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PITCH ANGLE CONTROL FOR VARIABLE SPEED WIND TURBINES USING GENETIC ALGORITHM CONTROLLER

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ABSTRACT

The pitch angle control is the most common means for adjusting the aerodynamic torque of the wind turbine when we rate wind speed, controlling various variables could be chosen, as generator power, generator speed and wind. As conventional pitch control customarily use PI controller, the mathematical model of the system should be well known. The controller design by the genetic algorithm is developed in this paper. The genetic algorithm control strategy may have the potential when the system contains strong non-linearity, such as wind turbulence is strong. The design of controller strategies at is minimum will address the following elements: Optimization of power production with simultaneous load reduction of the main wind turbine components, Adapt control with respect to real operational conditions.

In my research I found out that the genetic algorithm controller can achieve better control performances than conventional pitch angle control strategies.

Keywords: *Pitch Angle, Genetic Algorithm, Wind, Turbine, Control*

1. INTRODUCTION

Electricity generation from renewable resources, and particularly from the wind, is considered today as a competitive and necessary alternative to fossil resources.

Wind turbines can operate with either fixed speed (actually within a speed range about 1 %) or variable speed, Pitch-adjusting variable-speed wind turbines have become the dominating type of yearly installed wind turbines in recent years, Several reasons, such as the reduction of both the mechanical structure stresses and the acoustic noise and the possibility to control active and reactive power, have driven the choice for variable speed operation of wind turbines.

In fact, variable speed operation increases the energetic efficiency and reduces the drive train torque and the energy of generating flow unsteadiness [1].

Control of variable-speed fixed-pitch in the partial load regime generally aims at regulating the power harvested from wind by modifying the electrical generator speed; in particular, the control goal can be to capture the maximum power available from the wind. For each wind speed, there is a certain rotational speed at which the power curve of a given wind turbine has a maximum

There are usually two controllers for the variable-speed wind turbines which are cross-coupled each other.

In low wind speed below rated value, the speed controller can continuously adjust the speed of the rotor to maintain the tip speed ratio constant at the level which gives the maximum power coefficient, and then the efficiency of the turbine will be significantly increased, the generator is controlled by power electronic equipment, which makes it possible to control the rotor speed. In this way the power fluctuations caused by wind variations can be more or less absorbed by changing the rotor speed and thus power variations originating from the wind conversion and the drive train can be reduced.

Pitch angle regulation necessary in the in conditions above the rated wind speed when the rotational speed is kept constant. Small changes in pitch angle can have a dramatic effect on the power output. The purpose of the pitch angle control can be expressed as follows [2-4]:

Therefore, control systems for variable speed wind turbines should continue to evolve towards more and more effective and innovative solutions, also

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based on soft-computing methodologies, such as artificial intelligence and genetic

The output power of the turbine is given by the following equation:

$$P_a = \frac{1}{2}\rho\pi R^2 C_p\,(\lambda, \beta)\, v^3 \qquad (1)$$

Where ρ is the air density, A is the turbine swept area; v is the wind speed and the power coefficient Cp. The power coefficient is a non-linear function depending on the tip speed ratio λ and β blade pitch angle. $C_p = C_p(\lambda, \beta)$.

λ is defined as

$$\lambda = \frac{\Omega_t * R}{V_{wind}} \qquad (2)$$

Where Ω_t the rotation speed of the rotor, R is is the rotor radius and V_{wind} the wind speed.

The produced torque, T_t of the turbine can be found from

$$T_t = \frac{P_a}{\Omega_t} \qquad (3)$$

Cp value is calculated using a generic equation proposed in [5] given by

$$C_p(\lambda,\beta) = c_1\left(\frac{c_2}{\lambda_i} - c_3.\beta - c_4\right)e^{-\frac{c_5}{\lambda_i}} + c_6.\lambda \qquad (4)$$

Where

$$\frac{1}{\lambda_i} = \frac{1}{\lambda+0.08.\beta} - \frac{0.035}{1+\beta^3} \qquad (5)$$

With $c_1 = 0.5176$, $c_2 = 116$, $c_3 = 0.4$, $c_4 = 5$, $c_5 = 21$, $c_6 = 0.0068$

