A fuzzy based pitch angle control for variable speed wind turbines

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***Abstract*: The productivity of electricity increases with the necessity, which in turns pollutes the environment. There are certain methods to produce electricity in Eco-friendly manner. Wind turbine is one such application which is 100% pollution free, renewable and produces a lot of energy. In general wind turbines have two operating principles namely fixed speed and variable speed. In this paper we have designed the variable controller by using fuzzy algorithm. The neuro fuzzy controller monitors the wind velocity and regulates the pitch angle in order to maximize the power production. The proposed system has been evaluated using MATLAB/SIMULINK software and the results were furnished.**

Key words: Wind turbine, pitch angle, neuro fuzzy controller.

I. INTRODUCTION

During the beginning of 200 B.C Iran started using windmills which is the first known windmill in history named as the wind wheel of Alexandria, but Sistan (A region between Afghanistan and Iran) was the first to deploy the practical windmill during 7th century which had rectangular blades and were vertical axis windmills. In the beginning of 14th century Dutch windmills were employed to drain areas of yhr Rhine delta. Scottish in July 1887 introduced the first electricity generating wind turbine later after some days American inventor Charles F Brush built a wind turbine which was the first automatic turbine designed to produce electricity.

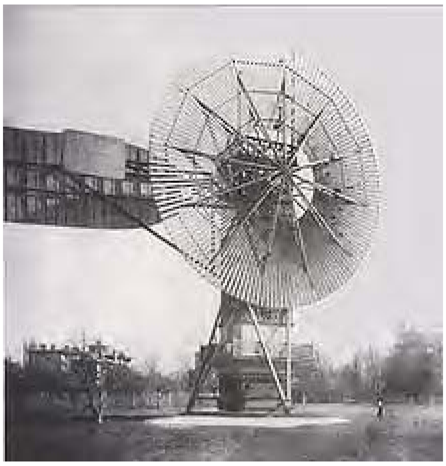

Fig.1: The first automatically operated wind turbine

30 MW of power is produced from 2500 windmills in Denmark during 1900. By 1908 there were 72 wind-driven electric generators operating in the US from 5 kW to 25 kW. Around the time of World War I, American windmill makers were producing 100,000 farm windmills each year, mostly for water-pumping. By the 1930s, wind generators for electricity were common on farms, mostly in the United States where distribution systems had not yet been installed. In this period, high-tensile steel was cheap, and the generators were placed atop prefabricated open steel lattice towers. After crossing several mile stones at present wind turbines were one of the major sources to generate electricity.

Power limitation can be achieved by two methods namely active and passive. Rotor blade freeze nearer to the rated speed. Where as in passive continuous regulation of pitch is done to obtain the rated power. Adjusting the pitch is done to measure the speed of rotor so as to generate power. During the beginning period pitch angle is adjusted manually. Later several methods were proposed for automatic pitch angle adjustment. In this paper we have proposed fuzzy controller to automatically adjust the pitch angle in order to increase the power production.

II. POWER CAPTURE OF WIND TURBINES

Wind power is proportional to wind speed in terms of cube and it can be given by

$$P_w = 0.5C_p(\beta, \lambda)\rho A \upsilon_w^{\ 3}$$

Where C_p represents air density, *A* is the area swept by blades and υ_w is wind speed. Wind turbines are capable of extracting only fraction of power from the wind. This term is limited to maximum of 59% by Betz limit. Mechanical power from the wind which is extracted by wind turbine is given by

$$P_w = 0.5C_p(\beta, \lambda)\rho A \upsilon_w^{\ 3}$$

where *Cp* represents the power coefficient of the wind turbine, β represents blade pitch angle and λ represents tip speed ratio. The tip speed ratio is defined as the ratio between the blade tip speed and the wind speed υ_w

$$\lambda = \frac{\Omega R}{\upsilon_w}$$

where Ωis the turbine rotor speed and *R* is the radius of the wind turbine blade.

