Pitch angle control for variable speed wind turbine using dual star induction generator

H . Mesai Ahmed, A. Bentaallah, Y.Djeriri,
Electrical Department, Faculty of Electrical Engineering,
ICEPS Laboratory, Djillali Liabes University
Sidi Bel Abbes, Algeria

M. Allam
IRECOM-laboratory (Interaction REseau COnvertisseur Machines)
University Djillali Liabes of Sidi Bel-Abbes, Algeria

A. Mahmoudi
LMSE-laboratory (Modeling Energy Systems)
Mohamed khider universiry of biskra, Algeria

***Abstract*— In this paper, we suggest pitch angle control used with Maximum power pointe tracking MPPT for a 1.5 MW wind turbine lead dual star induction generator. Pitch angle control and MPPT algorithm are the most common means for adjusting the aerodynamic torque of the wind turbine when wind speed is less or above rated speed. Various controlling variables may be chosen, such as wind speed, generator speed and generator power. The simulation results obtained with a random wind speed are presented in order to prove the validity of the proposed control.**

Keywords– Wind energy – DSIG - Maximum Power Point Tracking (MPPT) – Pitch control.

I.INTRODUCTION

Wind energy has an ecologically advantage over various other sources of energy such as coal, wood, and oil, but the initial cost is still high [1]. Squirrel cage induction motors are the most commonly used electrical machine in AC drives, because they are robust, cheap and have low maintenance cost . These advantages make the induction machine very attractive for wind power applications both for fixed and variable speed operation[2].

In order to increase the power of a drive system AC Power machine multi-Phase induction appeared an ultimate solution. Multiphase (more than three phases) drives have several advantages compared with conventional AC motors, such as reducing the amplitude and increasing the frequency of torque pulsations, reducing the rotor harmonic currents, reducing the current per phase without increasing the voltage per phase, lowering the dc-link current harmonics, and higher reliability. By increasing the number of phases it is also possible to increase the power /torque per rms ampere for the same volume machine [3]. A common type of multi- phase machine is the dual stator induction machine (DSIM), also known as the six phase induction machine. Generally, in a variable speed wind energy system, below rated wind velocity, the electrical torque is controlled in order to drive the system into an optimum speed for maximum energy conversion [2]

This paper presents a detailed modeling and control of DSIG in power generation for improving the wind energy utilizing rate. Firstly, the characteristics of VSCF wind turbine are analysed . Also, it introduces an effective control strategy to track the maximum wind energy capture by controlling the speed signals are all adopted pitch angle for generator optimal rotating-speed control, secondly, a mathematic model of DSIG is proposed, Finally, the whole wind generation system model is established, and simulating results indicate that deducting ability of turbine rotating-speed control is improved and wind turbine generating ability is enhanced.

II. WIND TURBINE MODEL

a. Modeling of the Wind Turbine and Gearbox

A theoretically undisturbed wind would cross this same surface S without a decrease in speed, the corresponding power Pv would then be[5] :

$$P_v = \frac{1}{2}\rho\pi R^2 V^3$$

Where V is the wind speed (m /s), ρ is the density of the air and R is the length of a blade or the radius of the wind turbine (m).

The wind turbine can recover only a fraction of the power of the wind and the aerodynamic power appearing at the rotor of the turbine is then written [6] [7]:

$$P_t = C_p P_v = \frac{1}{2}\rho\pi R^2 V^3 C_P(\lambda,\beta)$$

Where Cp (λ) is the power factor characterizes the aerodynamic efficiency of the turbine (Figure 1) .It depends on: the dimensions of the blade, the angle of orientation of the blade β and the ratio of the speed λ. The relative velocity λ is defined as the ratio between the linear speed of the blades (Ωt R) and the wind speed as follows[4] [8] [9]:

$$\lambda = \frac{\Omega_t R}{V}$$

Where Ωt (rad / s) is the mechanical speed of the turbine shaft.
The torque exerted by the wind on the turbine shaft is defined by:

$$C_t = \frac{P_t}{\Omega_t} = \frac{1}{2}\rho\pi R^3 V^2 C_c(\lambda,\beta)$$

Where Cc represents the torque coefficient:

$$C_c = \frac{C_P}{\lambda}$$

The gearbox conversion ratio *(r_{gb})*, is designed to match the low-speed turbine blades with the high-speed generator [10]. For a given rated speed of the generator and turbine, the gearbox ratio can be determined by:

$$C_g = \frac{C_t}{G} \qquad \Omega_t = \frac{\Omega_g}{G}$$

where Ω_t and Ω_g are the turbine and generator rated speeds in rpm.

