CONTROL OF PITCH ANGLES TO OPTIMIZE THE AERODYNAMIC USING PARTICLE SWARM OPTIMIZATION

BELGHAZI OUISSAM, DOUIRI MOULAY RACHID CHERKAOUI MOHAMED

***Abstract*—**The main objective of this paper is to maximize the energy captured by the wind turbine. The wind turbine is an energy converter device that captures energy from the wind and converts it into useful work. Pitch angle control is the most common means for adjusting the aerodynamic torque of the wind turbine when the wind speed is higher than the speed and control variables evaluated can be chosen, as the energy of the wind speed, the generator.

Different methods are available to control the pitch angle. In a previous work, we proposed the pitch angle control using the particle swarm optimization. The particle swarm optimization control strategy may have the potential when the system contains a strong non-linearity, such as the control objectives include fatigue loads or wind turbulence is strong.

The simulation results by using actual detailed model for wind power system confirmation the effectiveness of the proposed methodology..

***Keywords*—**Wind Turbine, Particle Swarm Optimization, Control, Pitch Angle..

I. INTRODUCTION

THIS rapid transition to green technology anywhere in the world, wind power is emerging as a serious source of new clean energy. The most thorough studies to date find the potential of wind energy on land and near-shore to be approximately 72 terawatts. Currently humans use about 7 terawatts from all sources globally. At the end of 2009, the installed capacity of wind farms in morocco reaches 253 MW, which is increased by 395, 31% compared with 2006. The state electricity to come from renewable energy sources and a goal of installing 2000 MW, of wind power in Morocco by 2020.

In the early stage of development of the wind energy, most wind farms have been equipped with fixed speed wind turbines and induction generators.

Since the wind generators can only operate at a constant speed, the power efficiency is fairly low for most wind speeds [1].

then Several research results have recently been reported on this control of wind turbine generator. In PID control was investigated under varying wind conditions to overcome the disadvantage of designing and tuning conventional PID controllers for capturing maximum wind power.

The modern heuristic techniques mainly include the application of the Artificial Intelligence (AI) approaches such as Particle Swarm Optimization (PSO)

In the proposed paper, is develop an intelligent controllers capable of capturing of a large scale wind energy

To tackle with the challenges from the scale of calculation, it is necessary to introduce an artificial intelligence method to seek the optimal in the large solution space. Here, we choose the particle swarm optimization (PSO) as the optimization approach for its adaptability and quick converging capacity.

PSO is selected partly because it has been used in solving similar problems such as part machine grouping [2] and manufacturing cell design [3], as well as it is found more robust [4]. On the other hand, the authors prefer PSO for its high efficiency in maintaining the diversity of the swarm, ease to adjust parameters, and no requirement for differentiable optimization problem.

The PSO algorithm was first introduced by Kennedy and Eberhart [5]. It was developed through simulation of social behaviors such as fish schooling and bird flocking.

The PSO provides a population-based search procedure in which the individuals, called particles, change their positions with time. Each particle adjusts its position according to its own best experience and the best experience of neighboring particles.

The particle swarm optimization (PSO) algorithm is a stochastic search technique, motivated by social behavior simulation of bird flocking or fish schooling, first developed by Kennedy and Eberhart [1].

Compared to other evolutionary algorithm, it has many advantages such as easy realized, fast convergent, promising performance on nonlinear function optimization. Many researchers have devoted to improve its performance in various ways, and many efficient results are detained. In these methods, cooperation methods play a very important role in improving performance of PSO.

In this paper, a PSO pitch angle controller is designed and analyzed. The simulations of the pitch angle control strategies are carried out and the conclusions are drawn at last.

II. MODELING OF THE WIND TURBINE

The wind turbine converts energy of wind flow into mechanical energy. The turbine shaft drives the generator rotor through drive train. A wind turbine is a complicated mechanical structure which consists of rotating blades, shafts, gearbox, electric machine, i.e., generator, and tower. Sophisticated design codes are necessary for predicting a wind turbine's performance and structural responses in a turbulent wind field. However, the simple drive train model of Fig. 1 and .2 is sufficient for the control system design [6] [7].

