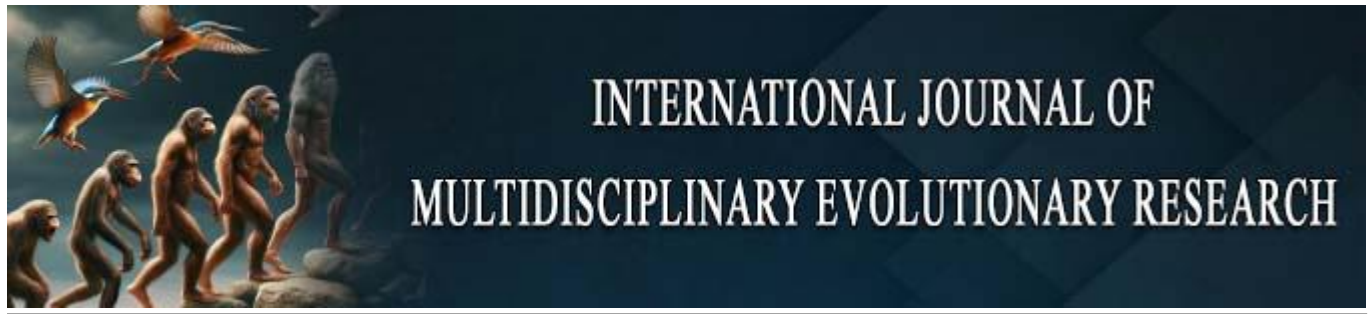




Reducing Carbon Emissions through Renewable Energy

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Abstract

Wind is a clean and inexhaustible source used to produce energy. Wind energy is energy extracted from the kinetic energy of the wind by using turbines or turbines to produce electrical energy. It is considered a type of electromechanical energy. Wind energy is one of the types of renewable energy whose use has spread as an alternative to fossil fuels. Abundant and renewable energy is found in all regions, but its availability varies from one location to another. It is clean, renewable energy that does not produce emissions such as greenhouse gases or greenhouse gases during operation, and it requires varying spaces depending on the size of the station and the type of towers used, Modern commercial wind turbines produce electricity by using rotational energy to drive a generator. These turbines consist of a shaft or tower high above which are large blades and the base which houses the motor. The blades of large wind turbines that produce up to 1.8 megawatts of power may be more than 130 feet (40 meters) long and can be placed on towers about 260 meters high. feet (about 80 metres), and smaller turbines can be used to provide power to individual homes.

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Introduction

Renewable energy sources (RES) supply 14% of the total world energy demand. RES includes biomass, hydropower, geothermal, solar, wind and marine energies. The renewable are the primary, domestic and clean or inexhaustible energy resources. Large-scale hydropower supplies 20 percent of global electricity. Wind power in coastal and other windy regions is promising source of energy. RESs are also called alternative energy sources. The share of RESs is expected to increase very significantly (30–80% in 2100). Increasing consumption of fossil fuel to meet out current energy demands alarm over the energy crisis has generated a resurgence of interest in promoting renewable alternatives to meet the developing world's growing energy needs, Excessive use of fossil fuels has caused global warming by carbon dioxide; therefore, renewable promotion of clean energy is eagerly required. To monitor emission of these greenhouse emissions an agreement was made with the overall pollution prevention targets, the objectives of the Kyoto Protocol agreement , In this paper, attempt has been made to find out the scope of renewable energy gadgets to meet out energy needs and mitigation potential of greenhouse gases mainly carbon dioxide

Materials and Methods

Wind energy

Cause of wind movement: Winds on Earth are formed as a result of temperature differences between different regions From the Earth, when solar radiation falls on an area, the air in it heats up, which leads to... Decreased density and reduced atmospheric pressure. As for the areas where the amount of solar radiation decreases The density of the air increases, and thus the atmospheric pressure increases, and the air moves from the pressure areas High pressure to low pressure areas and this flow of air from high pressure areas to Areas of low pressure are called winds. Since the equator region receives the largest amount of... Solar radiation. If we assume that the Earth does not rotate, we will have a simple system of currents Convection currents are where the hot air in the equator moves into layers High atmosphere Due to its low density, it heads towards the North and South Poles, displacing

the cold air Located from the poles to the equator. Since the Earth has rotational motion, forces arise They are called Coriolis forces.

They affect the movement of the wind, so the wind does not blow in a direct direction Rather, it deviates to the right of its direct direction in the northern hemisphere and to the left of

it in the northern hemisphere South due to its rotation around itself. There is another type of wind called local wind It blows over certain areas of the earth, such as land and water (wind) breezes, which It is generated in coastal areas as a result of the difference in the heat capacity of the sea and the coast, as in the figure (13-2).

LAND VS SEA BREEZE

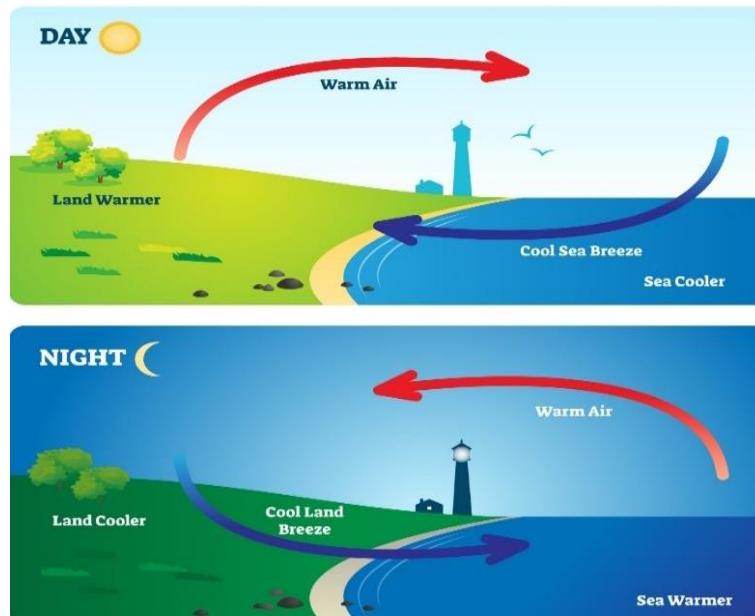


Fig 2-13: Land and sea breeze

The Earth gains heat quickly during the day and loses heat quickly during the night The sea gains heat slowly and loses it slowly, so the air in contact with the land heats up during the day Its density decreases and heads upward to be replaced by a cold air current coming from the sea, which is a sea breeze . During the night, the air current reverses, causing cold air to move from the land towards the sea and settle Its place is a warm current coming from the sea and this is the land breeze. In the same way it exists there in the regions Mountain is what is known as hill and mountain (wind). At night the wind comes down From the cold mountain surfaces towards the warm valleys. Due to the low pressure resulting from the varying degrees The temperature is between the valley and the mountain, while during the day, when the temperature of the highest mountains rises, the winds blow From the valley towards the mountain..

Types of wind turbines

Wind turbines are classified in Materials and Methods

1. Vertical axis turbine: The axis of rotation is vertical, and the movement of the affected surfaces is usually in the direction of the wind movement It has more than three blades and is usually used in mechanical applications such as water pumping.

There are different designs for vertical axis turbines, the most important of which are:

1-Darrieus Turbine

It was named after the French engineer Georges Darrieus, who designed it for the first time in 1930, and its shape The

exterior is similar to the mixer used in kitchens, but there are other letter-shaped shapes (V) and (H). This turbine contains two or more blades and is characterized by high performance over the speed range. It is limited to 7- 4.5 m/s and this design is usually used in the field of electrical power generation Figure (14-2) is a photograph of the Darrieus Turbine.

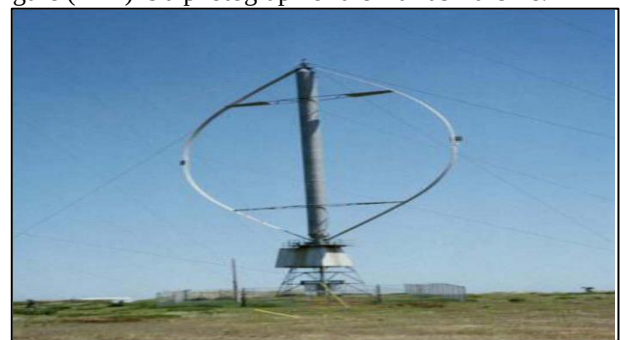


Fig 2-14: Different shapes of the Darrieus turbine.