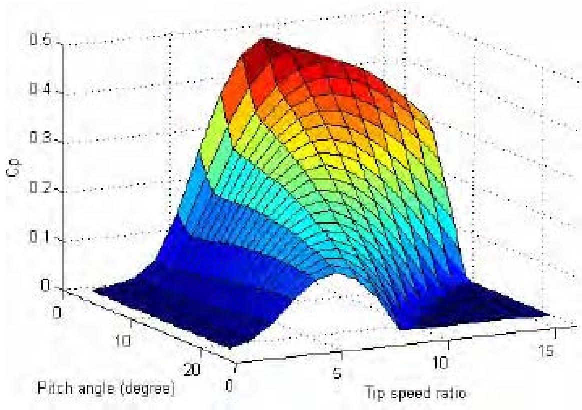

Fig.2: Power co-efficient characteristics

III. METHODOLOGY

A. Fuzzy logic controller:

If the system is non-linear and system dynamics are not defined then rule based fuzzy controller will be a best choice to deploy. System containing fuzzy logic has greater advantage as the steps involved in it are simple.

1. Input determination
2. Fixing rules
3. Defuzzification.

Figure 3 shows the fuzzy logic control system for wind turbines. The width of variation can be adjusted according to the system parameters.

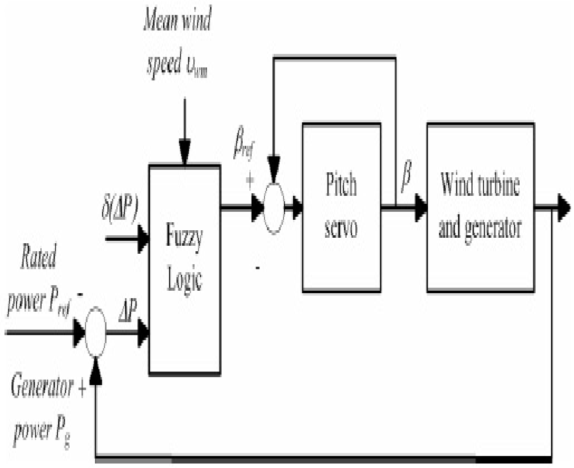

Fig. 3: Fuzzy logic system

The proposed fuzzy logic controller is based on the power deviation from its reference value Δp, its variation during a sampled time δ(Δp) as follows:

$$\begin{cases} \Delta P = P_{ref} - P_g \\ \delta(\Delta P) = \Delta P_n - \Delta P_{n-1} \end{cases}$$

Where P_{ref} is the rated power of the system and P_g is the measured generator power. The mean wind speed υwm, which used as the third input variable, is useful to compensate the non-linear sensitivity of pitch angle to the wind speed. Table I lists the control rules for the input and output variable. In the proposed fuzzy system, nine fuzzy sets have been considered for variables: negative large (NL), negative medium large (NML), and negative medium (NM), negative small (NS), zero (ZE), and positive small (PS), positive medium (PM), positive medium large (PML), positive large (PL). At lower mean wind speed, the low sensitive of the pitch angle control means that a large reaction of pitch angle to the control variants will be needed than at higher mean wind speed. This is seen in Table I. pitch angle control means that a large reaction of pitch angle to the control variants will be needed than at higher mean wind speed. This is seen in Table I.

Table 1: Rule of fuzzy logic controller:

υ_m	PS					PM					PL				
ΔP	NL	NS	ZE	PS	PL	NL	NS	ZE	PS	PL	NL	NS	ZE	PS	PL
δΔP															
NL	NL	NML	NM	NM	PS	NL	NM	NM	NS	PS	NML	NM	NS	NS	PS
NS	NL	NM	NS	PS	PM	NML	NM	NS	PS	PM	NML	NM	NS	ZE	PS
ZE	NML	NS	ZE	PS	PML	NM	NS	ZE	PS	PM	NM	NS	ZE	PS	PM
PS	NM	NS	PS	PM	PL	NM	NS	PS	PM	PML	NS	ZE	PS	PM	PML
PL	NS	PM	PM	PML	PL	NS	PS	PM	PM	PL	NS	PS	PS	PM	PML

IV. RESULTS AND DISCUSSIONS

MATLAB/SIMULINK Tool is used to evaluate the performance analysis of the automatic wind turbine using fuzzy based algorithm and the results were displayed below.

