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PI/FL Based On PMSG for Wind Turbine Used in Wind Energy Conversion System

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Abstract— **Nowadays, the use of electrical energy in the agricultural sector is of a remarkable importance essentially in the pumping of water. The use of this type of energy increases the cost of the use of the pumping station is therefore the invoice of electrical energy. To reduce energy costs, wind power is a solution to produce electrical energy from clean and sustainable way. In this work we proposed a wind water pumping system consisting of a wind turbine with a synchronous permanent magnet generator coupled to a water pump. We have presented in the first part the system modeling and simulation of intelligent control wind conversion, taking into account both the constant or variable wind speeds. In the second part a presentation of the wind pumping system. The pumping system proposed has been analyzed and validated by Matlab simulation.**

Keywords*— *Wind, PMSG, Intelligent Control PI, Fuzzy Logic.

Introduction

Information about final paper submission is available from the conference website. Nowadays, there are different types of generator used wind turbines to convert electrical energy from wind power, such as the double-fed generator (MADA) and permanent magnet synchronous generator (PMSG) [1]. PMSG shows good performance, due to the absence of gearbox and most require no excitation current, for this, this type of wind turbine can avoid the problem of wear gear, it can help wind to operate more reliably and reduce risks [1-2]. This paper focuses on dynamic modeling of the wind system, modeling of the power turbine based on a synchronous machine with permanent magnets power controlled by a hysteresis rectifier for pumping 150V load.

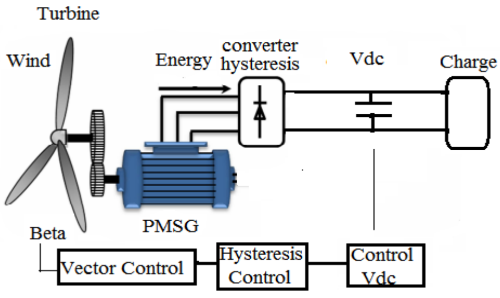
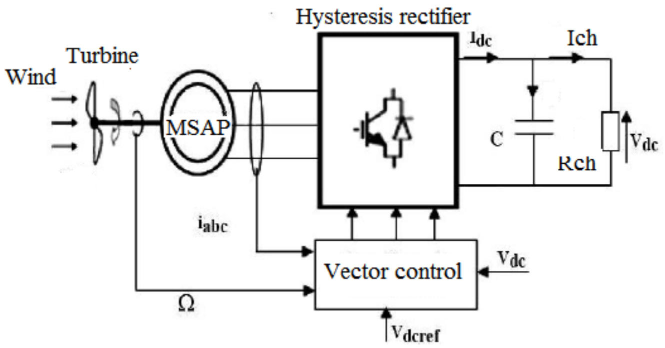


Fig. 1. General shematic control wind turbine PMSG system

I- MODELLING WIND GENERATOR



Structure of wind generato

The wind generator, consisting of a variable speed turbine coupled directly a synchronous permanent magnet generator via a rectifier converter hysteresis by regulating the current to a DC bus connected to the forward load is shoon in figure 2.

A. *Wind Turbine Model*

The wind turbine converts the kinetic energy of wind into mechanical energy. From the kinetic energy of the air mass of moving particles passing through the section of the active surface S of the wing, the power of the mass of air that passes through the area equivalent to the surface area S, wind is given by[10-14]:

$$P_w = \frac{1}{2}.\rho.S.v^3.C_p(\lambda,\beta) \qquad (1)$$

Where, $C_p(\lambda,\beta)$ is the power coefficient, λ is the speed ratio, β is the pitch angle, ρ is the air density, V is the wind speed and $S=\pi.R^2$ is the blades swept of the turbine.

