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Improvisation of Power in Variable Speed Wind Turbine DFIG Modeal with Adaptive Network Based Fuzzy Logic Controller: Review Paper

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ABSTRACT: Wind energy conversion system can play a crucial role as energy backup, which can be useful as a continuous electrical supply sub-system. The objective of this work is to maximize energy efficiency and the robustness of a grid which is connecting with doubly fed induction generator (DFIG). While connecting wind turbine to the grid, it is important to understand the source of disturbance that affect the power quality. Our aim is to improve quality of electric power which can be done with the help of the three ANFIS controller. Importance of the proposed approach is validated by comparing the results with some of the latest published approaches. This ANFIS controller can very helpful to provide the full load region to extract more energy from the wind. First ANFIS controller for the safety of rotor blade, so controller gets track varying wind speed to extract maximum aerodynamic efficiency from the generator. Second ANFIS controller programs the machine flux for light load efficiency improvement, and third ANFIS controller is useful as adjustable speed generators which provide robust speed control against WT oscillatory torque. This three ANFIS controller can help in the development of complete wind farm generator system, because ANFIS has better adaptability then normal fuzzy PI controller. ANFIS Controller performance's analyzed in the Simulink toolbox of MATLAB.

KEYWORDS: Wind power, Wind turbine (WT) Wind energy conversion system (WECS), Doubly fed induction generator (DFIG), Vector control, Active power, Reactive power, Maximum power point tracking (MPPT), Pitch control, Yaw control, Adaptive Network Fuzzy Inference system (ANFIS), Induction generator, power quality.

I. INTRODUCTION

Wind energy conversion system figure 1.1 is one of the superb sources of renewable energy due to its free availability hence wind power are the most rapidly growing energy generation technique due to its pollution free characteristics. Some of the serious issue like global warming, environmental abasement, social problems, that arise from energy use. Wind energy provides opportunities to diminish these consequences of energy use [1]. For economic development of any countries point of view WECS is thesaurus source for electricity generation. Since the beginning of the twenty first century, countries all over the world and international organizations have invested huge amount of money for the improvement of WECS efficiency.

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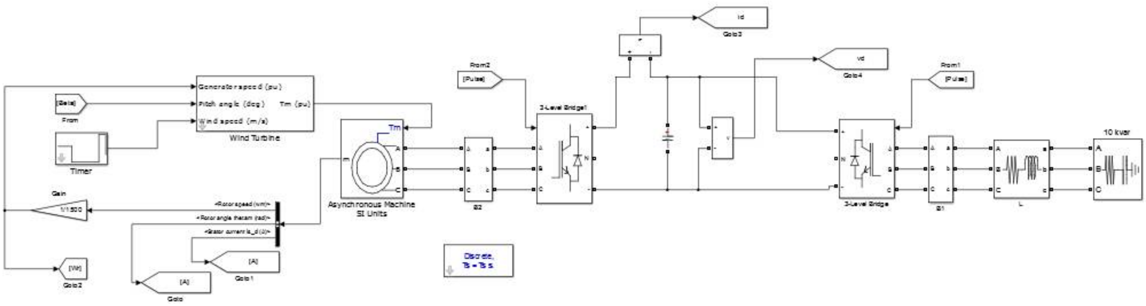

***Figure 1:* wind energy conversion system.**

Wind turbines can be distinguished namely constant speed and variable speed turbines [2]. The induction generator is widely used in both the operation schemes, for a constant speed wind turbine system show in fig 1.2. The generator is connected to the grid directly, and the rotor speed of the generator is decided by the grid frequency. The variable speed wind turbine system allows the variation of the turbine speed and generator speed, variable speed wind turbine figure 1.3, power generation system to achieve a maximum total electric power. A variable speed wind turbine has a pitch regulation mechanism that involves turning the blades about their axes to regulate the power extracted by the rotor [3].

