

A fuzzy logic controller for stability voltage and maximum energy extraction for fixed speed wind power generation systems

Widodo

Winarno

Abstract

This paper introduces two advantages of a fuzzy logic controller for the first is stability voltage and the second is maximum energy extraction for fixed speed wind power generation systems. Maximum energy extraction is determined by the tip speed ratio (TSR) and the power factor of a wind turbine in order to capture the maximum efficiency and control the speed of turbine in order to control voltage stability. While the TSR and power factor were taken as output variables we propose control the tip speed of generator in surrounding the value of maximum TSR. The proposed model produced fuzzy logic controller can keep the voltage stability at maximum TSR and nearest. The results indicate that we can do two task (power max extraction and stability voltage) in one design.

Keywords :Wind turbines , Tip speed ratio, energy extract, fuzzy logic stability control

1. Introduction.

Wind energy has four points of wind parameters corresponding to wind turbine with velocity and shape of shears basically; stall, fatigue, tip speed ratio, turbulence intensity and pitch, Fatigue load is forces on very turbulence wind, Stall is coefficient lift critically attack degree usually depend on velocity and shape of aerofoil Turbulence intensity is depend on velocity and Reynolds number, Pitch is a variable pitch turbine is one in which the rotor blade pitch angle is continuously adjusted by an internal hub mechanism to provide constant speed output over a wide range of wind speeds. It is a precision solution to overspeed

control. Tip speed ratio is why it's important in wind turbines. The tip speed ratio is simply a number from 0 - (theoretically a huge number, but usually 8 - 10) which tells you how fast the blades are moving in relation to the wind speed. For example, if we have blades whose tips are moving at 80MPH and a wind speed of 10MPH that would give us a tip speed of 8 (which is what the windmax blades give). In wind generators a higher tip speed ratio is better and here is why. We normally have 3 blades which are travelling through the air. A low TSR means that the blades aren't moving very fast and there is quite a bit of air that passes through the wind generator without even touching the blades. With a higher TSR

the blades are moving faster which means that they 'touch' more wind during each rotation. This means that they are able to extract more energy from the wind which means they are more efficient. The wind generator blades we use have a TSR of 8 and an efficiency of about 49% (maximum efficiency is around 60%). There is a downside to having that increased efficiency though a higher TSR means that the blades are rotating faster which means that your wind generator will produce more noise. When trying to figure out what TSR you should use for your wind generator make sure to think about noise? When the wind really gusts you'll hear some chopping. From fifth wind parameters, we can divide into two groups. The first group i.e. turbulence intensity and fatigue load causes drag forces. These are more say to the structure strengthens of wind turbine. And the second group is stall, tip speed ratio, and pitch say how to catch energy efficiently. We start with stall analysis. Shape of blade will determine coefficient of lift, in the one shape we get correlation between degrees of attack with coefficient lift

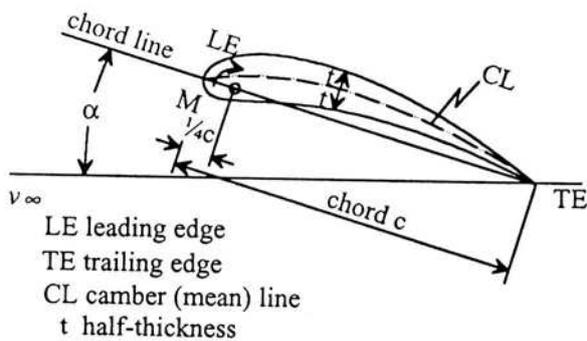


Figure 1

Lift is L, dragis D be formula in:

$$L = \frac{1}{2} \rho v^2 A C_L$$

$$D = \frac{1}{2} \rho v^2 A C_D$$

Where : A= wing area

$B = \text{span}$

Moment of pitch can be calculated

$$M = \frac{1}{2} \rho v^2 A c C_M$$

Now we can see on figure 2 the stall

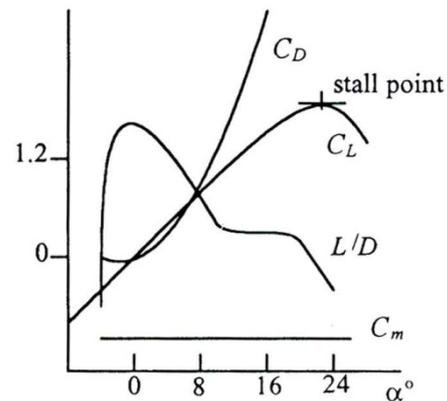


Figure 5 stall point

And figure 2 show the aspect of ratio

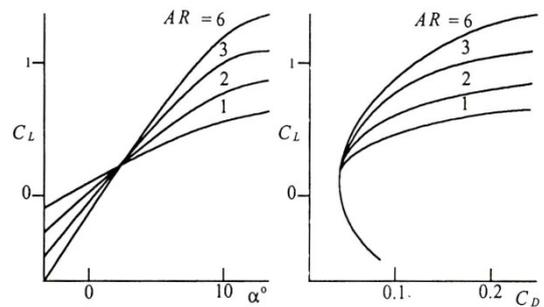


Figure 3 aspect ratio

Figure 3 aspect of ratio

Analysis of flow on blades depend on blade solidity σ , defined chord pitch ratio, c/s . forhigh solidity blade connect low solidity cause blade isolated. Show in figure7, flow A stationary cascade vvelocity (absolute) v_f, v_{waxial} and tangential components of velocity $v, v_{velocity}$

(relative) α, θ angle between the direction of the absolute and relative velocity, respectively, and the *tangential* direction F_a , F_t axial and tangential components of the force on a blade ξ stagger angles subscripts: 1-2, 3-4 refer to stationary (fixed) cascades (stator, guide vanes) 2-3 refer to moving (rotor) cascade Coefficient C_p , defined

$$C_p = \frac{(p - p_\infty)}{\frac{1}{2} \rho v_\infty^2} \quad \text{where}$$

re p_∞, v_∞ refer to undisturbed (approach velocity). distance x from chord line, show chord length c . Lift force is net pressure force on surface wing, power component perpendicular free stream. Relative to free stream, and coefficient lift

then $C_L = (\text{mean } C_p) \cos \alpha$. Pressure coefficient x/c , dan mean value can be calculated with area internal curve. The value approximate 0.98 see figure 7 Value $C_L = 0,98 \cos 8 = 0,97$.

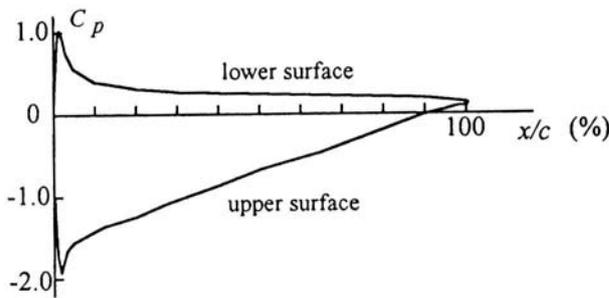


Figure 4 coefficient of lift

Note; at lower surface $C_p > 0$, the pressure is higher than free stream through hole length. At upper surface $C_p < 0$, and the pressure is higher than free stream and 10% from chord length no stream. NACA 4415 aerofoil is

composition geometri. First Integer showline of ordinatemean maximum (measure from chord line) in % chord. Second Integer show distance from leading edge to location maximum chamber, at one to tenchord. Two last integer show section of thickness in % chord. From stall lesson we goes to tip speed ratio is the conclusion of stall as show later

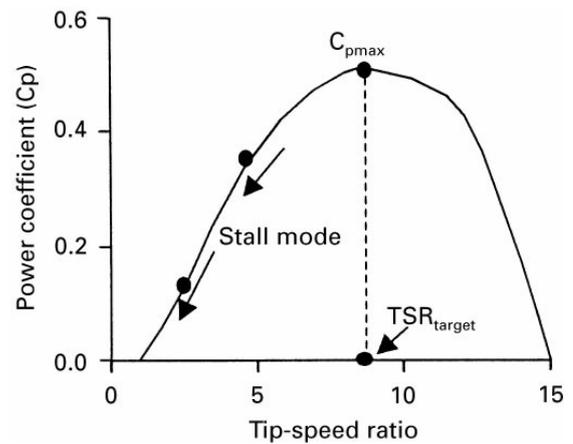


Figure 5 tip speed ratio

$\lambda = \frac{\omega_t R}{v}$ Performance of a 3 kW wind turbine generator with variable pitch control system Baku M. Nagai 1, Kazumasa Ameku, Jitendro Nath Roy

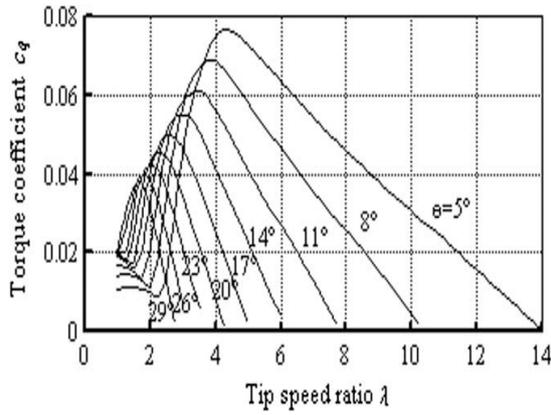


Figure 6 tip speed ratio on pitch angle

From two figures we know about efficiency energy with control of tip speed ratio and angle pitch we have two equation $y=0.13x - 0.0083x^2$ figure 8 and $y=0.008x + 0.112$ from figure 9 with solver solution from Microsoft excel get the value tip speed ratio is 8.313.