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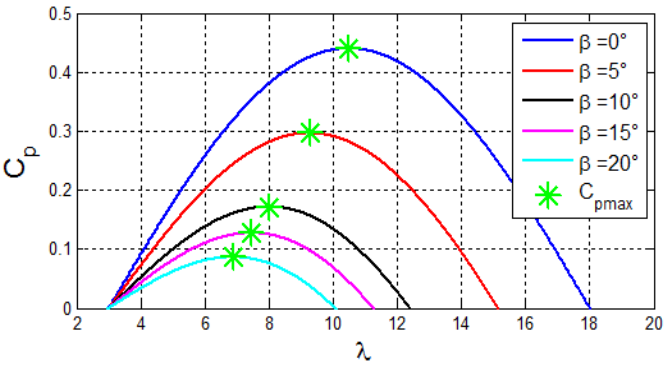

Fig. 2. Cp in terms of (β, λ) curve

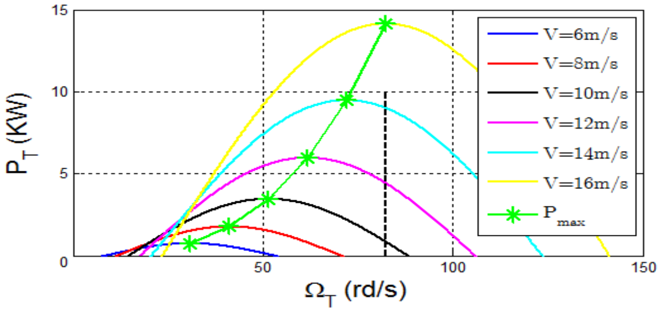

Fig. 3. Turbine Power with wind speed

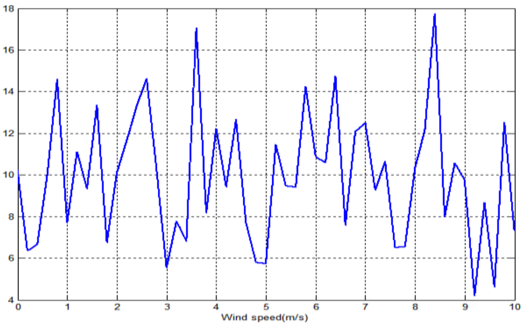

Fig. 4. Wind speed(m/s)

B. *Permanent Magnet Synchronous Machine Model*

In order to get a dynamical model for the electrical of the PMSG is the Park model that easily allows us to define the generator control system; the equations of the generator are projected on a reference coordinate system rotating synchronously with the magnet flux. The dynamic equations of the stator currents are given by: [4-7]

$$\begin{cases} v_d = R.i_d + L_s.\frac{di_d}{dt} - p.W.L_s.i_q \\ v_q = R.i_q + L_s.\frac{di_q}{dt} + p.W.L_s.i_d + p.Wj_f \end{cases} \quad (8)$$

Where, V_d and V_q are the d-q components of the stator voltages respectively, i_d and i_q are the d-q components of the stator currents respectively [14].

R is the phase resistance of the stator, Ls is the inductance cyclic of the stator, p is the number of pairs of poles and Φ_f is the permanent magnetic flux [4].

The electromagnetic torque equation of PMSG is:

$$T_{em} - T_r = J_m.\frac{dW}{dt} + f.W \quad (9)$$

Where the electromagnetic torque is:

$$T_{em} = 1,5.\frac{P}{2}.j_f.i_q = k_e.i_q \quad (10)$$

C. *Convert Model*

We model the rectifier by a set of ideals switches: that is to say zero resistance in the on state, infinite resistance in the off state, instantaneous response to control signals.
For the dynamic model of the system, we will divide the study of the converter into three parts: the AC side, the broken part composed by the switches and continuous side. In this context, the function of switches is to establish a connection between the alternating current side and the DC bus;