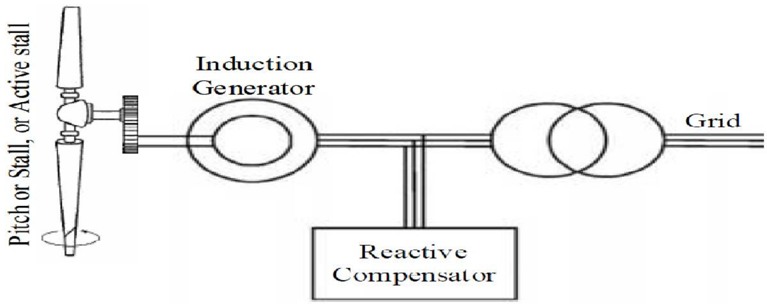

Figure 2: Fixed speed WECS

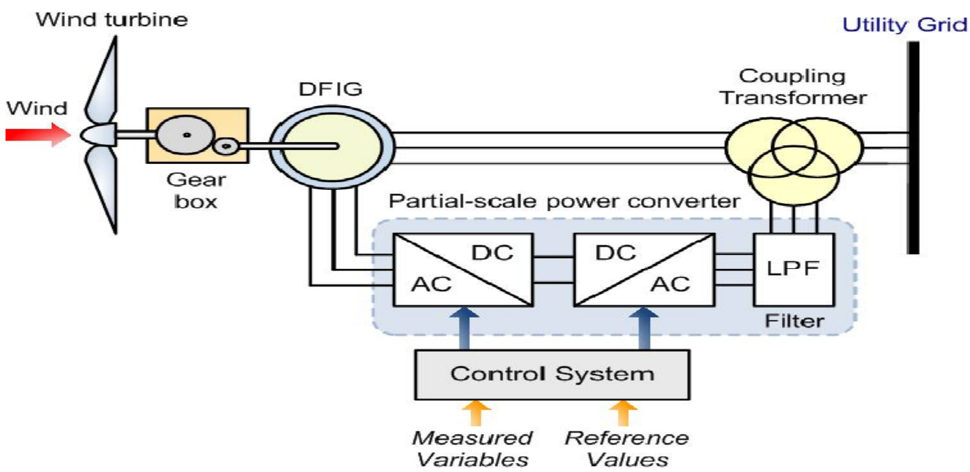

Figure 3:* Variable *speed WECS

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Integration of wind power into the grid generally affects its power quality. The components of power quality affected by wind turbine like voltage variation due to changes in wind speed, harmonic rise because of voltage fluctuations, flickering and generation of sub harmonics associated with the pulsating torque of the induction generator [1]. In the earlier technology WT are directly disconnect as any kind of disturbance Aries on the grid, but now a day WT has necessitated fault ride through capability whereby a turbine is expected to support the grid. This paper propose a few control algorithm can provide fully optimization and power efficient methods in case of variable speed wind generation system, so it is very help full for those people who have interest in the field of wind energy system.

II. EFFECTIVE PARAMETERS

Induction generators now a day commonly use in variable wind speed scheme, as self excited induction generator has variable voltage and frequency source that's the main reason AC-DC-AC link scheme interface with grid. It is playing very important role to maintain a power factor with the help of controller [5]. Voltage and frequency in generator vary due to following parameters.

1. Wind speed.
2. Rotor flux.
3. Generator speed.

With the design of fuzzy logic controller WT gets properly firing the rectifier and inverter, so extraction of maximum power from WECS can be achieve. The wind generators have sometimes produced oscillatory output power due to fluctuation caused by the tower shadow and disturbing effect of wind, hence result flicker cause in power quality which can result in spoiling of sensitive equipment. The performance of WT, such as tower shadow, wind velocity, turbine inertial these are the parameters which is use full for improvement of power quality, can be done with logical controller.

III.IMPROVEMENT TECHNIQUE

a. Wind speed controller

In the self excited induction generator have variation in parameter depend on wind speed, this means that, as wind speed changes, the generator speed has to track for maximum aerodynamic efficiency. This control function done by fuzzy controller, since wind speed is unknown parameter fuzzy logic search technique is use full for optimum point, accordingly increment or decrement in output power estimated. Figure indicates operation of fuzzy controller in which different-different wind velocity corresponding rated maximum power points [5].

