Pitch angle control using neural network in wind turbines

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Abstract
Wind energy is a growing renewable energy resource. Wind power can be improved or restricted by adjusting the pitch angles of the wind turbine blade. The wind turbine model is non-linear. Therefore, a smart controller must be designed to adjust the angles of the blade. In this study, the simulated and code method was with the MatLab program to control the angle between the chord line of the blade and incoming wind direction using a type of the neural network (NN) control. The results from the simulation show that the NN proposed controller is very effective for adjusting the pitch angles.

Key Words: Wind energy, NN control, pitch angles and MatLab program.

1. Introduction
The standard of wind turbines in power age is to change over the active energy of the wind into turning mechanical energy for the rotor turbine cutting edges. At this intention soon suitable the most mutual secondary wind turbine is the horizontal axis fan with two or three blades attached to higher of the tower. Choosing number of wind turbine blades is not an easy design option. The three-sharp edge frameworks cost in excess of two innovative frameworks. However, two-edge winds must work at turn speeds higher than three edges. In addition, the body blades of the two knife wind generators must be lighter in weight, more critical and thus more expensive [1]. The fundamental equation frames the vitality in the breeze at position an, opposite to the breeze heading blowing from the formula:

\[ P = 0.5\rho A C_p V^3 \]  \hspace{1cm} (1)
Where \((\rho)\) the air density (kg/m\(^2\)), \((A)\) area swept of the rotor blades (m\(^2\)), \(V\) wind speed (m/s),

Cp power coefficient, which describes the fraction of the wind captured by a wind turbine and \(P\) represents mechanical power in the moving air (Watt). As per Betz rules, the estimation of the force coefficient includes a hypothetical breaking point associated with 59.7 \% \[2\].

\[
\lambda = \frac{\Omega}{R/V}
\]

Where \(\lambda\) represents tip speed ratio (TSR) of the wind generator and \(\Omega\) Nominal rotor speed.

From equation (1) where \(C (\beta, \lambda)\) represent rotor power coefficient, can be calculated as:

\[
C_p = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right) \exp(-\frac{21}{\lambda_i}) + 0.0068\lambda
\]

\[\lambda_i\] In Equation 4 is placed into where in Equation 3 is calculated \(C_p\).

\[
\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{3\beta + 1}
\]

Where \(\beta\) pitch angle of blade.

As follows, Figure (1) represents an agreeable breeze speeding – power shape, which illustrates the controlled force accomplishable from the specific breeze generator. At exceptionally low wind paces, the created power is too low to even think about ending up being used. With the run of the mill models, the breeze generators are begun when the breeze quickness surpasses at least three than 4,000. The turbine is begun at the cut-in wind pace and its capacity will increment with another force on the breeze rate, for the second once the evaluated breeze speed is reached. On wind paces run by 12 m/s around 25 min, the low down guidelines or pitch-control techniques. At the point when this breeze pace surpasses 20–25 m/s the specific breeze generators are usually brought to have the power is confined to the positioned power on the breeze turbine with the help of option to stop maintaining a strategic distance from high precisely able burdens inside the turbine segments. This breeze stream speed is known as the abbreviated out breeze speed[3].
1.2. Constant Speed Wind Turbines

In early models including coordinated machines have just been utilized. Additionally, the speculation machine was all the more extensively embraced to its lower charge, better ecological solidness alongside unrivaled equipment similarity alongside fast wind changes. The cause in pre-determined wind turbines with a predetermined speed, the power generator used may be the acceptable type of generator, associated with the array. Inside the larger part connected with the wind generator's plan, the genuine generator is unquestionably associated while utilizing the center point utilizing sharp edges by means of a gearbox. They are set inside a nacelle on the highest point of the turbine framework[4]. The gearbox is expected to change the low rotational speed of the specific turbine with high rotational speed inside the generator. The rotational speed of acceptance power generators is normally 1,000 or even 1,500 unrests. The pace of this turbine depends on its rotor measurement. For workout, a 330 kW turbine conveys a rotational speed of around 18 – 1 out of 3 rpm, while the rotational pace of the 1,670 kW turbine is around10–19 rpm. A set-speed windmill is made to acquire the best effectiveness with one winding rate that will give this ideal tip speed with the wind speed proportion with the rotor airfoil. To have the option to catch unmistakably more wind vitality, some set-speed wind turbines have two or three diverse rotational rates. This is accomplished for all intents and purposes by situating two force generators in this nacelle or by a solitary generator acquiring two detached windings [2-4].

![Diagram showing power output and speed relationship in wind turbines.](image-url)

**Figure 1.** General mechanical power from a wind turbine.
1.3 Inconstant Speed Wind Turbines

There are numerous similitudes within the inconstant speed wind turbines as for the parts of the constant speed wind turbines. Those breeze generators work with a varied assortment of the tight speed. Constant-speed windmills operating within a narrow speed range operate unobtrusively with a dual-feed induction generator and have a transformer paired with the rotor setting. The rotational speed of the double-induction induction motor is about 1000 or 1500 rpm, so it is necessary to implement the gearbox [5,6].