II- CONTROL WIND GENERATOR

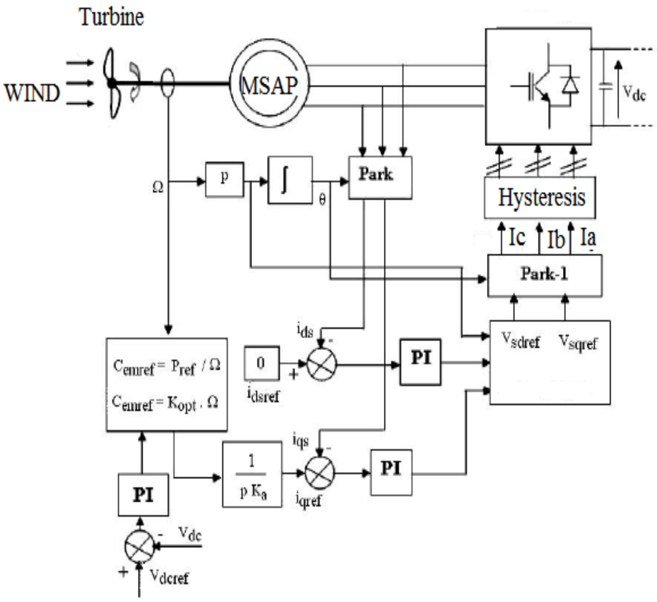

Fig. 5. Block diagram of the control of the rectifier and of the synchronous machine

A. *Control Generator*

The technique of vector control is used to establish a linear model and transform the synchronous machine with magnets in a structure equivalent to the current machine continuously separate excitation of the torque point of view, to permit decoupling of torque and flux. If the current Id is set to zero, as the constant flow, the torque is directly proportional to Iq,

$$C_e = k_t * I_q$$

Avec $k_t = p \cdot K_a$

B. Control Hysteresis

This strategy is an alternative to the control in the (a, b, c). She calls for the regulation of current Iq and Id to impose the reference currents and Idref and Iqref which are deducted sinusoidal reference voltages and Idref Iqref for rectifier control.

C. Currents Control

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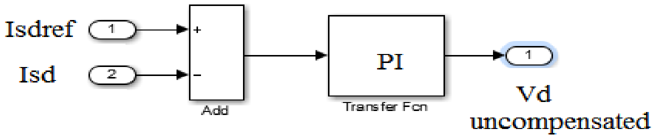

Fig. 6. Current control Isd, Isq loop with PI

D. DC Bus Control

The generator-side converter is controlled to catch the voltage load applied by the wind conversion. To size the voltage regulator, consider the following diagram, considering the performance of the hysteresis rectifier which uses voltage and loop current cascade, so here we will test the Vdc controller by two methods, regulation by the PI method and fuzzy logic method [14].

According to (10), in order to control the electromagnetic torque T_{em} , this study just controls the q-axis current i_q with the assumption that the d-axis current i_d is equal to zero. Furthermore, [8, 9], in order to catch maximum power, the optimum value of the rotation speed is adjusted. The tip speed ratio λ is obtained by the equation:

$$\Omega_{ref} = \frac{\lambda_{opt} \cdot V}{R} \tag{11}$$

Where, λ_{opt} is the tip speed ratio optimum and Ω_{ref} is the blade angular velocity reference.

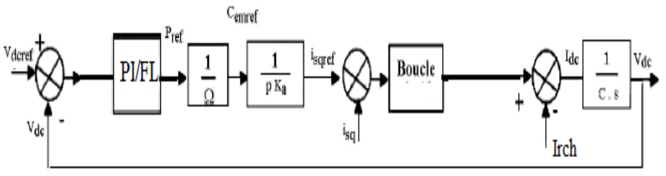

Fig. 7. Closed loop model for regulating the voltage Vdc with PI/FL

1) PI controller for DC bus

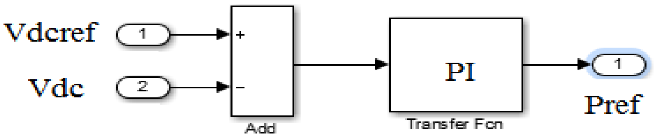

Fig. 8. Control Vdc with PI

2) Fuzzy logic controller for DC bus

The fuzzy logic controller for the DC bus has three parameters. The first input is the error of DC voltage, the second is the rate of change of error and the output is the power controlling current component. The inputs variables are calculated at every sampling instant say k [9].