2- Savonius Turbine

This turbine consists of two opposite cylinders in the shape of the letter (S), as shown in the figure (15-2). The wind directed at this turbine generates a high thrust force on the opposite side to the wind, while the other side opposite to the wind direction is under the influence of a force less than that side The other, causing the generation of torque that causes the turbine to rotate, and the power factor of this turbine Low compared to other designs, and there are many designs inspired by this basic principle Shown above.

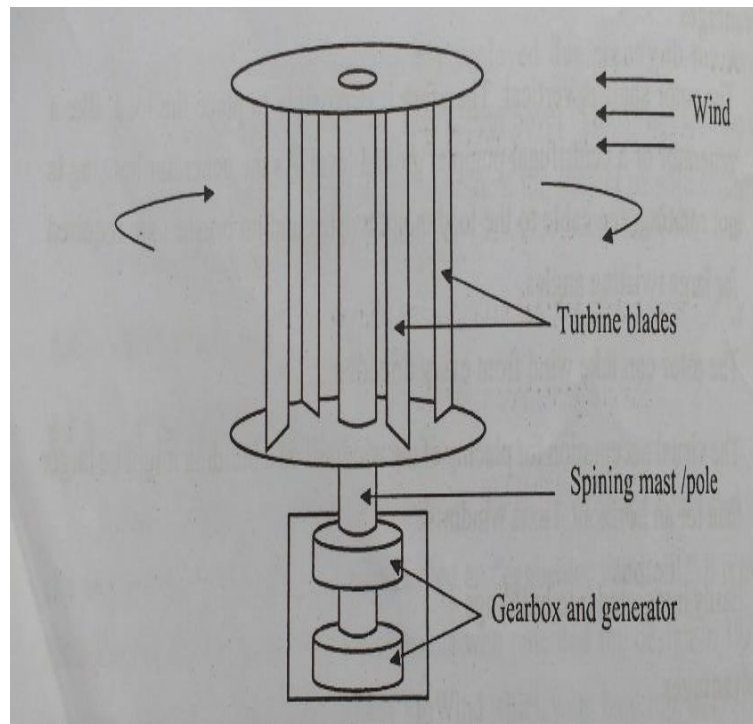


Fig 2-15: Savonius turbine

3- Musgrove turbine:

This design was developed for the first time by a research team led by Professor Musgrove in Britain. Its external shape

is similar to the letter (H), as shown in Figure (16-2), and strong winds cause generation. Torque is used to generate mechanical energy.

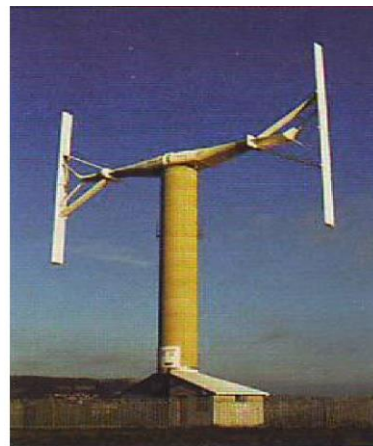
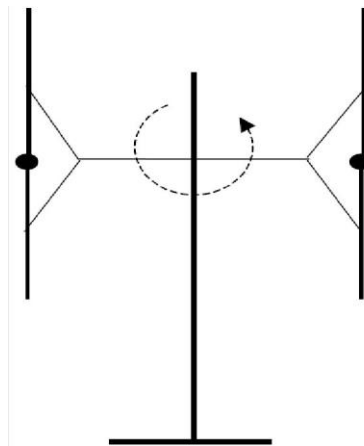


Fig 2-16: Flared turbine

2-Horizontal axis turbine

There are different designs for horizontal axis turbines. There is a single-blade turbine, which is less expensive due to the economy in materials manufacturing the blade resulting from eliminating an entire blade. Balancing problems appear clearly as a result of the presence of a single blade, which is treated by adding less to the other end, as shown in the figure (17-2). The most widely used horizontal axis turbines in the field of electric power generation are the three-blade turbines. The reason is that the distribution and balance of loads on the rotation axis is better than using one or two blades. Calculating the loads on the rotation axis is extremely important, as the weight of a single fiberglass blade is approximately 2 tons. There are multi-blade turbines, but they are often used to pump water.

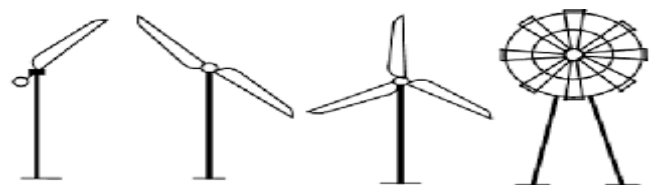


Fig 2-17: Horizontal turbine

Mathematical analysis of wind energy

The power rate of any moving fluid is equal to the product of the mass m and

The kinetic energy of the wind is therefore:

$$Pt = mKE = m \frac{v^2}{2} \quad (2-23)$$

The mass flow rate is calculated from the continuity equation:

$$m = \rho A v_i \quad (2-24)$$

Where:

$\rho = (\text{kg/m})$ density of air entering the turbine.

$A = (\text{m})$ The area of the part exposed to the wind or the area of the turbine fan.

By substituting equation (2-23) into equation (2-24), we get:

$$P = \frac{1}{2} \rho A v^3 \quad (2-25)$$

Equation (2-25) indicates that the power generated by the wind is proportional to the cube of the wind speed as well. Which is covered by the wind turbine blades when they move, so if the wind speed increases from 1 m/s to 2 m/s, the

resulting extracted power will increase 2^3 , that is, eight times, even if it increases. If the speed reaches 3 m/s, the extracted power will increase by 27 times. It is impossible to convert all the wind energy into mechanical energy, and to calculate the maximum energy possible. To exploit wind energy, we will take a horizontal axis turbine, assuming the thickness of the rotation axis. It is (a-b) as in Figure (9.5), where the speed and pressure of the air entering the turbine are V_i and P_i , respectively, and the speed and pressure of the air leaving the turbine are V_e and P_e , respectively. Speed distribution: We note that the speed of the air exiting the turbine is less than the speed of the entering air due to: The energy drain occurring in the turbine, which is converted into mechanical energy by applying Bernoulli's equation. We get: (a and i) (e and b) between the two points:

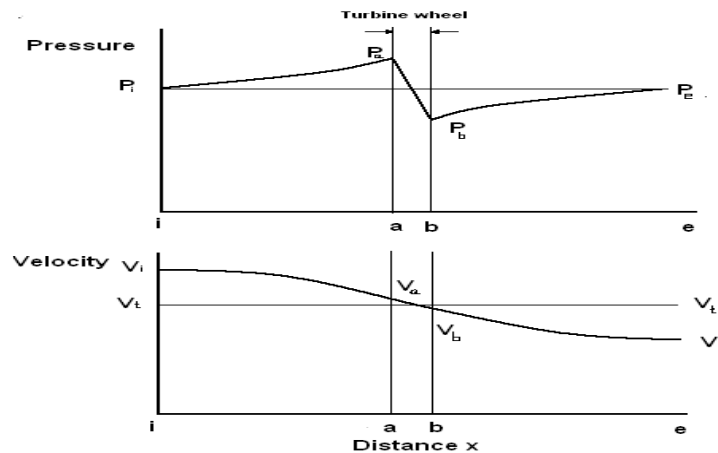


Fig 2-18: Distribution of speeds and pressures on a horizontal axis wind turbine

$$\frac{P_i}{\rho} + \frac{V_i^2}{2} = \frac{P_a}{\rho} + \frac{V_a^2}{2} \quad (2-26)$$

$$\frac{P_e}{\rho} + \frac{V_e^2}{2} = \frac{P_b}{\rho} + \frac{V_b^2}{2} \quad (2-27)$$

From the drawing we note that:

$P_e = P_i$ and $v_t \cong v_a \cong v_b$ (Because the change in speed is small)

By subtracting equation (2-25) from equation (2-26), we get:

$$P_a - P_b = \rho x \left(\frac{V_i^2 - V_e^2}{2} \right) \quad (2-28)$$

The force acting in a direction parallel to the direction of the wind on the turbine axis is calculated from:

$$F_x = \rho A \left[\frac{V_i^2 - V_e^2}{2} \right] \quad (2-29)$$

The force also equals the amount of change in momentum:
 $m = \rho A v_t$ (2-30)

Therefore, the axial force is: $F_x = \rho A v_t [v_i - v_e]$ (2-31)

By equating equations (2-30) and (2-28), we get:

$$v_t = \frac{1}{2} (v_i + v_e) \quad (2-32)$$

The difference between the incoming and outgoing kinetic

energy is the amount of work done: $W = kE_i - kE_e = \frac{V_i^2 - V_e^2}{2}$ (2-32)