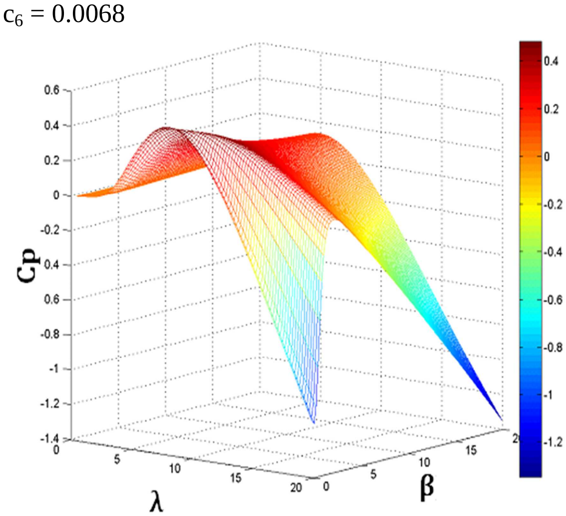

Figure 1. *Power coefficient as a function of the tip-speed ratio and pitch angle*

Fig. 1 shows that the average power conversion coefficient Cp, is maximum at a particular λ.

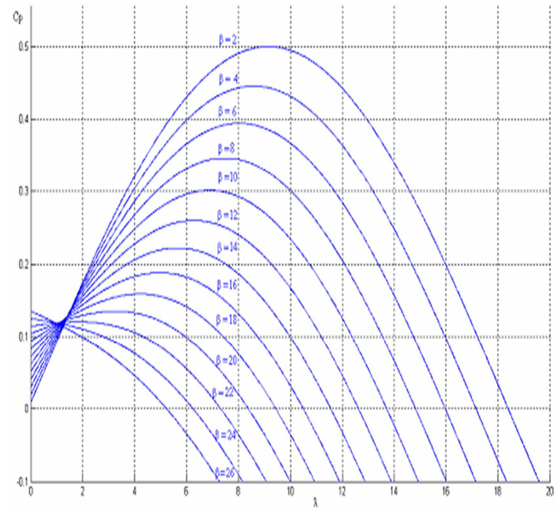

Figure 2. *Power Coefficient C_p (λ, β), for various values of pitch angle β*

The wind turbine operates, with different dynamics, from the cut-in wind speed (usually 3–4 m/s, for modern wind turbines) to the cut-out wind speed (around 25 m/s), as shown in Fig.3 .

Three distinct wind speed points can be noticed in this power curve:

- V_{wind_Cut-in}: The lowest wind speed at which wind turbine starts to generate power.
- Rated wind speed

- Wind speed at which the wind turbine generates the rated power, which is usually the maximum power wind turbine can produce.

- $V_{wind\_Cut-OUT}$:: Wind speed at which the turbine ceases power generation and is shut down (with automatic brakes and/or blade pitching) to protect the turbine from mechanical damage.

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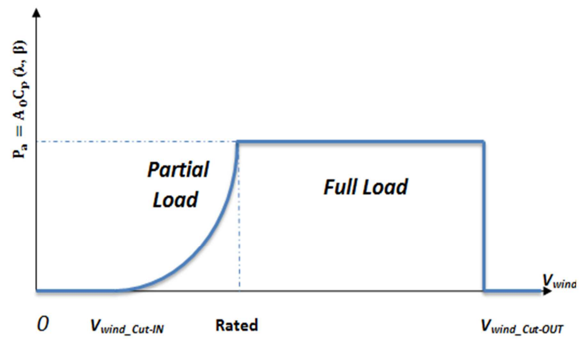

Figure 3. *Output power V_{wid}. wind speed characteristic*

2. GENETIC ALGORITHM PROCESSOR

A genetic algorithm (GA) is a robust optimization technique based on natural selection.

The basic goal of GA is to optimize functions called fitness functions. GA-based approaches differ from conventional problem- solving methods in several ways .

First, GA work with a coding of the parameter set rather than the parameters themselves.

Second, GA search from a population of points rather than a single point.

Third, GA use payoff objective function information, not other auxiliary knowledge. Finally, GA use probabilistic transition rules, not deterministic rules. These properties make GA robust, powerful, and data-independent.

A simple GA starts with a population of solutions encoded in one of many ways.

Binary encodings are quite common and are used in this report. The GA determines each string's strength based on an objective function and performs one or more of three genetic operators on certain strings in the population.