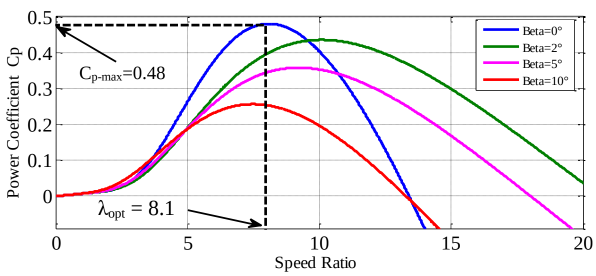


Fig.1 Coefficient of the pair Cp as a function of λ for different β.

in our work, we will use an empirically approximated expression for a high-power wind turbine [9]-[11]., is defined as follows:

$$C_p(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)\exp\left(\frac{-21}{\lambda_i}\right) + 0.0068\lambda$$

With: $\dfrac{1}{\lambda_i} = \dfrac{1}{\lambda + 0.08\beta} - \dfrac{0.035}{\beta^3 + 1}$

The characteristics of the optimal aerodynamic power of our wind turbine is expressed by:

$$P_t^{opt} = \frac{1}{2}\rho\pi R^2 V^3 C_p^{\max}(\lambda_{opt}, \beta_{opt})$$

This relation shows that a small variation of the wind speed V induces a large variation of the generated power Pt. From this effect, it is assumed that the electromagnetic torque developed by the machine is equal to its reference value whatever the power generated , MPPT algorithm :

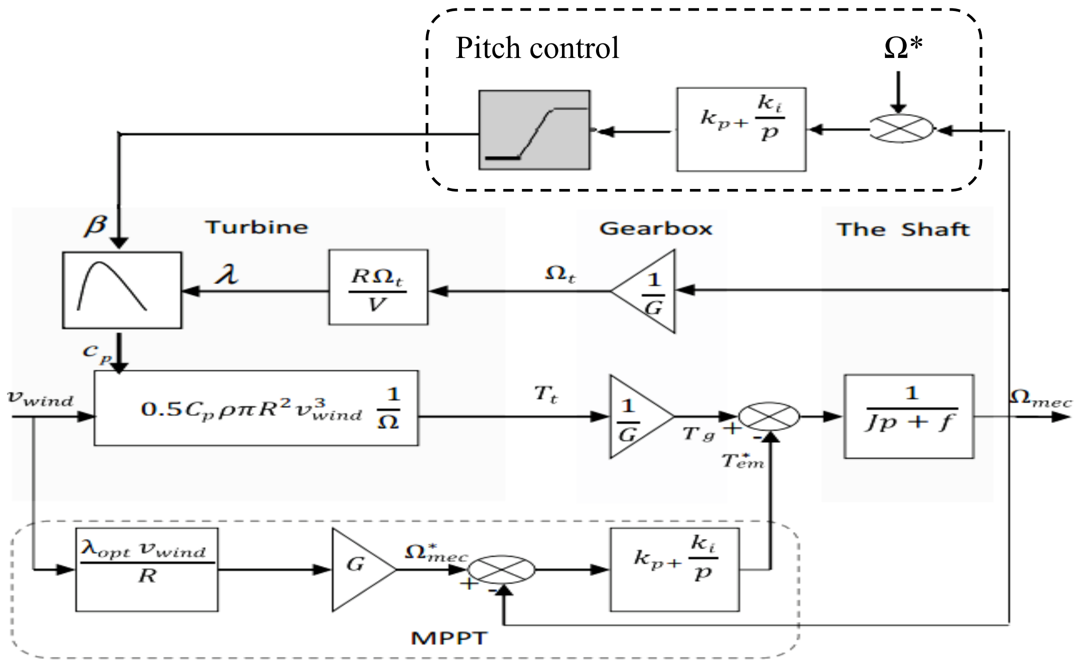


Fig. 2 Block diagram of the turbine model with variable speed control

b. Dual Star Induction Generator Model

The model of dual stator induction machine is composed of a stator with two identical phase windings shifted by an electric angle α =30°, and a squirrel cage rotor[12].

Under the assumptions of magnetic circuits linearity, and assuming sinusoidal distributed air-gap flux density[13] [14], the equivalent two-phase model of dual stator induction machine, represented in asynchronous frame (d, q) and expressed in state-space form, is a fourth-order model [9]-[11]:

$$\left[\dot{I}\right]=\left[L^{-1}\right]\left\{[B][U]-\omega_{gl}[C][I]-[D][I]\right\}$$