Power is defined as the work done per unit time and is given by the following equation: $p = \frac{1}{2} \rho A V_t (v_i^2 - v_e^2)$ (2-34)

By substituting for the value of V_t from eq(2-32) in eq(2-34):

$$p = \frac{1}{4} \rho A (V_i + V_e) (V_i^2 - V_e^2) \quad (2-35)$$

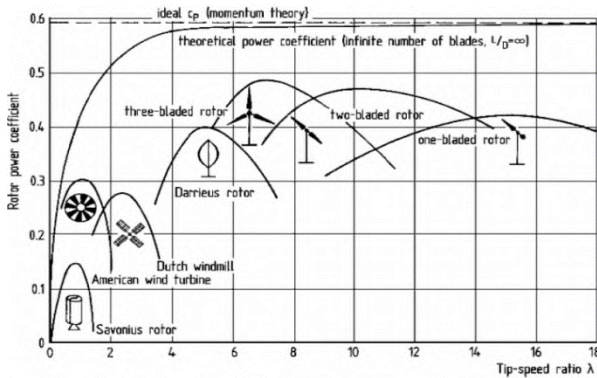
by deriving equation (2-35) relative to V_e and Equating it to zero, we find:

$$3v_e^2 + 2v_i v_e - v_i^2 = 0 \quad (2-36)$$

By simplifying the above equation, we find that the ideal wind speed emerging from the turbine is equal to: $v_e = \frac{1}{3} v_i$ (2-37)

The highest power is produced when the speed of the wind coming out of the turbine is one-third of the wind speed Inlet to the turbine. By substituting equation (2-36) into equation (2-37), we obtain the greatest power. It can be obtained from wind energy, which is equal to: $P_{max} = \frac{8}{27} \rho A v_i^3$ (2-38)

The greatest efficiency of wind systems is called the power factor. Which is equal to the ratio of the maximum power derived from wind energy (Equation 2-38) to the total wind energy eq(2-23): $\eta_{max} = \frac{P_{max}}{P_t} = \frac{8}{27} \times 2 \cong 0.6$ (2-39)



Power factor of different types of wind turbines 2-19

It can be said that wind turbines, no matter how efficient they are, cannot convert more than 60% of the total wind energy at best conditions. The turbine efficiency η ranges in percentage (30-40)%. The important factor in improving the efficiency of wind systems is the tip speed ratio, which links between Wind speed and wind turbine blade tip speed: $\lambda = \frac{\text{blad speed}}{\text{wind speed}}$ (2-40)

Because horizontal axis turbines often consist of two or three blades, and since the energy density does not exceed... 650 W/m². Therefore, to generate a capacity of 600 W/m², it is necessary to provide turbines with a total diameter of 43m. If the wind turbine rotates at a speed of 750 revolutions per minute, you will achieve a very tremendous speed. At the edges, if the turbine rotates at a very slow speed, most of the wind will pass straight through. The gap is between the blades, and therefore it will not give any power, but if it rotates at a high speed, the blades will distort and act as a strong wind barrier, and the rotor blades will create turbulence as they rotate in the air. In order to obtain the ratio of the ideal limb speed to the ideal wind speed (λ), then... The following formula has been proven experimentally: $\lambda = \frac{4\pi}{n}$ (2-41)

Where N Number of blades : $v = \omega r = \frac{2\pi r}{60}$

So $v = \frac{2\pi nr}{60}$ (2-42)

Forces acting on turbine blades: There are two types of forces affecting the horizontal axis wind turbine, the first type is: The peripheral forces affecting the direction of rotation of the turbine blades and the second type are Affecting the direction of the wind, which causes an axial thrust, which necessitates the construction of a strong tower to resist this thrust Axial.

$$F_x = \frac{\pi}{9} \rho D^2 V_i^2 \quad (2-42)$$

The axial forces are directly proportional to the square of the diameter, and therefore the turbine has, Large diameters require precise designs to confront these large forces.

Choose appropriate locations

The exploitation of any renewable energy must be preceded by a study of its characteristics. Energy for the purpose of using it in a way that ensures its economic feasibility, and wind energy is one of them. Of these energies. Therefore, thinking about exploiting it as an alternative energy must be

preceded by preparing the necessary studies. The characteristics of the wind in the area where wind energy is to be exploited, and there are a set of factors that determine The suitable area is.

1. The wind must be at an appropriate and continuous speed and suitable for the type of turbine used.
2. The location must be close to electrical power transmission lines and close to consumption areas.
3. The land on which the wind turbine is installed must be relatively cheap to reduce the cost Economic.
4. The site is located on open land and is not surrounded by any natural or artificial obstacle. Obstacles are factors that have a severe impact on wind speed, so they must be. The wind turbine is as far away from obstacles as possible to avoid its impact, and the best locations to install it. The wind turbine is either on the seashore or inside the sea in order to avoid losing part of the wind. Its energy is measured by friction resulting from surface roughness, and each surface is expressed as a coefficient length Roughness length (Z_0). The length in meters is known as the wind speed. It is equal to zero, as in Figure (20-2).

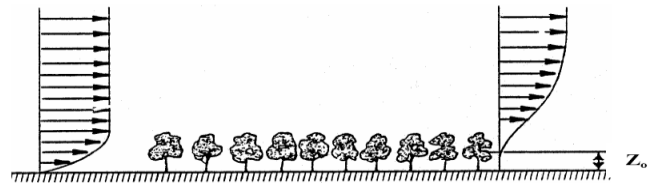


Fig 2-20: The effect of surface roughness on wind speed.

Wind turbines can also be installed at high altitudes such as mountains and hills, as shown in the figure (21-2). The shape of the wind flow over a hill and the following equation enables the calculation of the height (L) that occurs. It has the maximum increase in speed:

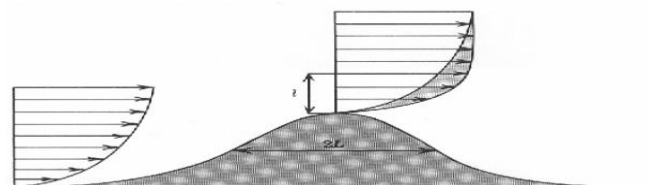


Fig 2-21: Wind flow over a hill, where $2L$ is the diameter of the hill and L is the height at which It has the highest increase in speed

$$L \cong 0.3z_0 \left[\frac{1}{z_0} \right]^{0.67} \quad (2-43) \text{ the height (L) that occurs It has the maximum increase in speed}$$

Where $2L$ is the diameter of the riser and L is the height at which the greatest increase in speed occurs. Wind speeds at the Earth's surface differ from those at high altitudes, the higher the altitude. The higher the wind speed, this can be understood from the following equation:

$$\frac{v}{v_r} = \left[\frac{H}{H_r} \right]^\alpha \quad (2-44) \text{ where:}$$

V = Wind speed at a certain height

V_r = The wind speed at standard height is (9.1m)

H = The height at which the wind speed is required to be calculated

$H_r = (9.1 \text{ m})$ The standard height at which the wind speed is measured at weather stations.

As for α , it is called the exponential wind shear coefficient, and the greater its value, the faster the falling wind speed On the turbine blades, it is less and is calculated from the following equation:

$$\alpha = \alpha_0 \left[1 - \frac{\log v_r}{\log v_0} \right] \quad (2-45)$$

$$\alpha_0 = \left(\frac{z_0}{H_r} \right)^{0.2} \quad (2-46)$$

Where Z_0 is the roughness length of the area adjacent to the turbine and V_0 is a constant speed of 67 m/s.

The **Cup Anemometer** shown in the figure is used (22-2) To measure wind speed, the number of turns is recorded electronically and translated into wind speed in units. Meter per second, and there are other types of anemometers such as pressure anemometers and fan anemometers. (Propellers Anemometer), Sonic Anemometer, and others. As for the direction of the wind, the **wind vane** is used to determine the direction, and the measurement is made During a full circle (360 degrees) the purpose of measuring direction is to know the prevailing direction of the wind As well as the distribution of measured speeds in different directions, this is taken into account when analyzing Data and planning of wind farms. The most appropriate way to measure wind speed in... A location is to place the anemometer at the top of the measuring tower so that it is not affected by the tower, preferably at a height The tower is the same height as the turbine to be installed.



Fig 2-22: Wind vane and anemometer.

There are several ways to determine appropriate wind characteristics, including:

a. Average wind speed method:

$$\bar{v} = \frac{\sum_{i=1}^n v_i}{n} \quad (2-47)$$

$\sum_{i=1}^n v_j$ = The sum of all measured wind speeds.
 n = Number of readings measured.