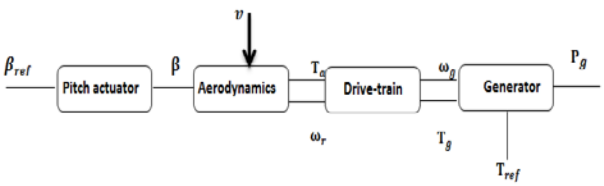

Fig. 1 Overall structure of the wind turbine model.

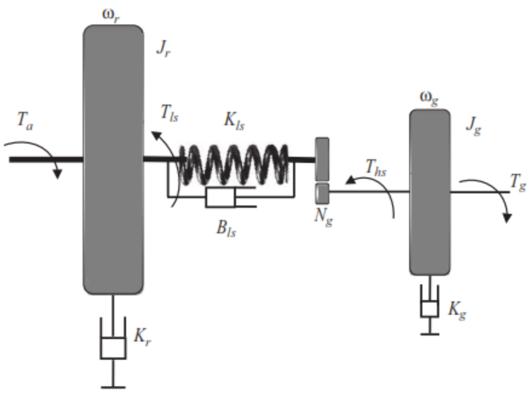

Fig 1 Wind turbine drive-train dynamics

The mechanical power of an air mass which has a flow rate of $\frac{dm}{dt}$ with a constant speed of v is given by Eq. (1).

$$P_{wind} = \frac{d(E)}{dt} = \frac{d\left(\frac{1}{2}mv^3\right)}{dt} = \frac{1}{2}\frac{dm}{dt}v^2 = \frac{1}{2}\rho A v^3 \qquad (1)$$

Where ß is the air density and A is the cross-sectional area of the air mass. Only a portion of the wind power given by Eq. (2) is converted to electric power by a wind turbine. The efficiency of the power conversion depends on the aerodynamic design and operational strategy of the wind turbine. Usually, the power generated by the wind turbine is represented by:

$$P = C_p P_{wind} = C_p\left(\frac{1}{2}\rho\pi R^2 v^3\right) \qquad (2)$$

Cp value is calculated using a generic equation proposed in [5] given by Eq. (3) Fig. 3

$$C_p(\lambda, \beta) = c_1\left(\frac{c_2}{\lambda_i} - c_3.\beta - c_4\right)e^{-\frac{c_5}{\lambda_i}} + c_6.\lambda \qquad (3)$$

Where $$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1+\beta^3}$$

And tip speed ratio λ which is defined as:

$$\lambda = \frac{R\Omega_r}{v}$$

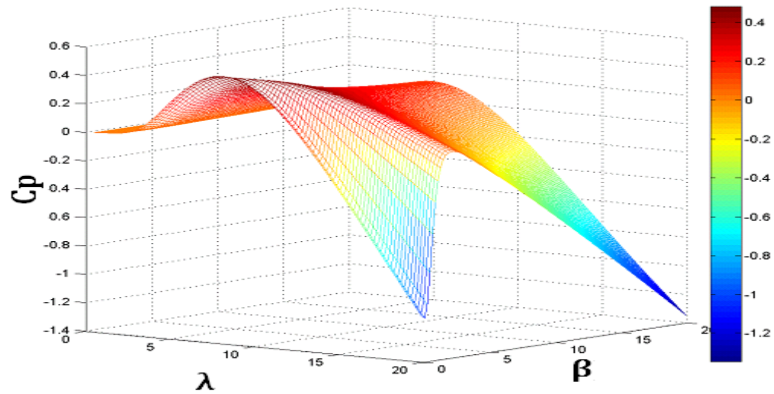

Fig 2 Power coefficient as a function of the tip-speed ratio and pitch angle

Where Cp represents the efficiency of wind power conversion and is called the power coefficient. R in the above equation is the rotor radius. The ideal maximum value of Cp is 16/27= 0.593, which is known as the Betz limit [8]. As shown in Fig.4, the power coefficient, Cp is a function of pitch angle β.