Where:

$$[U]=\begin{bmatrix}V_{ds1} & V_{qs1} & V_{ds2} & V_{qs1} & V_{dr} & V_{qr}\end{bmatrix}^{T};$$

$$[I]=\begin{bmatrix}I_{ds1} & I_{qs1} & I_{ds2} & I_{qs1} & I_{dr} & I_{qr}\end{bmatrix}^{T};$$

$$[B]=diag\begin{bmatrix}1 & 1 & 1 & 1 & 0 & 0\end{bmatrix}$$

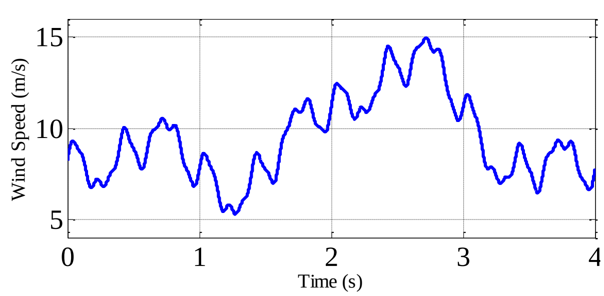
$$[C]=\begin{bmatrix}0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&0&0&0&0&0\\0&-Lm&0&-Lm&0&-(Lr+Lm)\\Lm&0&Lm&0&Lr+Lm&0\end{bmatrix}$$

$$[L]=\begin{bmatrix}(Ls1+Lm)&0&Lm&0&Lm&0\\0&(Ls1+Lm)&0&Lm&0&Lm\\Lm&0&(Ls2+Lm)&0&Lm&0\\0&Lm&0&(Ls2+Lm)&0&Lm\\Lm&0&Lm&0&(Lr+Lm)&0\\0&Lm&0&Lm&0&(Lr+Lm)\end{bmatrix}$$

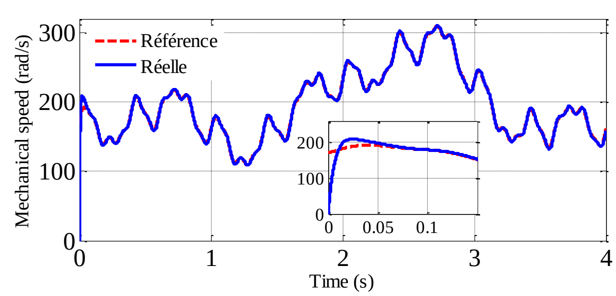
$$[D]=\begin{bmatrix}Rs1&-ws(Ls1+Lm)&0&-wsLm&0&-wsLm\\ws(Ls1+Lm)&Rs1&wsLm&0&wsLm&0\\0&-wsLm&Rs2&-ws(Ls2+Lm)&0&-wsLm\\wsLm&0&ws(Ls2+Lm)&Rs2&wsLm&0\\0&0&0&0&Rr&0\\0&0&0&0&0&Rr\end{bmatrix}$$

III. SIMULATION RESULTS

The proposed model of the variable speed wind turbine with DSIG is constructed with MATLAB/Simulink, The main parameters simulation model are shown as table 1.



(a)



(b)