B. Power speed rate method:

The power produced is directly proportional to the cube of the wind speed

$$P = \frac{1}{2} \rho v^3 \quad (2-48)$$

Results and discussion

Wind turbine power equation simulation by Using Matlab

Wind turbine is designed to convert the wind energy into electric energy. The wind turbine system consists of three main parts: the rotor, which includes the blades to convert wind energy to low speed rotational energy. The second part is the generator that includes the electrical generator, which include all control circuits with gearbox that convert the rotational low speed into electric power and finally the structure that hold all the previous components and that is the tower and nacelle. Wind turbine is classified into two main groups depending on their axis in which the turbine rotate. it can be classified into horizontal axis and vertical axis. Because the horizontal axis has the ability to collect the maximum amount of wind energy for the time of the day and can adjust their blades pitch angel to avoid high windstorms, they are considered more familiar and more common than vertical axis . Understanding of wind properties is very important for wind energy exploitation. Speed of wind is highly variable both geometrically from place to place and temporally, seasonal and in hourly means. In addition to seasonal changes in the wind speed, there are some variations on the shorter time scale. These variations are called synoptic variations and they have a peak at around 4 days. Beside the seasonal and synoptic components in the wind speed, there is a turbulence component. This turbulence refers to fluctuations in wind speed on relatively fast time-scale, typically less than 10 min. In studying the wind energy affection into a wind turbine it is very important to know the mean wind speed determined by the seasonal, synoptic and diurnal effects, which varies on a time, with turbulence fluctuations superimposed .

The determination of wind turbine properties and performance curves

Power, torque and thrust are three indicators that varying with the wind speed which characterize the performances of a wind turbine. The amount of energy captured by the rotor determine its power, the size of the gearbox determine its torque, while the rotor thrust has a great influence on the structural design of the tower. A wind turbine captures energy from moving air and converts it into electricity. Air density, power coefficient, air density and turbine swept area are parameters that affect the captured energy as shown in the following equation:

$$P = \frac{1}{2} \rho C_p v^3 A \quad (1-4)$$

Where:

P = Mechanical power in the moving air (Watt).

ρ = Air density (kg/m³).

A = Area swept by the rotor blades (m²). V = Velocity of the air (m/s).

C_p = Power coefficient.

Maximum power that can be achieved from an ideal turbine

rotor with infinite blades from wind under ideal conditions is 59.26% (0.5926 times) of the power available in the wind as proved by scientist Betz and this limit is known as the Betz limit. Wind turbines are designed to have two or three blades due to a structural and economic considerations, and hence, the amount of power they can get is closer to about 50% (0.5 times) of the available power. Tip speed ratio (TSR) of a wind turbine is defined as:

$$\lambda = \frac{\Omega R}{v} \quad (2-4)$$

Where:

Ω = Mechanical speed at the rotor shaft of the wind turbine (rad/s).

R = Radius of the blade (m).

V = Velocity of the air (m/s).

The TSR, and blade pitch angle β , are used to calculate the rotor power coefficient, denoted by CP. The rotor power coefficient can be calculated as:

$C_p = \frac{\text{Extracted power}}{\text{Power in wind}}$

$C_p = \frac{P_{\text{rotor}}}{P_{\text{wind}}} \quad (3-4)$

Variable-speed wind turbines are equipped with a pitch change mechanism (Pitch angle control) to adjust the blade pitch angle and obtain a better power coefficient profile cause it control its rotation speed.

Wind turbine modeling

Wind turbine consists of the following subsystems as shown

in figure (1):

- Rotor blades and hub.
- Nacelle contains shafts, gearbox, couplings, brake, and generator.

- Tower that hold the Nacelle.
- Electrical system such as switchgear, transformers, cables, and power converters.

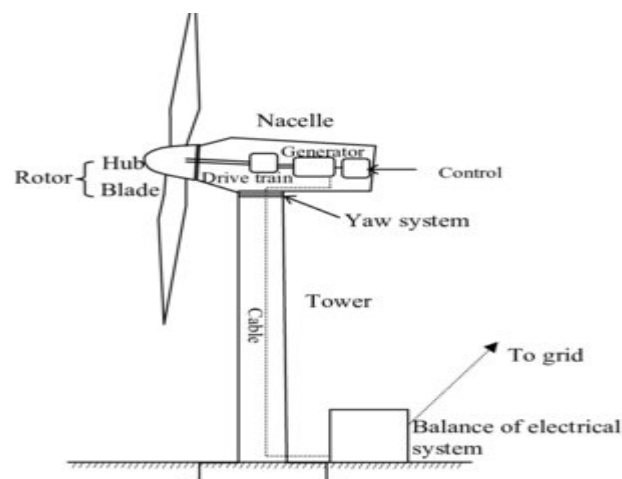


Fig 4-1: Wind turbine diagram.

Power equation simulation

A MATLAB-Simulink model (Fig. 2-4) has been build to show how these factors (equation 1-4 and 2-4) affect the generated power from wind turbine while figures (3, 4, and 5) show the output results. The Simulink model can be used for wide ranges of wind turbines. The specification of the suggested wind turbine is listed table (1) and can be changes to any values by changing the setting values of the blocks :

Table 1

Rotor Diameter	Swept area
52 m	2.125 m ²

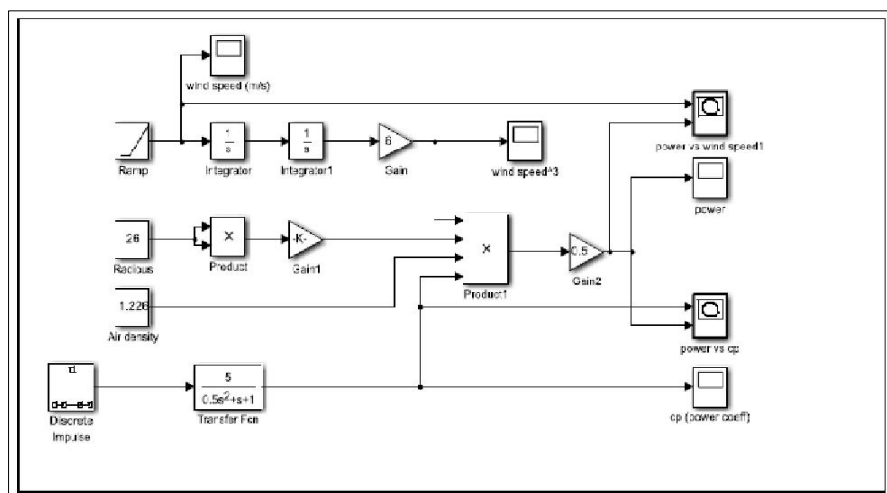


Fig 4-2: Simulink Model for Power Calculations.

Results for the power equation simulation

From the results one can see the variation of wind speed with time as shown in figure (3-4) and in actual the wind speed is not constant so the curve is nonlinear, wind speed in this simulation block diagram can be generated by integration two times the

Ramp function as shown in the first top part of figure (2) and after that multiply it by 6 to get the wind speed $\wedge 3$, also the

power and power coefficient. Swept area must be taken into consideration in terms of the local area conditions to capture power as maximum as possible in order to get best wind turbine As can be seen from figures (4 and 5) the output power of a wind turbine is directly related to the wind speed and tip speed ratio as explained in equation 2 which in turns is a function of blade pitch angle, the power increase with wind speed till some value and after that it will decrease

because of the control system which placed in the nacelle of the safety of the turbine.

the wind turbine in order for

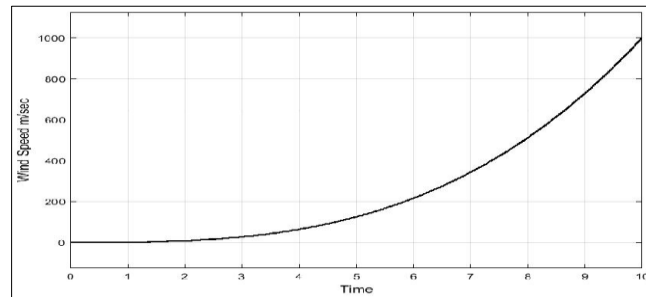


Fig 4-3: Wind speed m/s simulation.

Blade swept area has great effect on power. The diameter of the rotor has directly proportional with the power can be extracted from the wind. Air density has a great effect on wind turbine performance. The power available in the wind is directly proportional with air density too as air density increases, the

power also increases and vice versa. In addition, air density is a function of air pressure and temperature. It proportional directly with air pressure and proportional inversely with temperature. In the same time temperature and pressure proportional inversely with increasing elevation.