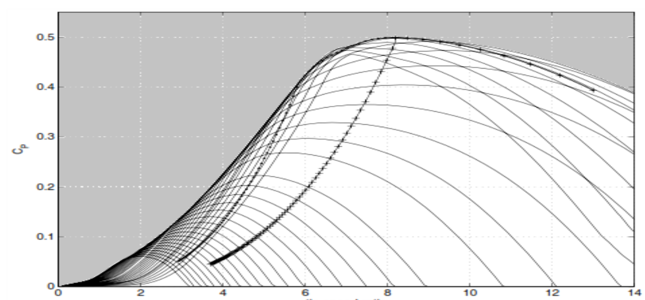

Fig 3 Power coefficient Cp vs tip speed ratio for various of pitch angles

The operating region of a wind turbine depends on the wind speed and is divided into three zones; the no generation zone, the partial load zone, and the full load zone in Fig.5 [5].

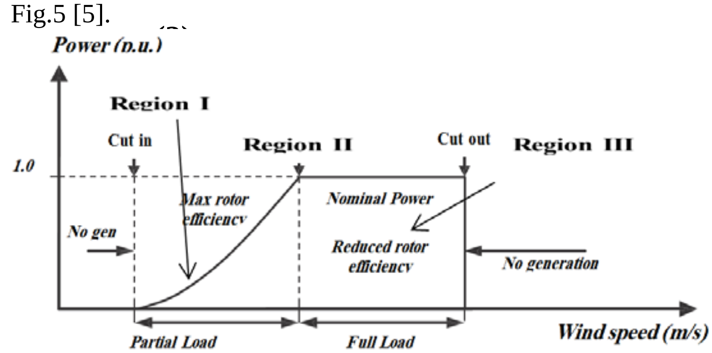

Fig 4 Wind turbine operating regions

- ***Region I:*** The blade pitch angle is fixed at β_0 and the rotor speed is varied so as to maintain the tip speed ratio constant

(λ_0). Therefore, the rotor speed changes proportional to the wind speed by controlling the generator reaction torque. In the *region I*, only the generator torque control is active, while the blade pitch is fixed at β_0.

- ***Region II:*** This is a transition region between the other two regions, that is, the Cp_{MAX} (***Region I***) and power regulation region (***Region III***). Several requirements, such as a smooth transition between the two regions, a blade-tip noise limit, minimal output power fluctuations, etc., are important issues in defining control strategies for this region.

- ***Region III:*** This is the above rated wind speed region,where wind turbine power is regulated at the rated power. Therefore, the rotor speed and the generator reaction torque are maintained at their rated values. In this power regulation region, the blade pitch control plays a major role [10].

III. THE PARTICLE SWARM OPTIMIZATION

The PSO simulates many species that live in groups, like the behaviours of bird flocking. Consider the following scenario. A group of birds are randomly searching for food in an area.

There is only one piece of food in that area being searched. All the birds do not know where the food is, but they know how far the food is in each iteration. So what is the best strategy to find the food?. The effective one is to follow the bird which is nearest to the food.

PSO learned from this scenario and used it to solve the optimization problems. In PSO, each single solution is a “bird” in the search space. Here it is called as a “particle”. All the particles have fitness values, which are evaluated by the fitness function to be optimized and have velocities which direct the flight of the particles. The particles are “flown” through the problem space by following the current optimum particles.

PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following the two “best” values. The first one is the best solution (fitness) it has achieved so far (the fitness value is stored). This value is called as the p-best. Another “best” value is tracked by the particle swarm optimizer is the best value, obtained so far by any other particle in the population. This best value is the global best and called as the g-best. When a particle takes part of the population and its topological neighbors, the best value is the local best and is called the i-best. After finding the two best values, the particle updates its velocity and positions with following Eq. (4) and (5) [9].

$$V\_i\ (t+1) = wV\_i\ (t) + c\_1\ r\_1\ (P\_pbest\ (t) - P\_i\ (t)) \quad (4)$$
$$+c\_2\ r\_2\ (P\_gbest\ (t) - P\_i\ (t))$$

$$V_i(t+1) = wV_i(t)(t) + V_i(t+1) \quad (5)$$

The vector $P_i(t) = [p_{i1}, p_{i2} \ldots\ldots p_{in}]^T$ stands for the position of the ith particle;

$V_i(t) = [v_{i1}, v_{i2} \ldots\ldots v_{in}]^T$ stands for the velocity of the ith particle;

P_{pbest} is the best position that the ***ith*** particle has achieved so far; and P_{gbest} is the best position of current generation.

w is the inertia weight, small value benefits for local convergence and the large value benefits for global convergence. In general, the value of w is between ***0.4 and 0.9***. c_1, and c_2 are called cognitive learning rate and social learning rate, respectively; the typical values of them are equal to 2, the pseudocode of PSO is shown in Fig.6.

```
If  v_i(t+1) > v_max
    Then  v_i(t+1) = v_max