GA concepts could be adapted into the form that is suitable for computer implementation. Fig.4 shows the flowchart of GA.

1. The Initialization generates an initial random population consisting of individuals whose characteristics are coded by the string of zeros and ones.
2. The Elitism given a fitness function based on a suitable performance criterion; calculate a fitness value for each string within the population.
3. The Reproduction based on a probability basis; choose pairs of individuals to bread offspring strings, where individuals with a higher fitness value will be more Hkely to be selected than those with a lower fitness value.
4. The Crossover divides the binary coding of each parent into two or more segments and then combines to give a new offspring string that has inherited part of its coding from each parent.
5. The Mutation inverse bits in coding of the offsprings with a low probability.
6. If search goal is achieved, or an allowable generation is attained, stop. Otherwise return to step 2).

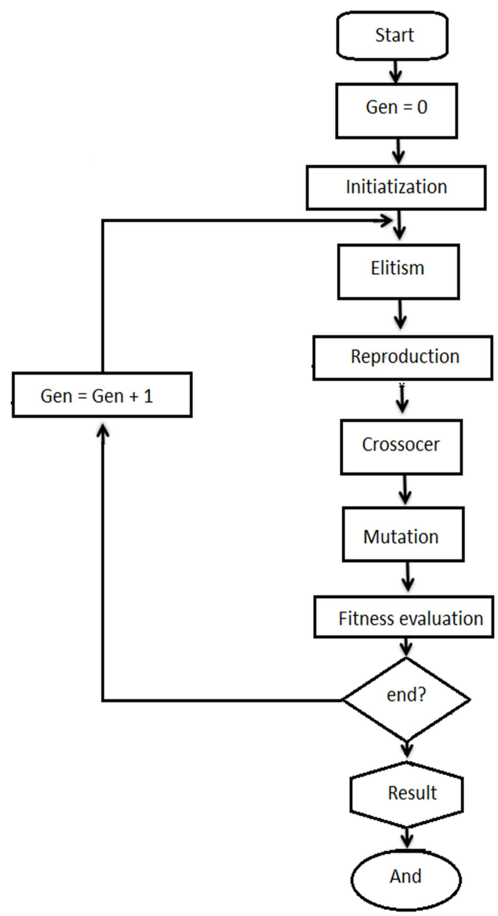

Figure 4. *The flowchart of GA*

A genetic algorithm processor can be constructed to directly execute the operation of a genetic algorithm [1, 2, and 3].

It is shown in the Fig 2. Such a processor can be used in situations where high throughput is required and where the logic of the genetic

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algorithm is expressible in simple units which can be synthesized in hardware. This is generally the case as genetic algorithms are inherently simple and contain only a few logic operations.

3. GENETIC ALGORITHM CONTROLLER FOR PITCH ANGLE CONTROL

Genetic algorithms are an optimization technique; they seek the highest quality, thus optimizing the objective function. If we try instead to minimize a function, it will change so that the quality function is maximized.

In this paper, we use the genetic algorithm as Controller; differently such as an optimization technique.

The proposed Genetic algorithm controller approach can be better explained by considering the turbine power curves shown in Fig. 6.

Assuming that the wind turbine operates initially at point A, the fuzzy control system from measured speed ratio $\lambda_A = \frac{\Omega_{tA} * R}{V_{wind}}$ and β_A angle pitch, turbine power Pa can derive the corresponding optimum operating point B, giving the desired rotor speed reference $\lambda_B = \frac{\Omega_{tB} * R}{V_{wind}}$ and send a control signal for new β_B.

Therefore, the generator speed will be controlled in order to reach the speed Ω_{tA} and βallowing the extraction of the maximum power Pb from the turbine.

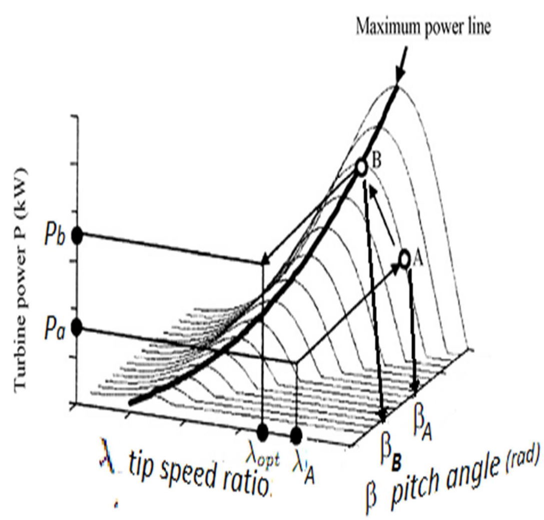

Figure 5. Shows the block diagram of the blade angle control system.