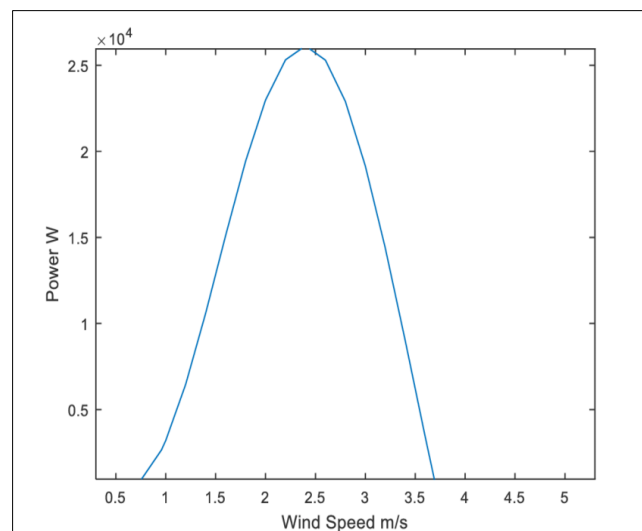


Fig 4-4: The relation between wind speed and power.

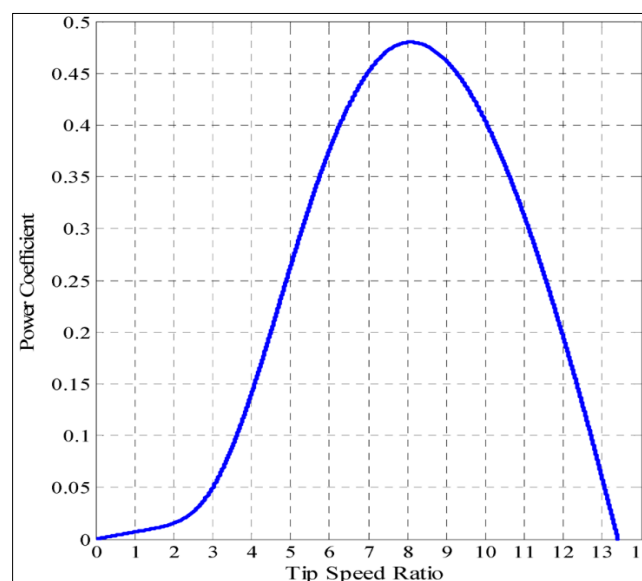


Fig 4-5: The relation between wind speed and C_p .

Wind turbine plant modeling

A wind power plant has been designed by using Matlab-Simulink as shown in figure (6), which is equivalent to the above block diagram. The designed system consist of a 1.5 MW (can be changed to any value) wind turbine connected to a load 400 KVA and electric power source 25 KV through three phase transformer, the active and reactive power is

measured for different wind speed and different pitch angle of the blade. Figures (8, 9, and 10) shows the relation between turbine speed (which it depend on wind speed) and the turbine output power for different wind speed and pitch angle of the blades. These values can be changed by changing the system blocks parameters very easily and this is the advantage of using MATLAB-Simulink.

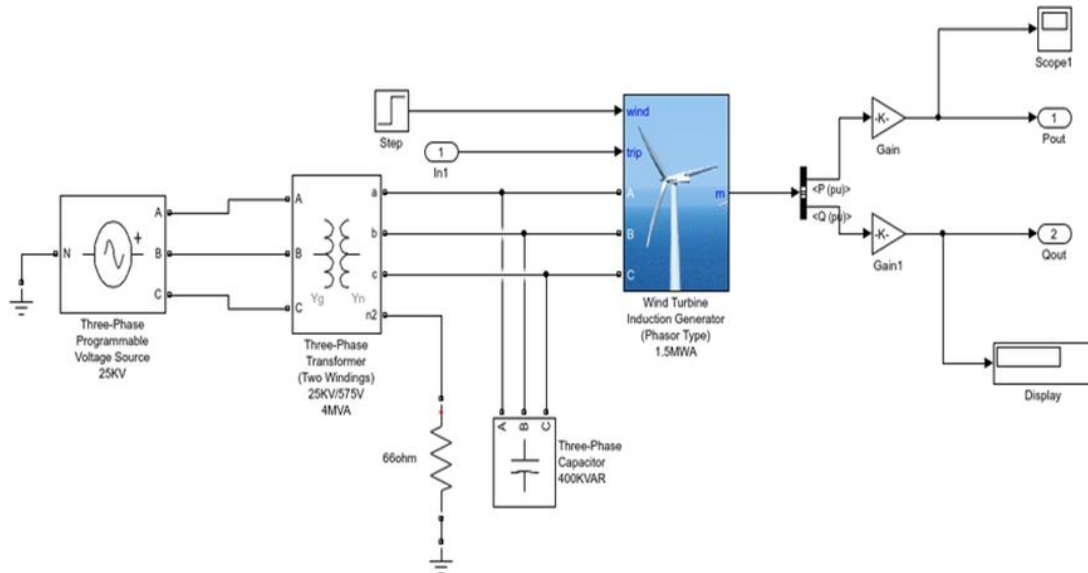


Fig 4-6: (1.5 MW) wind turbine power plant.

Pitch angle can be defined as the angle of attack of the wind with the blade. Changing pitch angle means that the angle of attack of the wind is changed, this can be done by changing the set of the wind turbine in Matlab-simulink in the wind turbin parameters block as shown in figure (7), for example when the pitch angle is zero and wind speed is 12 m/sec we get maximum power as shown in figure (9) but if we change the pitch angle to 5 and 10 respectively for the same wind speed the output power is decrease and this indicate the effect of pitch angle on the output power as shown in figure (8). So the pitch angle value must be evaluated for optimum wind

speed in order to get best output power such as it change automatically when the speed is high or low and this done buy using proper position control, the optimum pitch angle value is

set as set point for the wind turbine. This position control system change the pitch angle according to wind speed, for example for high wind speed the pitch angle decrease and for low wind speed the pitch angle increase to get constant speed and after that to obtain best output power and for the safety of the blades structure.

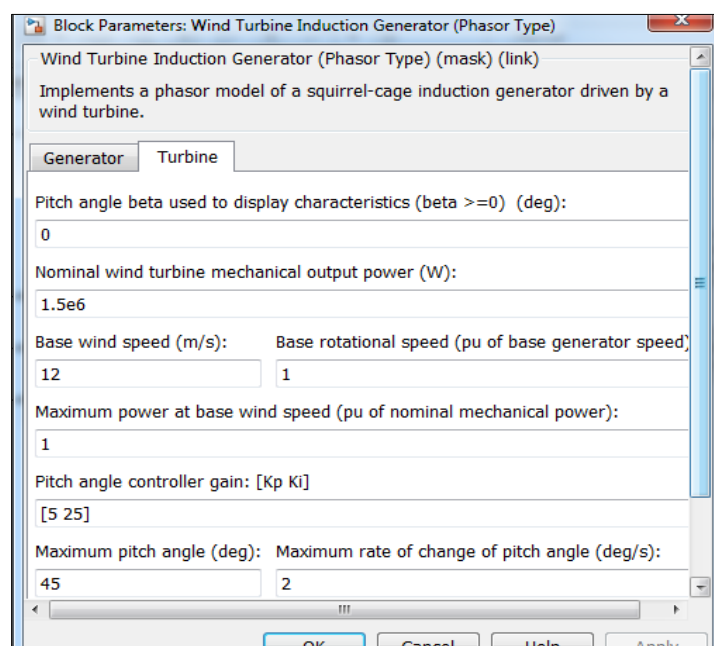


Fig 4-7: The wind turbine parameters setting block.