      Else if v_i(t+1) < -v_max
      Then v_i(t+1) = -v_max
If  p_id(t+1) > p_max
    Then  p_id(t+1) = p_max
      Else if p_id(t+1) < p_min
      Then p_id(t+1) = p_min
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Fig 5 the pseudocode of PSO

Where p_{max} and p_{min} are the maximum and minimal radii of variables, respectively; vmax is the maximum velocity of particles.

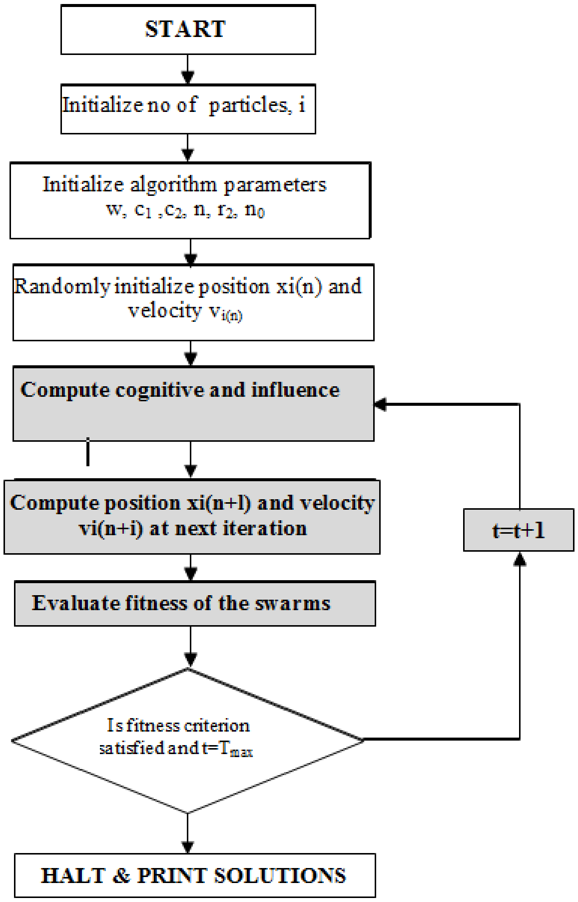

Fig 6 The PSO flowchart

IV. SIMULATION RESULTS

In this section in order to evaluate the performance of the PSO controller, the simulation results obtained by MATLAB/SIMULINK. Where Ω_r are the rotor speed of the wind turbine.

The curves Figs 3 and 4 shows the variation of Cp with λ tip speed ratio for a fixed pitch angle of β in β_0. As the pitch angle is away from β0, the value of Cp becomes. smaller. Therefore, Cp has the maximum with the condition of λ_0 and β0 by proposed PSO control strategy. For a wind turbine to extract the maximum energy from the wind, the wind turbine should be operated with the Cp_{MAX} condition, Fig 8 shows the overall control strategy.

That is, the wind turbine should be controlled to maintain the fixed tip speed ratio of λ in λ_0 with the fixed pitch of $\beta_0 = \beta_{PSO}$ in spite of varying wind speed. Referring to Eq. there ought to be a proportional relationship between the wind speed v and the rotor speed Ω_r to keep the tip speed ratio at constant value of λ_0. The wind turbine simulation based on the PSO flowchart of is shown in Figs 9.

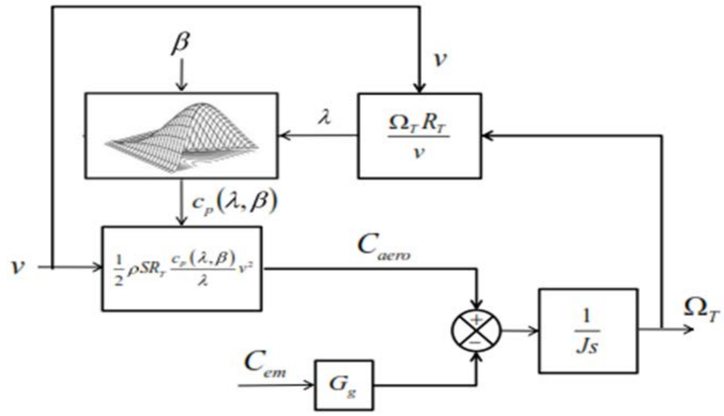