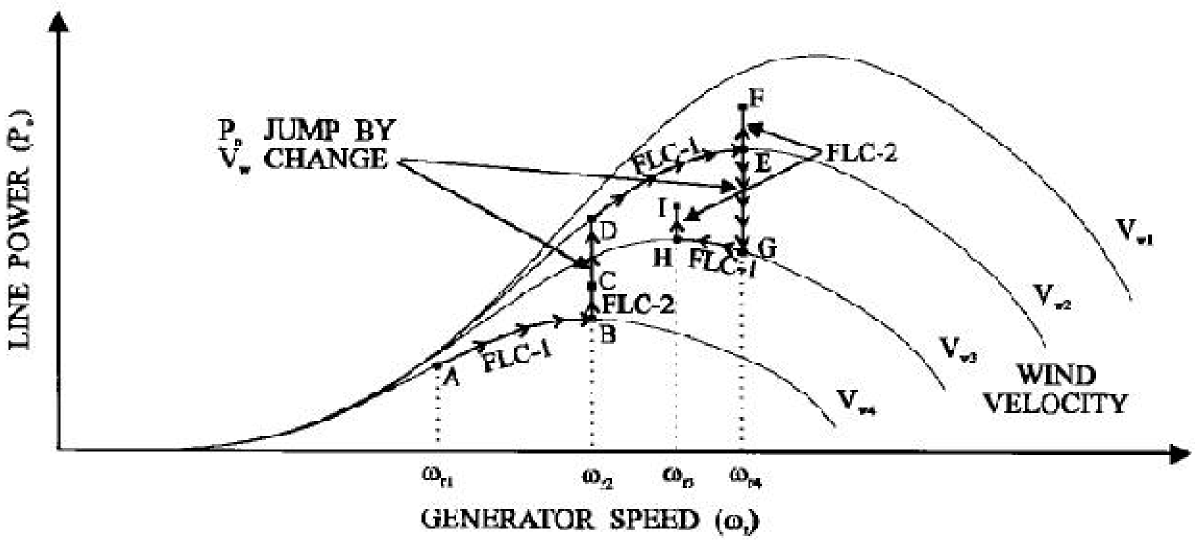

Figure 4: **System operation indicating performance of fuzzy controllers**

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For controlling maximum power point tracking requires the knowledge of system specifications and mechanical sensors such as anemometer. For improving maximum power point without requiring wind speed measurement and knowledge system specifications of turbine methods are such as power signal feedback (PSF) and perturbation and observation (P&O) or hill climbing searching (HCS) measurement method has been used for maximum power point tracking in wind energy conversion system. For determination of variable pitch tracking control method based on fuzzy controller has the same reason of perturbation and observation method that uses changes of duty cycle in converter for maximum power point tracking [6].
A hybrid control technique is proposed for tracking the maximum power generation system. The hybrid technique for implementation of controller is based uses PSO algorithm along with Recurrent Neural Network is placed within the PWM inverter controller. The PSO algorithm is used for calculating the DC link reference voltage. The control signal is generated from the RNN technique are given to the inputs of the current controller which generates the controlling pulses. By using the current control law, the load current reference can adjust. So operating point of the power curve, which is based on the DC link voltage and current is provides low errors of power coefficient, DC link voltage and tip speed ratio with a high percentage of average power [7].

For maximum power delivery to the grid from available wind power, Neuro fuzzy controller makes the wind turbine speed to be tuned fine until it gets the error free output which the user need. For maximum power optimization, the variation of the wind speed is controlled by the pitch angle of the wind turbine. Neuro-Fuzzy control with back propagation learning algorithm well suited for searching the optimum speed at which the turbine should operate under varying wind conditions [8].