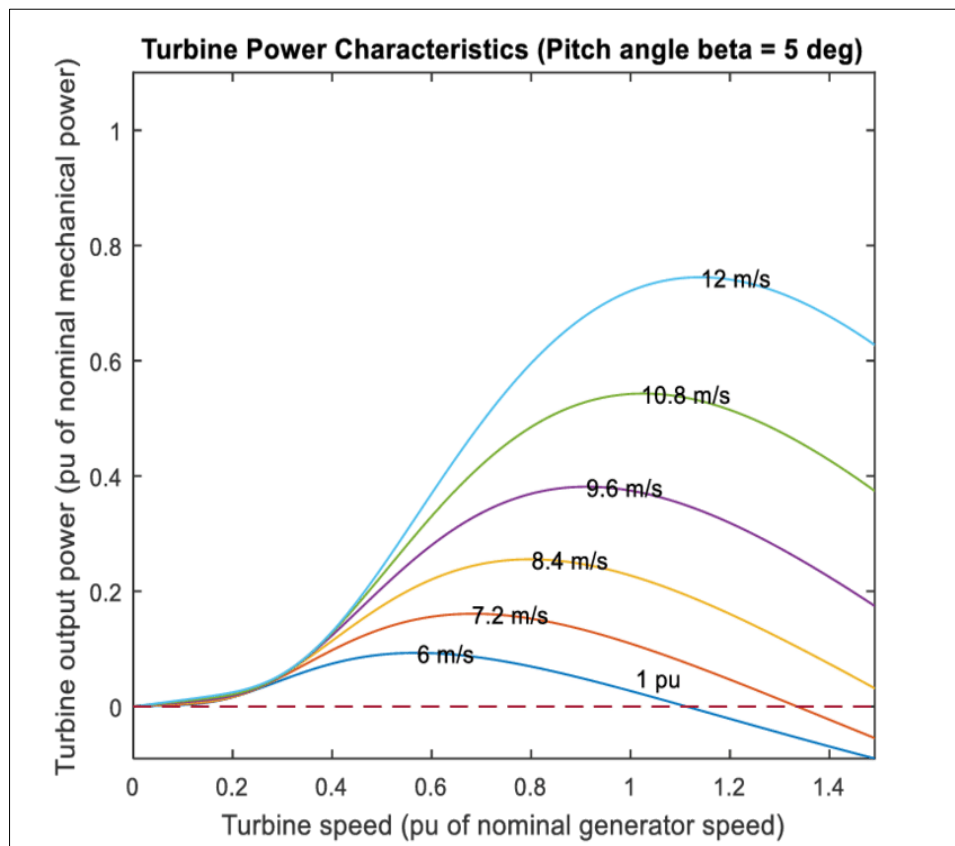


Fig 4-8: Turbine speed vs. output power for pitch angle equal 5.

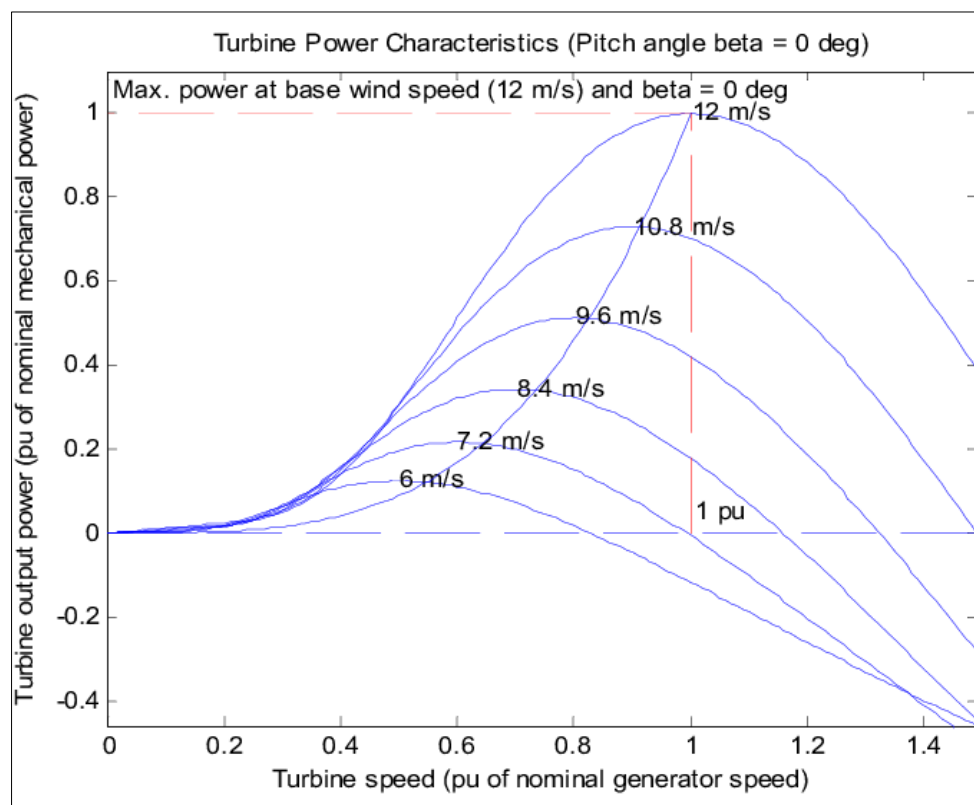


Fig 4-9: Turbine speed vs. o/p power for pitch angle equal zero.

Power in an electric circuit can be defined as the rate of flow of energy past a given point of the circuit. In alternating current (AC) circuits, energy storage elements such as inductors and capacitors may result in periodic reversals of the direction of

energy flow. The portion of power that, average over a complete cycle of the AC waveform in net transfer of energy in one direction is known as Active power (sometimes also called real power). In this research, one can see the effect of changing wind speed on the output power (Active power)

when the pitch angle is constant. This can be done in the same wind turbine parameters block as shown in figure (7-4). The output power of the wind turbine depend on wind speed, so the output power change when the wind speed is change as shown in figure (10-4). The maximum power for the wind turbine designed in this research is 1.5 MW as described previously

when the wind speed is 12 m/sec and higher and that because of the pitch angle position control while for less wind speed the output power is decrease, the position control is work to increase the output power by changing the pitch angle to a certain value so the fan rotate at higher speed and vise versa .

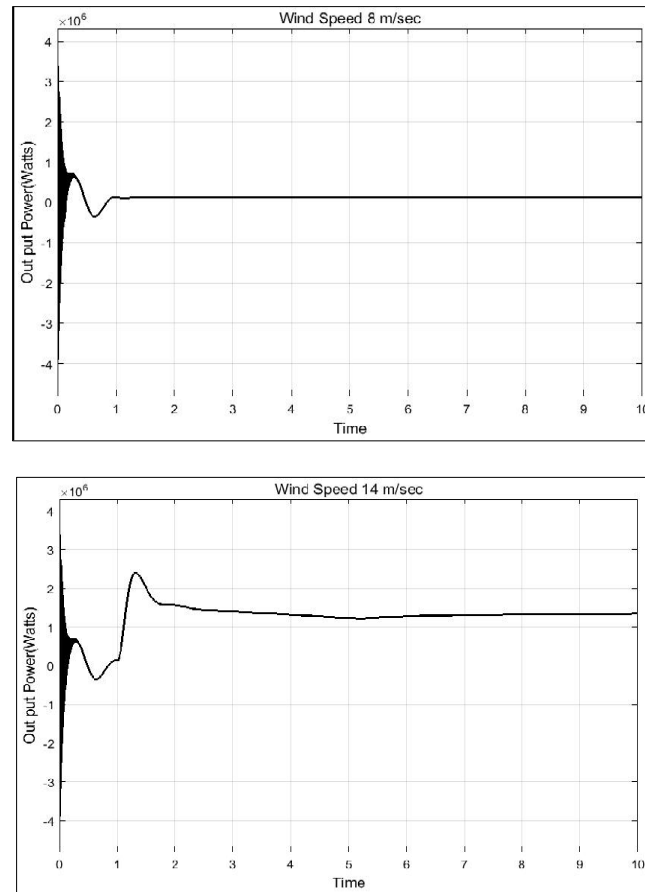


Fig 4-10: Wind turbine output power for different wind speed.

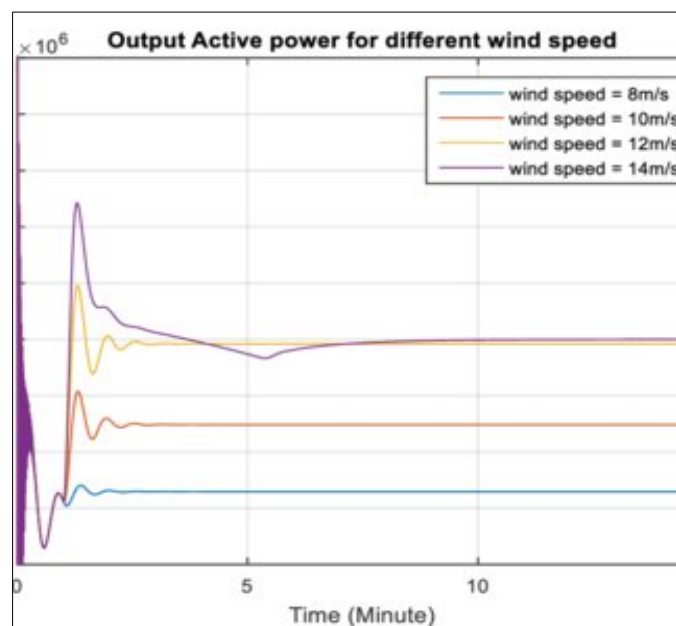


Fig 4-11: Wind turbine active power.