Fig 8 The Overall Control Strategy PSO

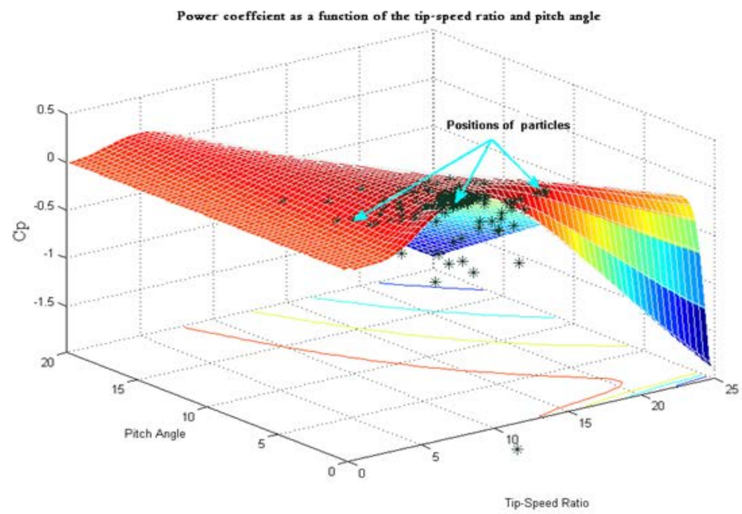

Fig 9-a The evolution the PSO Controller for the pitch angle of wind turbine t=0

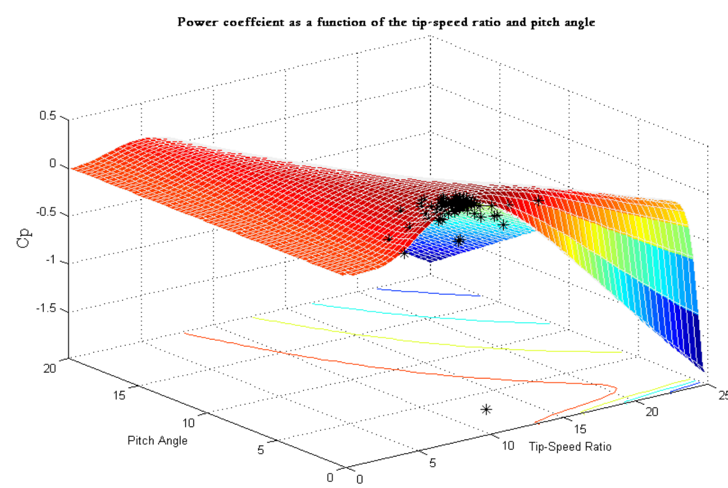

Fig 9-b The evolution the PSO controller for the pitch angle of wind turbine t_i

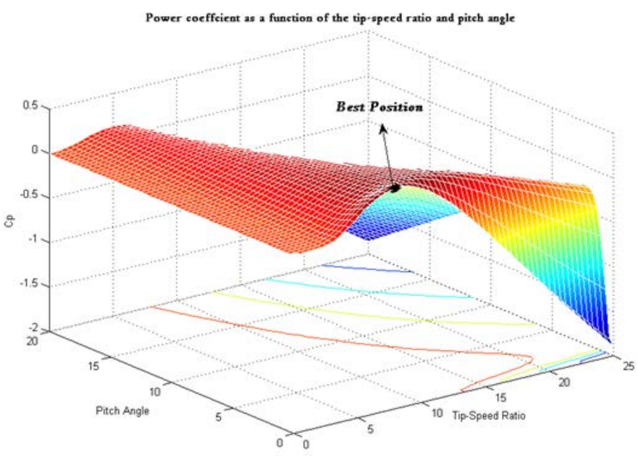

Fig 9-c The evolution the PSO controller for the pitch angle of wind turbine t=T_{MAX}

In PSO Controllers, variable wind speed data given in Fig.10 –a are applied to test the system. Wind speeds varied considerably in short periods of time between **t=0s** and **t = 50s.** The proposed optimization strategies are examined in figs.10, with some of the parameters of PSO that is used are shown in Table 1.

Table .1 Parameters OF PSO

Parameters	Values
Swarm size	20
Max iteration	100
Inertia weight factor (w)	0.73
Confidence coefficients (c1 ¼ c2)	

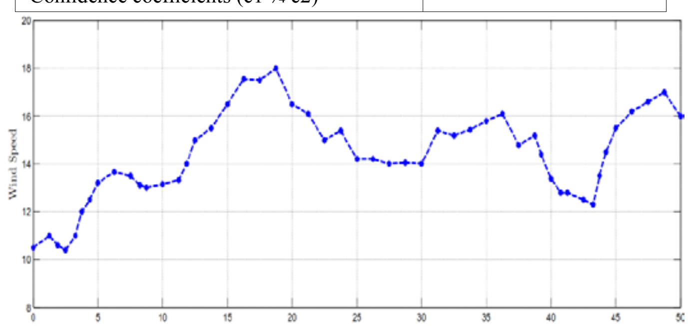

Fig 10-a Wind Speed Variations

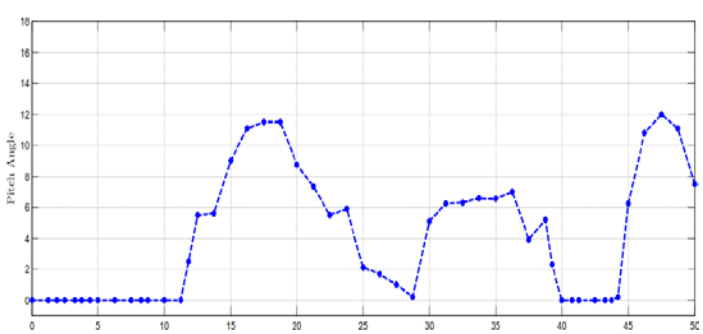

Fig 10-b Pitch Angle Variations

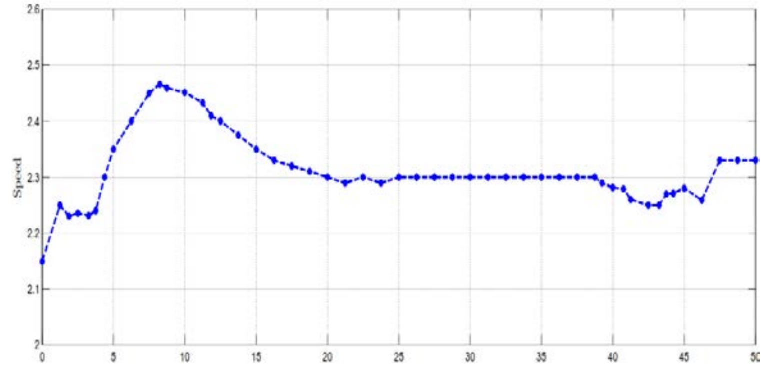

Fig 10-c Rotor Speed Variations

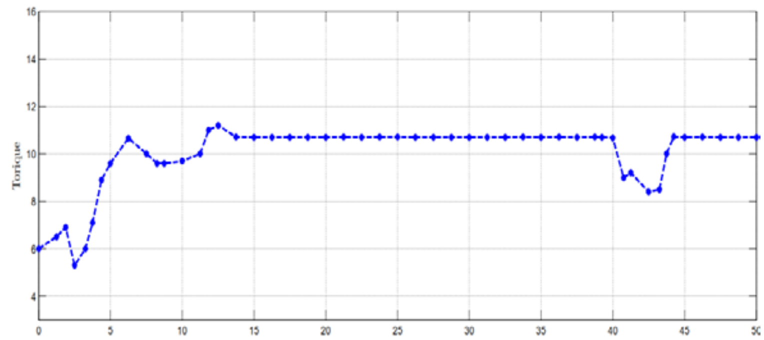

Fig 10-d Torique Variations

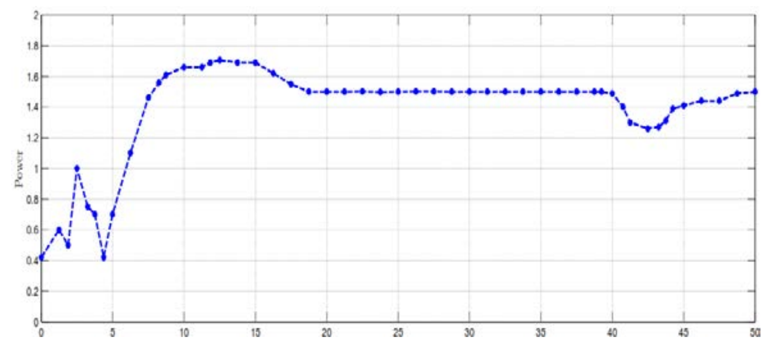

Fig 10-e Power Variations

Power generation is below the rated power due to the wind speed being low <13m/s, between t=0s and t = 12s; and between t = 40s and t = 44s.

Whole the speeds of wind starts apply to 14 m/s and reach 19 m/s the curves of power, output speed of the generator and Torique are illustrated in Figs. 10

In the study, pitch angle intelligent controllers are used to make the braking of the turbine blades in the wind speeds most >13m/s. When the wind speed has increased over the nominal speed, the field controller prevented overcharging of the turbine, and does not allow the production of a superior power than the rated power of the system.

The angle of inclination of the blade is increased so that of turbine blades are braked and slowed down as can be seen in Fig. 10-b. The pitch angles of the performances were modified according controller outputs PSO trained.

The intelligent controller is proposed to blade pitch position control above the rated wind speed. Actually, the controller gave better results. Simulated wind turbine parameters are obtained from a real turbine and generating system. Hence, proposed controllers can be easily adapted to real time applications.

V. CONCLUSIONS

The proposed optimization strategies are examined, the wind turbine is a complicated non-linear process involving multi parameters, multi inputs and multi outputs. In this research, parameter optimization for based on regression analysis and the PSO algorithm.

The evolution algorithm of particle swarm optimization (PSO) is then applied to obtain for wind turbine is operated so as to extract the maximum energy from the wind. The validity of the model and the optimization technique is validated using a case study on a wind turbine model.

The simulation results have shown the superiority of proposed method in comparison with the commonly used methods in capturing maximum power.

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