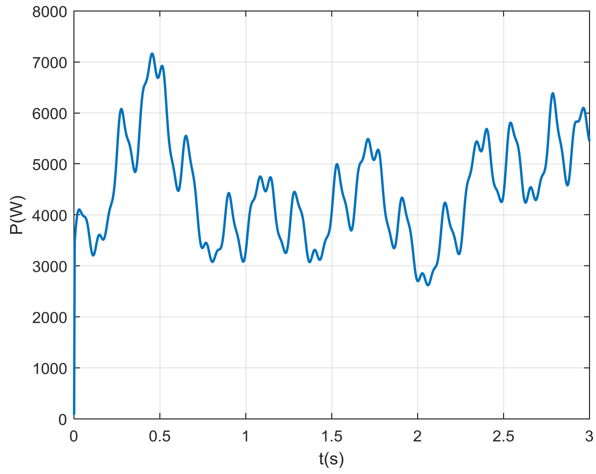

Fig. 12 Wind turbine power

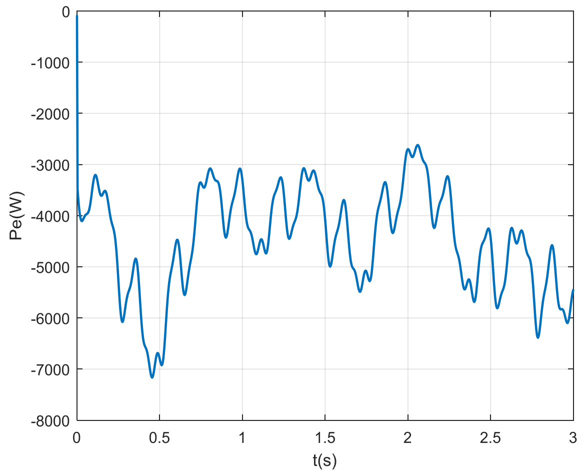

Fig. 13 Electromagnetic power

It can be seen in "Fig. 6" and "Fig. 7" a fast and good following of the rotor speed to its reference with an adaptation to speed of the wind ("Fig. 5") represented in the fast dynamic response (0.0036s) as shown in "Fig. 8". The generator torque and the wind turbine torque are equal in the steady state, they are also well adapted to the wind speed, "Fig. 9". Thanks to the good speed control, the power coefficient is well adjusted to its maximal value (0.5) after a small dynamic (0.0036s) as shown in "Fig. 10" and "Fig. 11". In addition, although the wind speed variations, the power coefficient remains max and constant, which means that the maximal power is achieved. All these above leads to harvest the maximal available power whatever the wind speed variation (under its nominal value), which involves the adaptation of the rotor speed value the mechanical power and electrical generated power (knowing that loses are neglected) to the wind speed, therefore the MPPT control is well assured.

5. Conclusion

In this paper, a MPPT control for wind energy system was proposed. In the aim of picking up the maximum power, the MPPT control with speed control based on Fuzzy logic controller was used. According to the wind speed variation, the wind energy conversion system has given good dynamic performances. The validity of the controlled wind turbine has been checked by simulation results. In addition, this applied strategies can increase dynamic performances and the efficiency of the wind turbine.

6. References

[1] Boualam Benlahbib, Noureddine Bouarroudj, Saad Mekhilef, DAHBI Abdeldjalil, Thameur Abdelkrim, Farid Bouchafa, "Experimental investigation of power management and control of a PV/wind/fuel cell/battery hybrid energy system microgrid", International Journal

of Hydrogen Energy, (Elsevier). Vol 45 (53); pp_29110–29122, October 2020, https://doi.org/10.1016/j.ijhydene.2020.07.251.

[2] S. M. Dehghan, M. Mohamadian,and A.Y.Varjani,"A New Variable-Speed Wind Energy Conversion System Using Permanent-Magnet Synchronous Generator and Z-Source Inverter " , IEEE, Trans. vol. 24, NO. 3, September 2009, pp 714- 724, https://doi: 10.1109/TEC.2009.2016022.

[3] Abdeldjalil Dahbi, Abdellatif Reama, Messaoud Hamouda, Nasreddine Naït-Saïd, Mohamed-Said Naït-Saïd, 'Control and study of a real wind turbine', Computers and Electrical Engineering (Elsevier), vol.80, N106492, pp_1- 16th, 2019, https://doi.org/10.1016/j.compeleceng.2019.106492.

[4] Hanzo.Power Conversion and Control of Wind Energy systems. Edition IEEE, press 2011.

[5] Dahbi Abdeldjalil, Hachemi Mabrouk, Nait said Mohamed Said, Nait Said Nasreddine ‘Realization and Control of a Wind Turbine Connected to the Grid by Using PMSG’, published in Energy Conversion and Management (EC&M) (Elsevier), Vol 84c, pp-346_353, Mai 2014, https://doi.org/10.1016/j.enconman.2014.03.085.

[6] Dahbi A, Nait-Said N, Nait-Said M-S. A novel combined MPPT-pitch angle control for wide range variable speed wind turbine based on neural network. Int J Hydrogen Energy2016;41.https://doi.org/10.1016/j.ijhydene.2016.03.105

[7] Ananthamoorthy N. P. ‘Speed and Torque Control of PMSM using Hybrid Fuzzy PID Controller’, Journal of Vibration and Control, Vol. 85 No 2 September, 2012, pp. 160 – 171, https://doi.org/10.1177/1077546313488160.