Addition, the purpose to decrease the design and mode of the nacelle, the intermediate dynamo is used. An intermediary source that uses a massive turbo-blade diameter might turn on at very low velocity and needs a gearbox equipped to increase the speed. The use of a frequency adapter is the use of a mainly driven power generator and wind generators that operate within a wide, adaptable speed range equipped with a frequency adapter[7]. In a traditional constant speed wind generator, the gearbox and the actual generator must be installed on the steel bed board special, stratify with each other. The determined generator can straightforwardly wind up coordinating with the packaging unit. Moreover, the generator unit and bolster framework can be the principal parts in the motor unit suspension [5-7].

2. The Components of the Wind Energy Transformation Systems

Wind energy can track its harness through a wind energy conversion regulator, consisting of wind generator blades, generator, electronic power conversion tools and related control system. Figure (2) shows a block diagram that includes different parts of the WECS system. Various WECS options are available based on synchronous or asynchronous machines, stop control systems or even pitch control. The sensible point of these frameworks is indistinguishable: to change over the dynamic vitality of the breeze into power and to bring this vitality into a utility lattice [8].
Figure 2. Model block diagram the power generation system for wind turbines.

Figure (2) represents the natural mass diagram of the model wind energy system. The real mass shows that the wind dynamo and source option are a big section of the wind power transformation. Typical wind turbines are directly divided into two basic parts. The first part a horizontal axis wind turbine, such as the original wind generator used for water pumping and second part a vertical axis wind turbine, such as the Darius product of ideal fashion, which is named after the inventor of France directly. Many modern large windmills are horizontal-axis wind turbines[9].

Wind turbines have installed in locations where wind energy is abundant. Wind speed is higher in the sky than the earth. The optimal location must be passed from long framework to avoid turbulence, which is the join between the variable speeds of the wind while it barge real obstacles. Wind turbine harvest horizontal axis wind energy opposite actual wind-related direction [10].

In additional, the classification of wind turbines depends on the axis of rotation and the number of blades to two types the horizontal axis turbines and the vertical axis turbine.

Moreover, wind turbine components comprise: rotor (sharp edge), whose changes the energy in the breeze to rotational shaft vitality, a drive train, a gearbox, a generator and a pinnacle that
bolsters the rotor. Additional, other gear including (electrical links, controls, interconnection hardware and ground bolster gear[11].

In additional, Wind Power has Pros and Cons, from pros wind power generating electrical energy from wind energy does not ensure the revival of gases or air pollutants such as (carbon dioxide, nitric oxide and methane) or acid rain. The use of wind energy, decrease dependence on traditional fuel and nuclear fuel. In addition, wind power does not need water sources during operation, such as any conventional sources and some renewable another [4-9].

Moreover, there some cons of the wind power is environmental problems resulting from the use of wind energy systems are noise, electromagnetic interference, and visual effects such as reflections of sunlight from the turbine blades as through rotating and the risk of collision by migratory birds [6-12].

Therefore, the purpose from used the neural network (NN) controller is to keep up the appraised power over the evaluated wind speed by regulated the pitch angle of the rotor wind turbine. There the relationship curve is nonlinear between tip speed ratio (λ) and power coefficient (Cp) are highly affected by the pitch angle. NN control have been demonstrated an effective method in dynamic systems of control. Really, field main applications for NN controller is nonlinear systems of the controller. The neural network of approximate capabilities made it an option for general-purpose non-linear controllers. Figure (3) represent block diagram of the wind turbine using NN controller.

![Figure 3. Block diagram of the wind turbine using NN controller.](image-url)
3. Neural Network

Neural networks (NNs) are registering and data handling frameworks comprising of enormous quantities of basic and exceptionally interconnected components of the structure that imitate the structure of the natural sensory system. Neural networks are crude electronic models that depend on the neural structure of the cerebrum. Be that as it may, a run of the mill fake neuron has a less complex structure than organic neurons. NNs are typically sorted out into layers, for example, input layers, concealed layers, and yield. The information layer is associated with at least one of the shrouded layers, where the real handling is done through weighted associations. Every neuron in the concealed layers is associated with all the neurons in the yield layer. Preparing results are acquired from the yield layer. Learning in NNs is done through special training algorithms that are developed based on learning rules, and are supposed to mimic the learning mechanisms of biological systems. NNs have been applied to many engineering problems such as observation, recognition and classification. There is a wide range of types and designs of neural systems fluctuating on a very basic level in the manner they learn, the subtleties of which are all around reported in the writing. In this study, the multi-layer perceptron and spiral premise work are utilized as an edge pitch edge controller by utilizing Neural Network Toolbox of Matlab [13].