$$e(k) = V_{dcréf}(k) - V_{dc}(k)$$

$$\Delta e = \frac{e(k) - e(k-1)}{T_s} \tag{12}$$

Where, $V_{dcref}(k)$ and $V_{dc}(k)$ are respectively; the reference and measured voltage at instant n.

In Fuzzification stage the crisp variables e(k) and Δe(k) are converted into fuzzy variables which can be identified by membership function. The fuzzification maps the error and change in error to linguistic labels of fuzzy sets.

The proposed controller uses following linguistic labels: NB (Negative Big), NM (Negative Medium), NS (Negative Small), NVS (Negative Very Small), Z(Zero), PVS (Positive Very Small), PM(Positive Medium), PB(Positive Big)[14].

TABLE I. RULES TABLE FOR DC BUS

e Δe	**NB**	**NM**	**NS**	**EZ**	**PS**	**PM**	**PB**
NB	NB	NB	NB	NB	NS	NP	EZ
NM	NB	NB	NB	NS	NP	EZ	PS
NS	NB	NB	NS	NP	EZ	PS	PM
EZ	NB	NS	NP	EZ	PS	PM	PB
PS	NS	NP	EZ	PS	PM	PB	PB
PM	NP	EZ	PS	PM	PB	PB	PB
PB	EZ	PS	PM	PB	PB	PB	PB

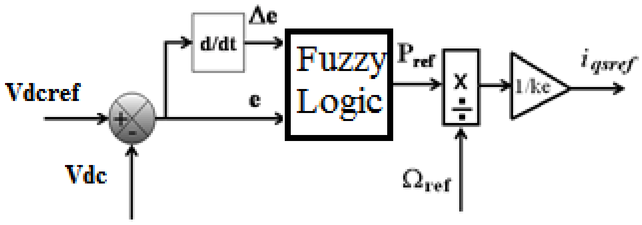

Fig. 9. Strategy Fuzzy DC bus controller

The activation function of both the output layer are linear and unbiased while that of the hidden layer is sigmoid and biased.