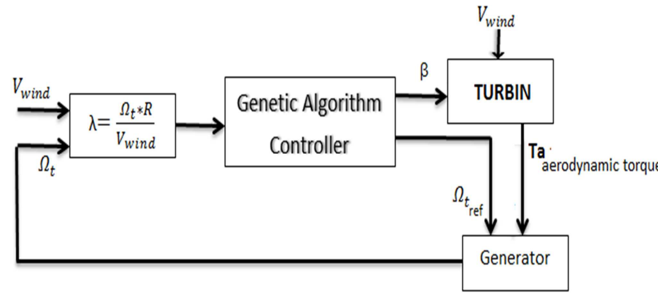

Figure 6. The proposed Genetic algorithm controller

4. SIMULATION RESULTS

Pitch angle control systems of the wind turbine were simulated using MATLAB/SIMULINK tool to test the control strategy and evaluate the performance of the system.

The speed variation of the random wind studies here is shown in Fig. 7, which randomly varies between 10m/s to 18m/s.

The variations of torque, active power, and pitch angle vary with the wind speed change are shown in Fig.7 (b), 7(c), and 7(d), respectively.

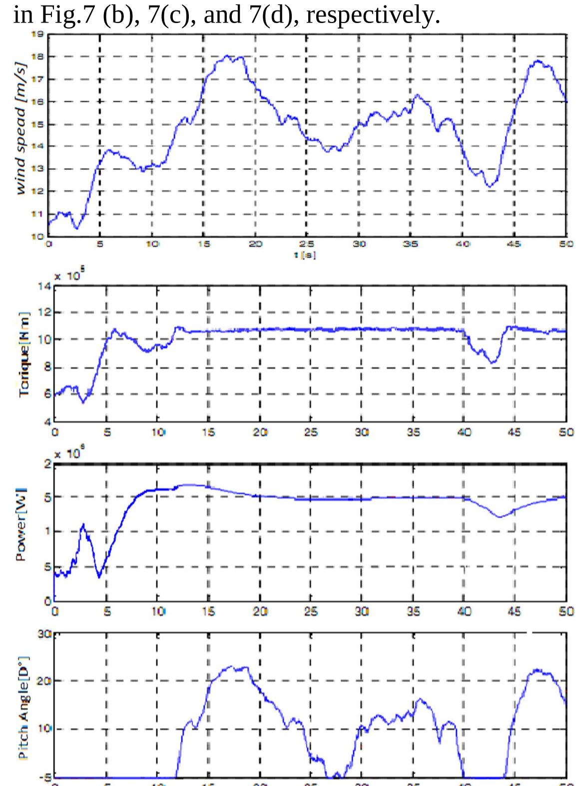

Figure 7. Pitch angle control strategy: wind speed.

For low wind speeds below 7 m/s the turbine operates at a maximum power coefficient. The

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rotational speed of the rotor omega is variable due to power reference signal of the torque control.

For wind speeds of 7.6 m/s to 10.4 m/s the turbine operates with a constant speed of 350 rpm and the tip speed ratio goes down according to wind speed.

At this point the power reference signal is at its maximum.

In both cases, the speed controller is passive, keeping the pitch angle constant to the optimal value (-5°).

At 10 m/s rated power is reached and rotor speed is controlled by pitch adjustment.

5. CONCLUSION

In this paper the method of wind turbine controller design was presented.

Summarizing, the control technique of wind turbines would be ideal if the extracted energy for each wind speed is maximal. This is difficult to achieve, especially when the wind speed is lower (or Higher) than rated.

The approach proposed in this paper used of designing a controller based on the use of artificial intelligence specifically algorithm genetics.
The simulation results represent that when the wind speed changes, this designed controller can achieve constant output power and constant rotation speed of wind turbines; it has better dynamic performances.

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