3.1. Multi-layer perceptron networks

Multi-layer perceptrons (MLP) spread a huge gathering of feed-forward neural systems with at least one layers of neuron. In many applications, MLP systems having three layers notwithstanding info and yield layers have been utilized. Neurons in input layer have an unadulterated straight initiation work, yet some nonlinear enactment capacities as logarithmic and digression sigmoid capacities are utilized in the neurons in covered up and yield layers [2-8]. A structural plan for a MLP organize having just one concealed layer is delineated in figure 4.
Figure 4. A schematic diagram of (MLP) neural network.

Additional, in figure 4 represent the NN controller has the input layer of two inputs, a hidden layer of 5 neurons and output layer of one output. The two inputs are the flow speed and the changing speed rate of wind dynamo, one output is the varying pitch angle.

The algorithm NN controller training according to the following steps.

The first step all weights at random initializing, the second step calculates the output vector, then the error propagation terms, the third of the equation (5) and the equation (6) to procedure to update the weights, then from Eq.(7) and Eq.(8) calculate the total error (E) and fourth step repeat the calculation by back to the second step until the total error is less than the wished for error.

\[ W_{ip}(t+1) = W_{ip}(t) + \frac{\alpha}{l} \sum_{n=1}^{l} X_{pn} f_{1}^{n}(net_{i}) E_{in} w_{i} \]  \hspace{1cm} (5)

\[ W_{i}(t+1) = W_{i}(t) + \frac{\alpha}{l} \sum_{n=1}^{l} E_{in} f_{2}^{n}(net) Z_{in} \]  \hspace{1cm} (6)

Where \( l \) is learning size, \( \alpha \) is the learning rated, \( X_{pn} \) neuron in the input layer, \( w_{i} \) is the connection weight between the \( i_{p} \) neuron in the hidden layer and the input layer and \( W_{ip} \) is the connection weight between the \( i_{p} \) neuron in the hidden layer[12-13].
\[ E(n) = f_2(n) - Y^B(n) \quad , \quad n=1,2,\ldots,l \]  
(7)

\[ E_{\text{total}} = \frac{\sum(E(n))^2}{l} \quad , \quad n=1,2,\ldots,l \]  
(8)

Additional, equation (9) represents \( f_1 \) and \( f_2 \) the transfer functions of hidden and output layer neuron.

\[ f_1 (u) = \frac{1-e^u}{1+e^u} \quad ; \quad f_2 (u) = u \]  
(9)

### 3.2 Algorithm Neural Network Controller

In figure 5, the flow graph of the neural system pitch controller calculation is introduced. For operation up, the first stage is grouped in quite a while, regardless of whether the current generator speed is more noteworthy, equivalent, or not exactly the evaluated generator speed. Moreover, the changing pace of generator speed is considered in deciding to increment or reduce pitch angle \( \beta \). For instance, when the current generator speed is more prominent than the evaluated speed, the changing pace of generator speed is again considered to expand the pitch angle. In the event that the changing speed of generator speed is likewise expanding, at that point, the pitch angle is resolved to increment. Something else, the pitch angle is not changed. Diminishing the pitch point has additionally a similar technique when the current generator speed is littler than the appraised speed. Also, when the current generator speed is equivalent to the evaluated speed, the pitch point changes relatively to the changing speed of generator speed. The pitch point is expanded when the changing speed of generator speed is certain.
4. Modeling and Results

In this section, we will design wind energy using the Matlab program. Consequently, some of the parameters shown in table 1 we use in the wind power model design.

| Table 1. represent some parameters for the wind power system. |
|-------------------------------------------------------------|
| Nominal output power (Pm) | 5 MW |
| Radios of the blade (R)     | 52 m |
| Sweep area (A)              | 8490 $m^2$ |
| Wind speed (V)              | 25 m/s |

Figure 5. Flow chart of the algorithm neural network controller.
Figure 4. Model of the wind turbine with NN controller in Matlab.

Figure 5. Wind speed (a) and varying randomly wind speed (b).

Figure (6) represent to obtain the change in the pitch angle according to results with a neural network controller, in both cases; the power produced is regulated to the rated power of the wind turbine as shown in figure (7).
Figure 6. Pitch angle with NN controller.

Figure 7. Output power of the wind Turbine.
3.1 Conclusion

The angle of inclination of the wind turbine blades is controlled using a neural network controller. Output power is maintained at a constant value within certain limits. Consequently, a more stable the grid output power is provided for extended periods of time safely because the generator is protected from the highest output value. We use the neural network unit as it works well to adjust to changes in the system. Therefore, changes that may occur during the time system parameters will not affect the performance of the control system. In addition, the neural network controller compensates for controlling difficulties, according to the nonlinear system.

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