A. *Simulation Results and Discussion*

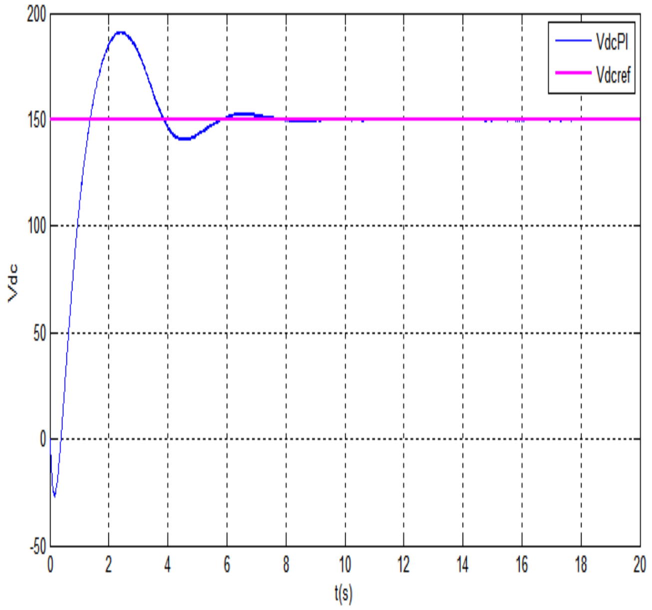

Fig. 10. DC voltage response with PI

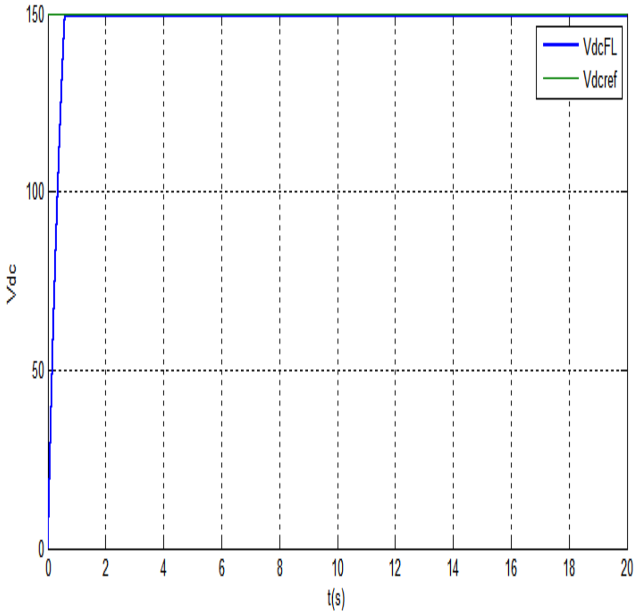

Fig. 11. DC voltage response with Fuzzy Logic

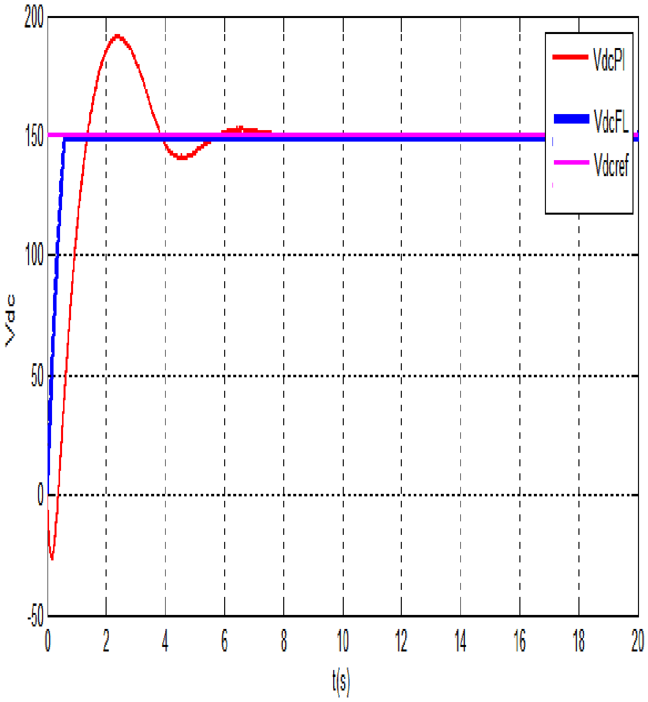

Fig. 12. Comparison between the different controllers

The operation of the complete system was simulated in MATLAB-Simulink environment. Using the electrical parameters of the machine (see annex).

The reference voltage at the rectifier output being taken as 150 V, we simulated the voltage rectified by two methods: the method of the PI controller is given by the figure 11, and by fuzzy logic method is shown in figure 12 by a model of variable speed wind.

CONCLUSIONS

This paper presents the dynamic model of PSMG wind generation system in Matlab/Simulink. The proposed method is based on fuzzy logic and PI controller to control the generator side bus with DC variable speed. Fuzzy logic controller capacity is checked and it is found that it has a faster response than the conventional PI controller. The results show that in combination with the two thequniques. The output will get the optimal power for charging [14].

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Wind Turbine Parameters
T=3000W
R = 2.04 m
$C_p = 0.49$

PMSG Generator Parameters
Pg=3800
Ld=Lq=8.3mh
J= 0.0026 $Kg.m^2$
n=1500 rpm
$R_s = 0.94\ \Omega$
$\Phi_f = 0{,}12$ Wb