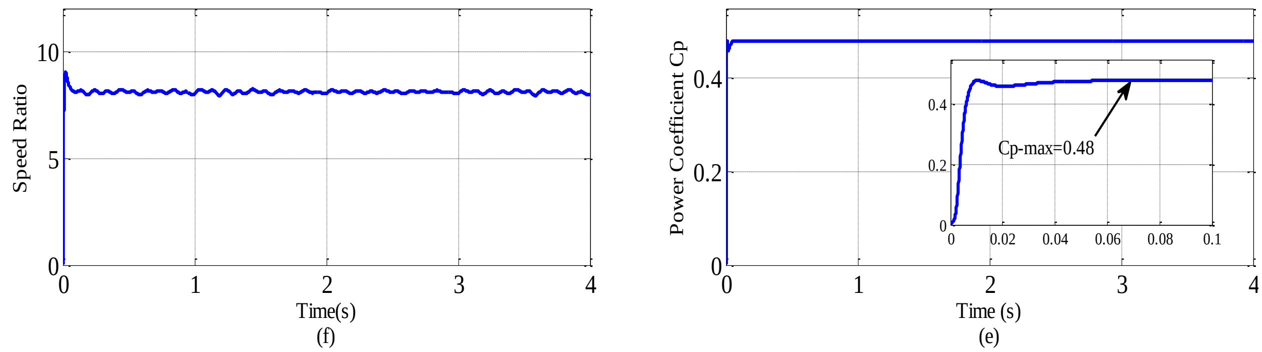


Fig.3 Wind turbine performances with MPPT control

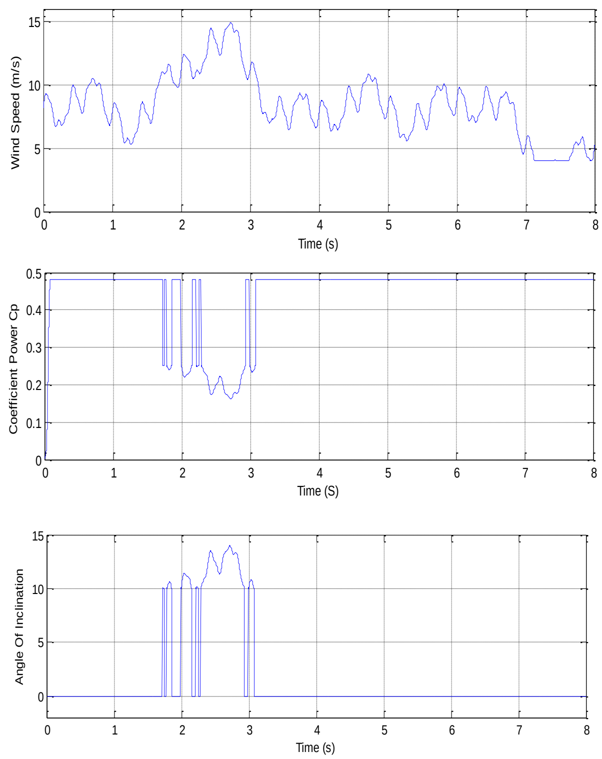


Fig.4 Wind turbine performances with MPPT and PITCH control

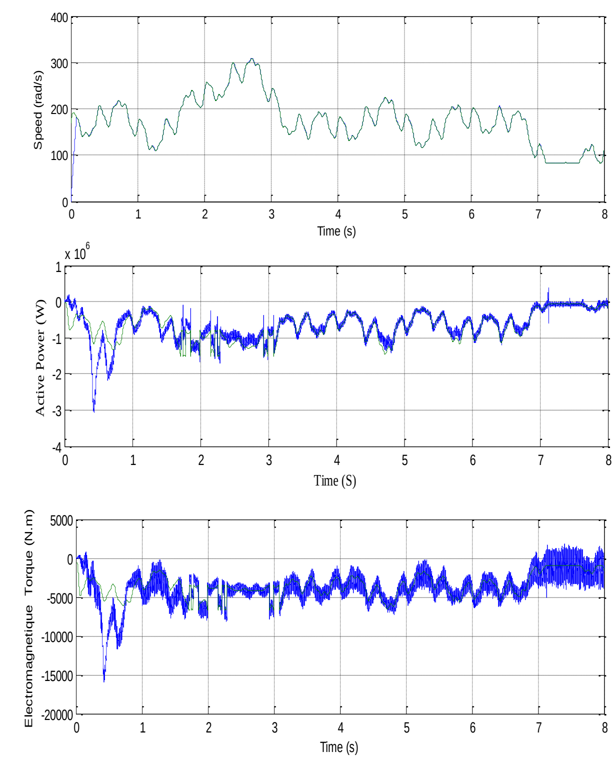


Fig.5 DSIG performances with MPPT and PITCH control

VI. Conclusion

This paper present a performance study with simulation of a variable-speed wind turbine based dual star induction generator, a detailed mathematical model of DSIG integrating to wind turbine with MPPT algorithm is developed and a pitch angle controller has been added to limit wind speed in order that regulate the aerodynamic power generated by the wind turbine.

The MPPT-PITCH proposed approach achieves good performances for power extraction below rated speed and regulate the pitch angle above rated speed over by PI controller

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- ***Abbreviations and Acronyms***

L_m	Magnetizing inductance
R_r	Rotor resistance
R_{s1}, R_{s2}	Stator resistances
L_r	Rotor inductance
L_{s1}, L_{s2}	Stator inductances
ω_s	Synchronous reference Speed
ω_{gl}	Rotor electrical angular speed
$V_{ds1.2}$,$V_{qs1.2}$	d-q stator voltages
V_{dr} ,V_{qr}	d-q rotor voltages
I_{ds} I_{qs}	d-q stator currents
I_{dr} I_{qr}	d-q rotor currents
P_s Q_s	Active and réactive Power
T_{em}	Electromagnetic Torque
DSIG	Dual star Induction Generator
MPPT	Maximum Power Pointe Tracking

TABLE I. Appendix parameters

Turbine					
R (m)	Number of blades	G	C_{pmax}	λ_{opt}	
35.25	3	90	0.48	8.01	
DSIG					
P_n (MW)	U_s (V)	F (Hz)	Pair poles	I_n (A)	U_{dc} (V)
1.5	400	50	2	2000	1130
R_{s1} ,R_{s2} (Ω)	R_r (Ω)	L_{s1} , L_{s2} (H)	L_r (H)	L_m (H)	J (kg.m^2)
0.008	0.007	1.34e-4	6.7e-5	0.0045	1000

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