Also in this research, measuring the reactive power has been done in order to get complete information about wind turbines. Reactive power can be define as the portion of power due to stored energy, which returns to the source in

each cycle, figure (12-4) shows the wind turbine reactive power curves for different wind speed. Finally figure (13-4) shows an image of the MATLAB- Simulink scope display which shows the output curve of the suggested wind turbine.

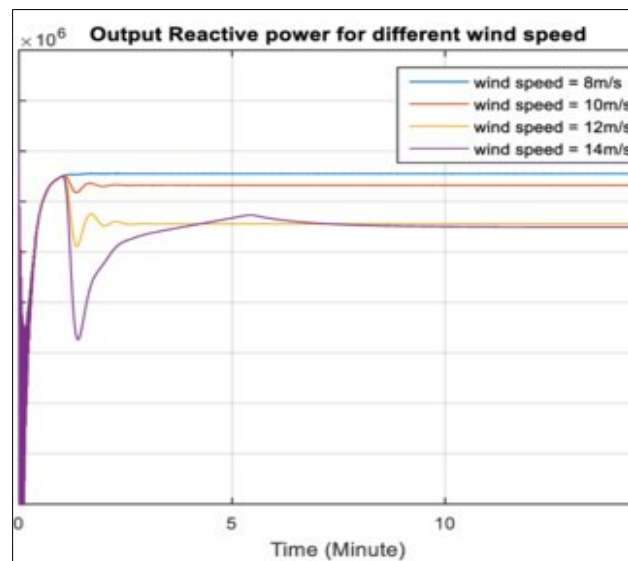


Figure 4-12 Wind turbine reactive power.

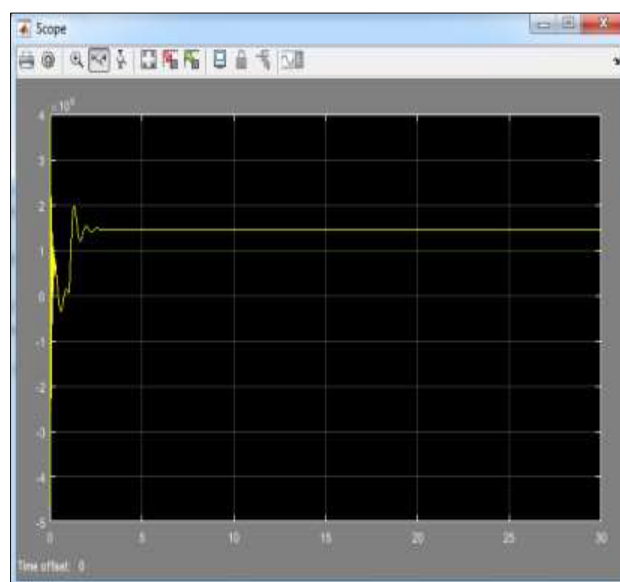


Fig 4-13: Scope display of the MATLAB-Simulink.

Power System Model Integrated with Wind Farm Using DFIG AC generator

A dynamic model of a DFIG wind turbine can be indicated in terms of the equations of a piece system. The stator winding is connected directly to the grid, while a bidirectional power converter feeds the rotor windings, allowing variable frequency operation in the rotor currents. This power converter is made up of two back-to-back insulated gate bipolar transistor (IGBT) bridges (rotor side converter, or RSC; and grid side converter, or GSC) linked by a DC bus. The wind turbine is also equipped with a blade pitch angle controller that limits wind power capture and rotational speed for high winds. Figure 1 represents its configuration. The output power of the turbine is controlled to follow a determined power–speed characteristic, called tracking characteristic. The electrical output power on the network the wind turbine terminals are added to the power losses is

compared to the reference power obtained from the tracking feature. In the converter system on the rotor side, AC voltage and Volt Ampere Reactive (VAR) are regulated.

The DC–DC intermediate circuit contains two converters: first converter AC to DC and second converter DC to AC. The intermediate DC to DC circuit consists of current regulation, DC voltage and pitch control system. The last one is adjusted at zero degrees by the regulator of pitch angle to the extent that the speed is required to follow the characteristics of the control system. The DC voltage output from intermediate circuit was applied to the grid side converter which consists of an insulated gate bipolar transistor (IGBT) two-level inverter, generating an AC voltage at 60 Hz. A 12 MW wind farm consisting of eight 1.5MW wind turbines connected to a 25 kV distribution system exports power to a 120 kV grid through a 30 km, 25 kV feeder. The wind speed is maintained constant at 15 m/s.

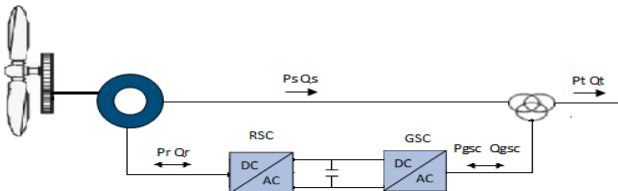


Fig 4-14: Doubly fed induction generator (DFIG) wind turbine scheme by Rotor side converter (RSC) and grid side converter (GSC).

In the second chapter, we talked about this generator

along with its equations, which are:

$$p_w = 0.5\rho\pi R^2 v^3 C_p \quad (4-4)$$

$$C_p = \frac{1}{2}(\lambda - 0.022\beta^2 - 5.6)e^{-0.17\lambda} \quad (4-5)$$

$$\lambda = \frac{v}{\omega\beta} \quad (4-6)$$

Simulation DFIG AC generator in MATLAB

The Figure 15-5 define the model based on the doubly fed induction generator. This model consists of eight 1.5 MW wind turbines connected to a 25 kV distribution system which exports power to a 120 kV grid through a 30 km, 25 kV feeder. The eight 1.5 MW wind turbines form a wind farm of 12 MW of power.

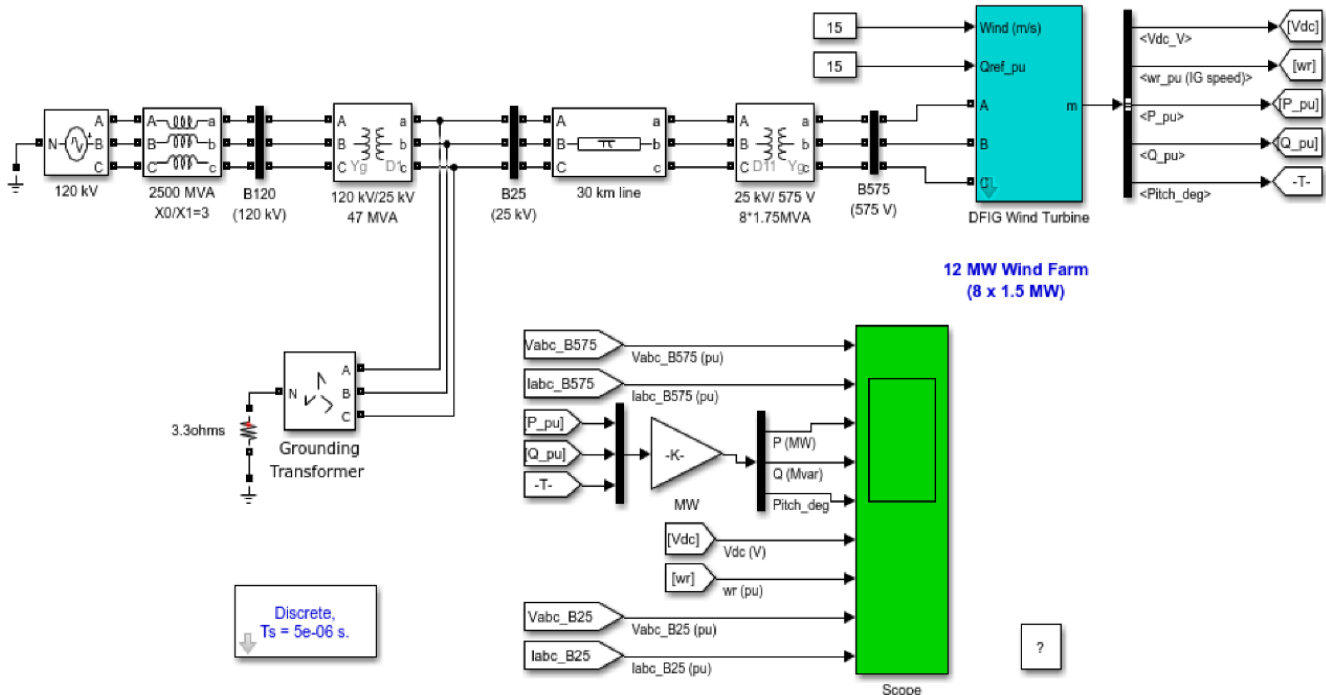


Fig 4-15: Schematic of the doubly fed induction generator model of MATLAB/Simulink.