2. ANFIS model application

Intelligent ANFIS control on modeling and analysis of no complex data. Second, it appropriate for incorporating the qualitative aspects of human experiences within its mapping rules. Artificial neural networks (ANNs) have used to identify models for complex systems. For the same purpose, ANNs and FL are combined, and are referred to as ANFIS, which takes advantage of the learning capabilities of ANNs and modeling superiority of FL (Cam & Yildiz, 2006) to acquire optimal output data in the study. The algorithm consists of the least-squares method and the back-propagation algorithm. The first method was used to optimize the consequent parameters, while the second method in relation to fuzzy sets was employed to arrange the premise parameters (Ubeyli & Guler, 2005). In

the model application, the type of profile, the end losses, the profile type losses for the type of profiles considered were taken as input variables, tsr

3. Results and discussion

and general 8.5. we have table 1 for the value of TSR

Table 1

no	type	TSR value
1	Anfis	8.54
2	Conventional	8.5
3	Solver	8.313

4. Design of Fuzzy logic controller

Table 1 show the maximum extraction energy and this paper propose the voltage controller to work on TSR value 8.313 until 8.54.

5. Conclusion

In this study, we can propose two advantage first maximum energy extraction and second voltage stability based on the validation with solver of Microsoft excel the performance of ANFIS and ANN methods for predicting tip speed ratio and power factor in wind turbines were investigated. Two ANFIS models were developed to predict TSR and power factor. For this purpose, the data set of blade profile types (LS-1 and NACA 4415) was used as training and checking data. Then the data set was used as testing data to evaluate the ANFIS models and also ANN method. Results indicate that the errors of ANFIS models in predicting tip speed ratio and power factor are less than

those of the ANN method. All ANN and ANFIS developed and evaluated in this study had a maximum mean percent error of $\pm 4.32\%$ (with $\pm 0.5\%$ for majority of data points). The proposed approach is illustrated in the paper by using selected blade profile types of wind turbine (LS-1 and NACA 4415).

References

- V. Calderaro, V. Galdi, A. Piccolo, P. Siano "A fuzzy controller for maximum energy extraction from variable speed wind power generation systems" *Electric Power Systems Research* 78 (2008) 1109–1118
- R. Ata , Y. Kocyigit, An adaptive neuro-fuzzy inference system approach for prediction of tip speed ratio in wind turbines, *Expert Systems with Applications* 37 (2010) 5454–5460.
- Alata, M., Al-Nimr, M. A., & Qaroush, Y. (2005). Developing a multipurpose sun tracking system using fuzzy control. *Energy Conversion and Management*, 46(7–8), 1229–1245.
- Cam, E., & Yildiz, O. (2006). Prediction of wind speed and power in the central Anatolian region of Turkey by adaptive neuro-fuzzy inference systems (ANFIS).
- Jang, J. S. R., & Sun, C. T. (1995). Neuro-fuzzy modeling and control. *Proceedings of the IEEE*, 83(3).
- Kazeminezhad, M. H., Etemad-Shahidi, A., & Mousavi, S. J. (2005). Application of fuzzy inference system in the prediction of wave parameters. *Ocean Engineering*, 32, 1709–1725.
- Kosko, B. (1991). *Neural networks and fuzzy systems, A dynamical systems approach*. Englewood Cliffs, NJ: Prentice Hall.
- Negnevitsky, M., & Potter, C. W. (2006). Innovative short-term wind generation prediction techniques. In *Power systems conference and exposition* (pp. 60–65), IEEE PES, October 29, 2006–November 1, 2006.
- Negnevitsky, M., Johnson, P., & Santoso, S. (2007). Short term wind power forecasting using hybrid intelligent systems. In *Power engineering society general meeting* (pp. 1–4). IEEE, 24–28 June 2007.
- Potter, C., & Negnevitsky, M. (2003). Short term power system forecasting using an adaptive neural-fuzzy inference system. In *Australian and New Zealand intelligent information systems conference (ANZIIS)* (Vol. 8, pp. 465–470).
- Potter, C., Ringrose, M., & Negnevitsky, M. (2004). Short-term wind forecasting techniques for power generation. In *Australasian universities power engineering conference (AUPEC 2004)*, Brisbane, Australia, 26–29 September, 2004.

Appendix

Fuzzy logic design under simulink figure