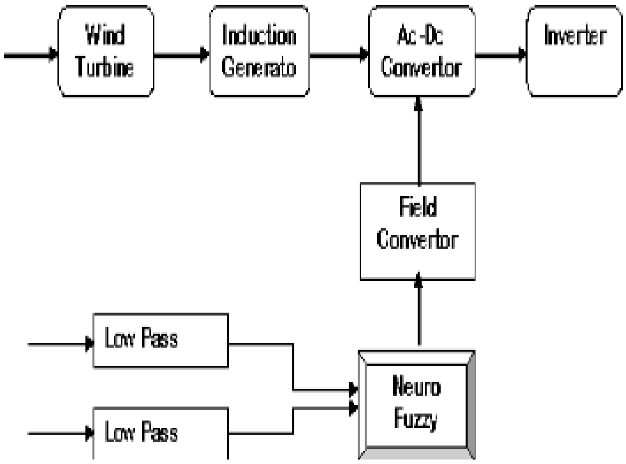

Figure 5: **Neuro Fuzzy Controller**

b. **Fuzzy controller for generator flux.**
Generator power has cubic relation with wind velocity, therefore generator running at light load with variable speed. At light load rotor flux can reduce from rated value so core loss in the generator also reduces. There by overall improvement in the machine efficiency. Ratings of rotor flux reduce with decreasing excitation current, and hence developed torque increases. As the flux is decreases the machine, iron loss also reduces [5].

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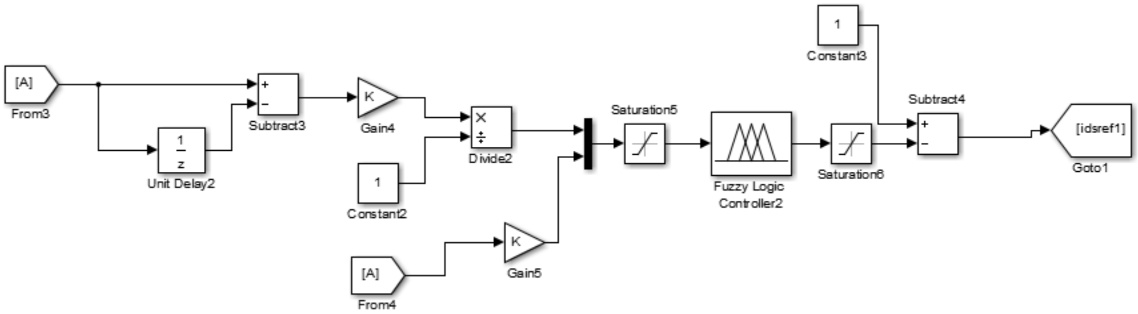

Figure 6: **Generator flux programming controller**

In order to achieve high dynamic control of active and reactive power, the active and reactive power states and stator flux position are used to determine which voltage vector is applied. The active and reactive power is calculated and the stator flux is then estimated. The rotor speed/position is measured and is used to transform the stator flux from the α–β frame to the rotor α_r –β_r frame [9].

c. **Fuzzy controller for robust generator speed.**

Wind energy is transformed into mechanical power through wind turbines and hence it is converted into electrical power. The mechanical power is calculated by using the following equation force experienced.

$$F=0.5\rho AV^2 \quad (1)$$

Rotor torque equation is given by

$$T=0.5\rho AV^2R \quad (2)$$

R=rotor radius, ρ is the air density, A is the area swept out by turbine blades, V is the wind speed (m/s), Cp is the power coefficient, which depends on two factors, the blade pitch angle β and the tip speed ratio and, λ.

The connection between the mechanical power and the wind speed passing through the turbine rotor can be given by the equation

$$P_m = 0.5\rho AV^2 \times C_p \quad (3)$$

Where P_m is the mechanical output power, $0.5\rho AV^2$ is the power contained in wind turbine [10 11]. Generator speed loop Fuzzy controller can provide robust performance against turbine oscillatory torque. Turbulence associates with wind velocity and some of the other factors like wind vertex, and pulsating torque, elimination done with the generator speed loop controller [5, 12]. Figure 7 generally a PI control approach is use full. Here speed loop error and the error change converted into per unit scale factor with the help of fuzzy membership function and rule matrix, were iterated by simulation.