we will represent and analyze simulation 1 over a period of 60 s by showing the graphs of the rotational speed, pitch angle, active power and DC link capacitor voltage and the current of wind turbines. Most of the variables of interest cited above were represented in pu values where the base power is the nominal power of each wind turbine (1.5 MW). The value 1 pu delimits the nominal power of the wind turbine. We will start by representing two important mechanical parameters, which are the rotational speed and the pitch angle of wind turbine. As we can see, the rotational speed of the rotor is regulated through the angle of the blades. From Figure 15-4a, the pitch angle starts to oscillate right after the disturbance. Nevertheless, it can be seen the oscillation decays after 5 seconds and the system is stable. Moreover, it is clear in Figure 15-4b that the rotational speed of the wind turbine starts at 1.2 pu during the first 10s of the simulation. However, the rotational speed decreases as well to a value below (1pu), which means the generator rotor of the wind

turbine does not rotate at its rated value anymore. This behavior shows that the rotational speed is highly dependent on wind power. From Figure 15-4c, it can be seen that the DC link capacitor voltage shows small fluctuations on rotor active power and output power caused by wind speed variations. The voltage and currents considerably change the generator's active and reactive powers, which are shown in Figure 15-4d. It also remarks in Figure 15-4e,g, that the wind farm DC voltage is the sum of the DC voltages of wind turbines, which means that the GSC is controlling the wind farm DC voltage by maintaining it to a set constant value and also assuring the active power exchange from the generator to the grid. It can also be seen from Figure 15-4f, h that the active power and reactive power diminution of the wind turbine fluctuates until the end of the simulation. The other parameter that is necessary to verify in order to check that our Simulink model is working perfectly is the DC voltage.

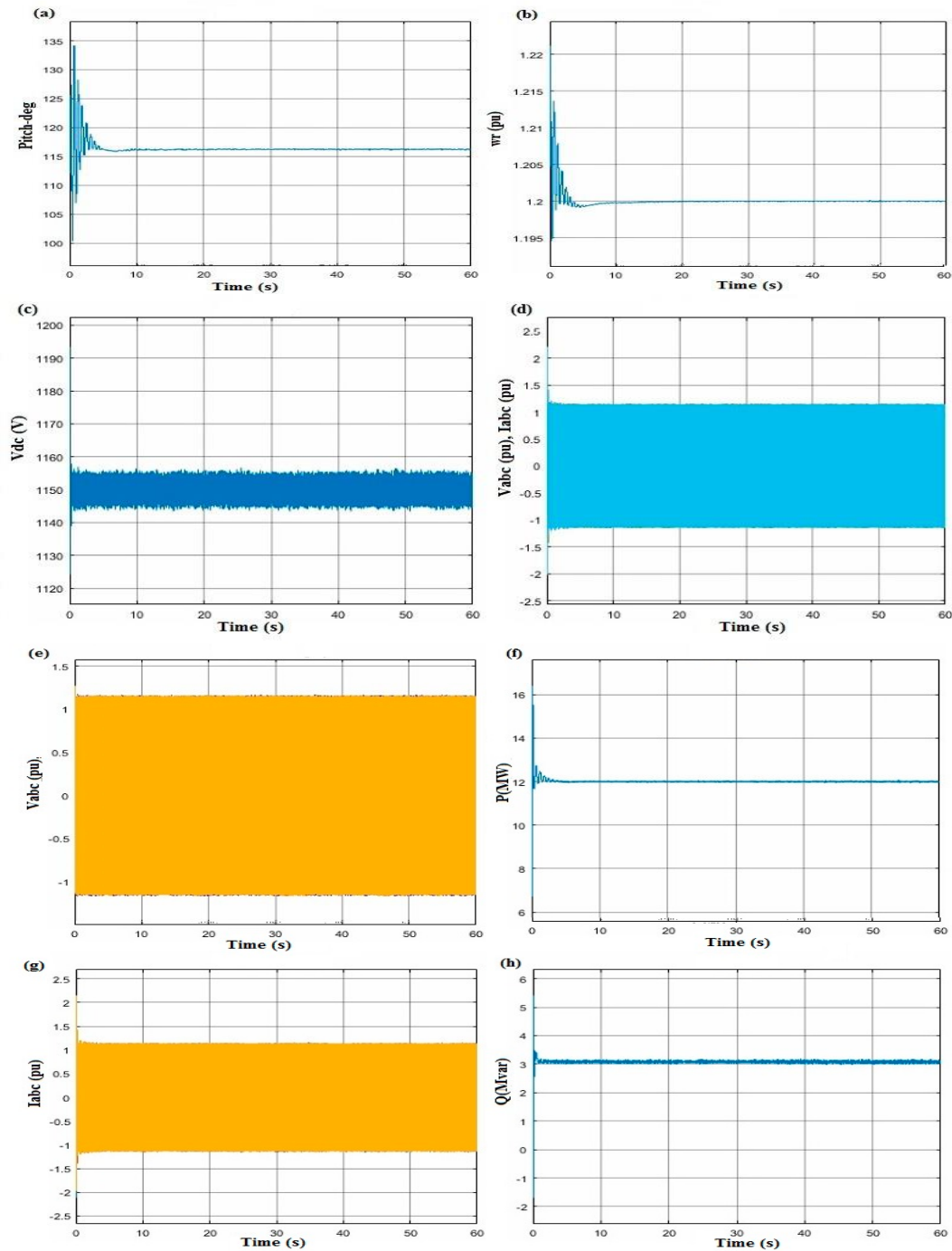


Fig 4-16: Schematization of the set output variables of DFIG: (a) pitch-deg; (b) W_r (pu); (c) V_{dc} (V); (d) V_{abc} (pu) I_{abc} (pu); (e) V_{abc} (pu); (f) I_{abc} (pu); (g) P (MW); and (h) Q (Mvar).

Conclusion

1-Studies of wind energy for power generation purposes have a great interest in the electricity market. The good exploitation of wind energy may enhance the renewable power generation capabilities, increase its capacity factor, and participate in

generating electricity at good costs. Many parameters taken into consideration during manufacturing or installation of wind turbines, such as air density, wind speed, and power coefficient as a function of pitch angle and blade tip speed as shown in figures (3, 4, and 5). In this research modeling and simulating of a wind turbine generator by using MATLAB/Simulink have been done as shown in figure (6). A model built in this study is easy to be understood. The integration of the developed wind turbine

model with the public electrical grid was presented in the work. After building the model, it has been used in order to verify its usefulness; a study of its behavior when integrated in whole power system was needed. Many wind speed levels taken into consideration i.e. from low with 8 m/s as the mean value, medium with 10-12 m/s as the mean value and high with 14 m/s as the mean value. These allowed predicting and supervising the active and reactive power produced by the system as shown in figures (8, 9, 10, 11, 12, and 13).

2- the DFIG and the dynamics operation were modeled to evaluate the responses and

to assure the electrical distribution with the wind in terms of grid voltage and frequency fluctuations. Moreover, the main objective of this paper is the study on the dynamic behavior

of the DFIG characteristic analysis and its effectiveness and optimal performance to assess the impact on the output variables of a wind farm contain many wind turbines. For this reason, the continuation of the proposal of this research is to make a hybrid system consisting of several wind turbines and an energy storage system will be selected to provide a clear idea and exact view of the distribution and degree of fluctuations as presented in the analysis and simulation in the pitch angle, current, and voltage curves to prevent such fluctuation situations and others. Each subsystem will be controlled via non-isolated power converters, and then coupled with grid or local load through the inverter. Simulations of the intelligent control system will also be improved through energy management among all the components of the hybrid system. Therefore, it is not enough to claim that one energy storage device is the best among all the others for each generator, but it is more appropriate to state that each of them has a better performance and is the most suitable for certain applications. Different configurations will be studied to eliminate the weaknesses of DFIG generator wind turbines that will allow the use of electronic power converters. The storage devices comprised in the hybrid system add the flexibility and capacity to the control and regulate the active power generation of the hybrid system, which yield to adapt the changes on the grid demand.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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