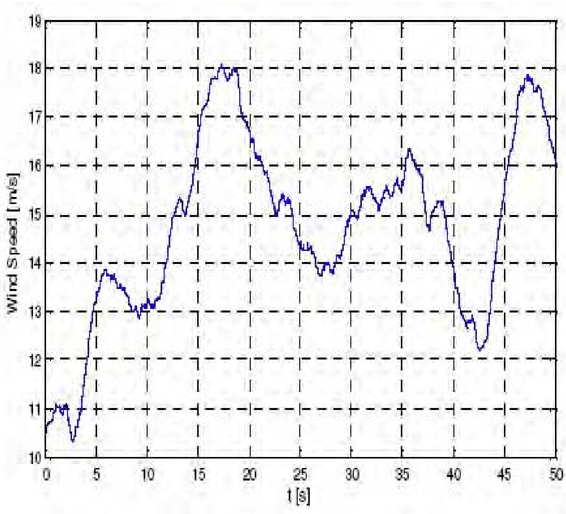

Fig.4: Wind speeds with a mean of 11 m/s.

Figure 4 shows the speed of wind that is 11 minutes per second. Fig. 5 shows the results of the conventional pitch angle control strategy where wind speed is used as the controlling variable. Fig. 6 shows the results of the conventional pitch angle control strategy where generator power is used as the controlling variable. The comparison of with and without gain scheduling is shown that the former has rapid pitch angle respond to the wind speed variation which is favor for minimum power and torque ripples.

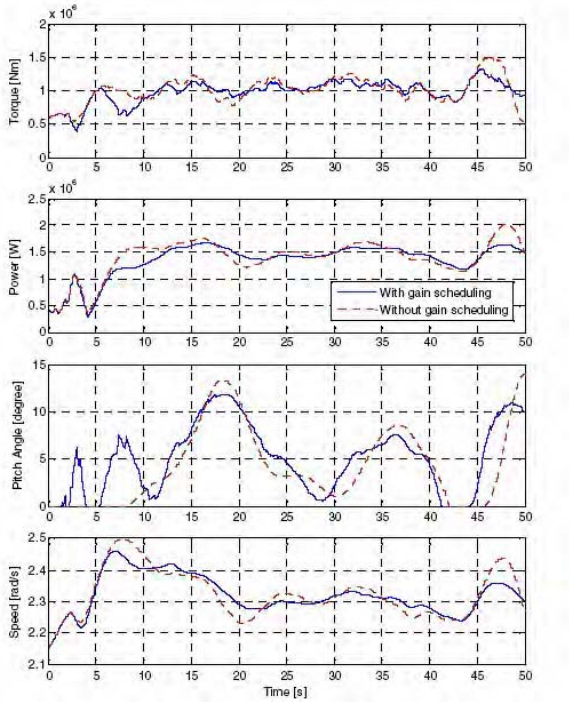

Fig.5: Generator control of pitch angle power

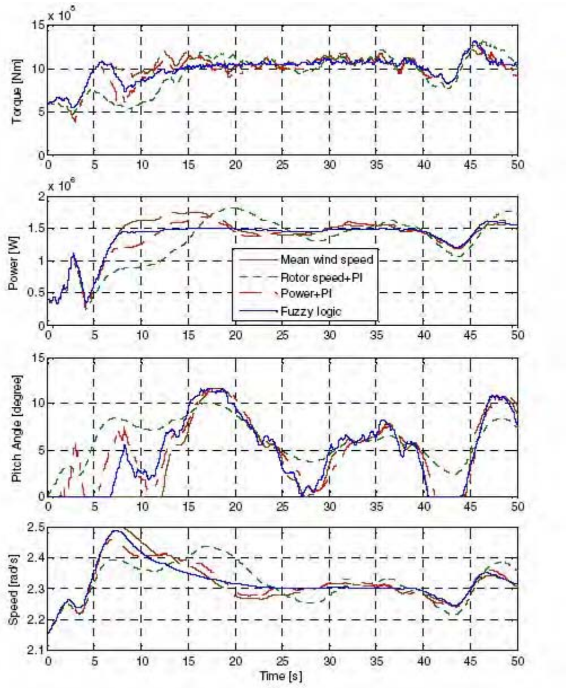

Fig.6: Comparison of pitch angle control

V. CONCLUSION

At present power generation using wind turbines are common and are efficient. We proposed a system to increase the system efficiency by controlling the pitch angle automatically using fuzzy algorithm, results were stimulated using MATLAB/SIMULINK and efficiency is proved.

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