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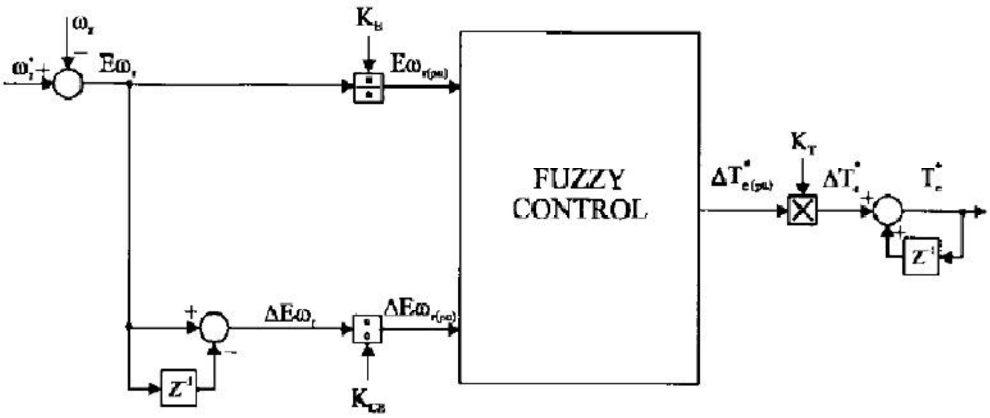

Figure 7: **Generator speed loop controller**

Since a wind turbine not available in laboratory, it was simulated in real time in the DSP by solving following turbine model equation [5]. In a WT model with wind velocity and generator speed turbine torque can be calculated with the equation (4)

$$T'm = Tm + Tosc \quad (4)$$

$T'm$ = turbine torque.
Tm = mechanical torque.
Tosc = turbine steady state oscillatory torque.

Where

$$Tm = Cp(\lambda).(0.5.\frac{\rho\pi R_\omega^3}{\eta G})v_\omega^2 \quad (5)$$

$$Tosc = Tm(A\cos\omega_m + B\cos 2\omega_m + C\cos 4\omega_m \quad (6)$$

$\eta G = wind\ farm\ capacity\ factor$,
A, B, C are the constant coefficient.

IV.FUZZY AND ANFIS LOGIC

i. Fuzzy logic

Fuzzy logic controller is rule based controller where a set of rules represents a control decision mechanism to correct the effect of certain cause used for generation systems. A fuzzy logic based controller will use fuzzy membership functions and inference rules to determine the appropriate process input. The main application of fuzzy logic in engineering is in the area of control systems. The fuzzy logic controller must take the input and also take measurements from the process. This information can use to generate the appropriate input to the process. Designing a fuzzy controller can be done with several different computer based tool's the tool we will be using is the Fuzzy Logic Toolbox in MATLAB with Simulink. Fuzzy controller consists of four functional aspects they are, Fuzzification, Knowledge Base, Interface Mechanism and Defuzzification [4]. To compensate problem in the system, fuzzy controller is used to monitor process variable continuously, if any, deviation in the process variable parameter occurs, the controller adjusts them. Generally, how controller reacts intelligently way is decide with logic use in controller design technique. Fuzzy logic technique is very use full because fuzzy controller converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert experience or knowledge database to convert these numerical variables into linguistic variables, the following seven fuzzy levels or sets are chosen as: NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PB (positive big) [13 14].

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The fuzzy controller is characterized as follows:
1. Seven fuzzy sets for each input and output;
2. Fuzzification using continuous universe of discourse;
3. Implication using Mamdani's 'min' operator;
4. De-fuzzification using the 'centroid' method.

1. ***Fuzzification:*** The process of converting a numeric variable (real number) convert to a linguistic variable (fuzzy number) is called fuzzification.

2. ***De-fuzzification:*** The rules of FLC generate required output in a linguistic variable (Fuzzy Number), according to real world requirements, linguistic variables have to be transformed to crisp output (Real number).

3. ***Database:*** The Database stores the definition of the membership Function required by fuzzifier and defuzzifier.

4. ***Rule Base:*** The elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse input/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in fig 8.

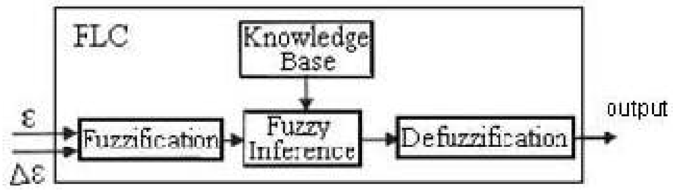

Figure 8: **Basic representation of FLC**

ii. Adaptive Neuro-fuzzy inference system (ANFIS)

ANFIS is a simply a fuzzy inference system, prepare with the help of a neural network algorithm. ANFIS is a hybrid of two intelligent system models**.** It is a combination of the low level computational power of a neural network with the highest level reasoning ability of a fuzzy inference system. An adaptive neural network has, the more advantages like excellence, learning ability, good optimization and greater balancing capability. However a Fuzzy Control is one kind of Intelligent Control which is based on rules that these rules are constructed with the knowledge of experts. Fuzzy Control is one kind of artificial intelligence system and it doesn't need an accurate, dynamic model, but control rule uses to collect control decision table, then comes up with outputs [13 16]. ANFIS serve as a basis for constructing a set of fuzzy if-then rules, with appropriate membership functions to generate the stipulated input-output pairs. ANFIS has the ability to divide the data into groups and adapt these groups to arrange a best membership function that is clustering the data and deducing the output desired with minimum epochs. With the help of given input/output data set, ANFIS constructs a fuzzy inference system whose membership function parameters are adjusted using either a backpropagation algorithm, or in combination of backpropagation with an at least square type of method [15].

Architecture and basic learning

- An adaptive network is a multi-layer feed forward network in which each node performs a particular function on the incoming signals.
- The nature and the choice of the node function depend on the overall input-output function.
- No weights are associated with links and the links just indicate the flow.
- To achieve desired input-output mapping the parameters are updated according to training data and gradient-based learning procedure.

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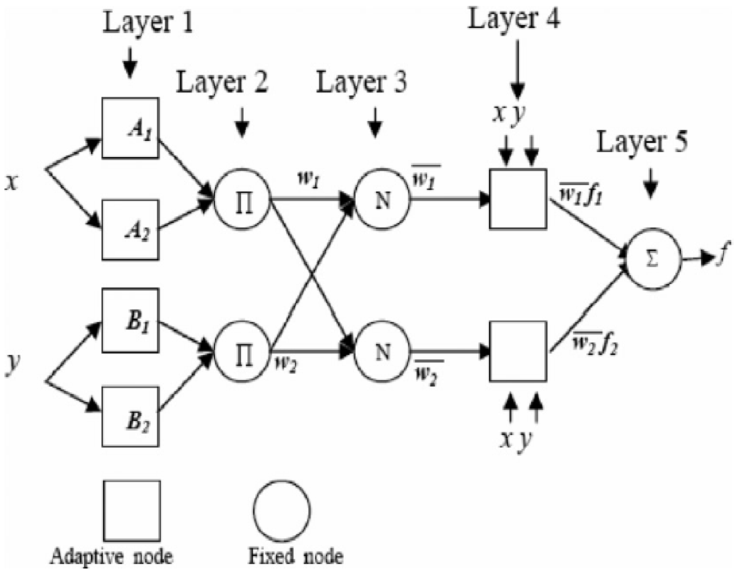

Figure 9: ANFS Architecture

V. COMPARATIVE PARAMETERS

To make logical controller a comparison between different-different techniques provided in the table form given below.

Table 1 comparative parameters

Parameters	***PI controller***	***Fuzzy PI***	***Fuzzy PID***	***PSO-RNN***
Generator type	DFIG	PMSG	DFIG	PMSG
Wind velocity (m/sec)	6-9	7-22	6-12	12-20
Generator speed (rpm)	1200	9720	1800	1440
Rated power (K watt)	0.5	4900	1495	1750

VI. DISCUSSION AND CONCLUSION

In this survey paper in various logical and different-different algorithm based controllers proposed by different-different researchers have been discussed. It is concludes that improvement in power quality very challenging task.
The above table shows the improvement in power quality with various factors. After the survey, it is observed that there is some more existing scope of enhancing the power quality with use of ANFIS controller, for extracting maximum power from a variable speed wind. Because turbine output power mainly depends on its angular speed and the wind speed, but these parameters are nonlinear in nature, ANFIS can best suitable type logic for the development of the controller.

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