Task: 04

Date: 20.05.2021

Wind turbine:

A wind turbine is a device that converts the wind’s kinetic energy into electric energy. It is manufactured in a wide range of sizes, with either horizontal or vertical axes.

The size of wind turbines varies widely. The length of the blades is the biggest factor in determining the amount of electricity a wind turbine can generate.

Small wind turbines that can power a single home may have an electricity generating capacity of 10 kilowatts (kW).

The largest wind turbines in operation have electricity generating capacities of up to kilowatts (10 megawatts)

Components used in wind turbine:

1. Anemometer:
   Measures the wind speed and transmits wind speed data to the controller.
2. Blades:
   Lifts and rotates when wind is blown over them, causing the rotor to spin. Most turbines have either two or three blades.
3. Brake:
   Stops the rotor mechanically, electrically, or hydraulically, in emergencies.
4. Controller:
   Starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. Turbines do not operate at wind speeds above about 55 mph because they may be damaged by the high winds.
5. Gear box:
   Connects the low-speed shaft to the high-speed shaft and increases the rotational speeds from about 30-60 rotations per minute (rpm), to about 1,000-1,800 rpm; this is the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gearboxes.
6. Generator:
   Produces 60-cycle AC electricity; it is usually an off-the-shelf induction generator.
7. High-speed shaft:
   Drives the generator.
8. Low-speed shaft:
   Turn the low-speed shaft at about 30-60 rpm.
9. Nacelle:
   Sits atop the tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake. Some nacelles are large enough

for a helicopter to land on.

10. Pitch:

    Turns (or pitches) blades out of the wind to control the rotor speed, and to keep the rotor from turning in winds that are too high or too low to produce electricity.

11. Rotor:

    Blades and hub together form the rotor.

12. Tower:

    Made from tubular steel (shown here), concrete, or steel lattice. Supports the structure of the turbine. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

13. Wind direction:

    Determines the design of the turbine. Upwind turbines—like the one shown here—face into the wind while downwind turbines face away.

14. Wind vane:

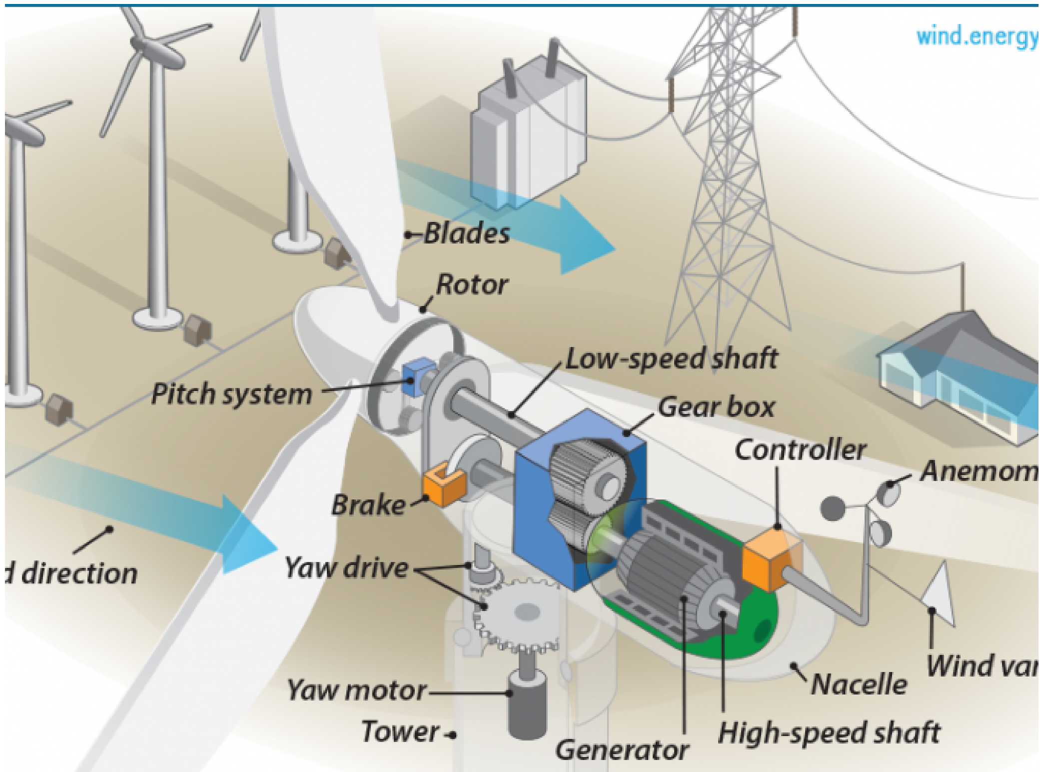
    Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

15. Yaw drive:

    Orients upwind turbines to keep them facing the wind when the direction changes. Downwind turbines don't require a yaw drive because the wind manually blows the rotor away from it.

16. Yaw motor:

    Powers the yaw drive.



Types of wind turbines:

1. Horizontal axis turbines:
    a. Horizontal axis wind turbines(HAWT) are the most common wind machines designed also widely in use.
    b. HAWTs utilise aerodynamic blades(airfoils) fitted to a rotor which can be positioned either upwind or downwind.
    c. There are typically three blades and operate at high blade tid speeds.

Advantages:
    a. They are the most stable and commercially accepted design. Today, most of the large – grid-integrated – commercial wind turbines work on three-bladed horizontal axis designs.
    b. They have a relatively lower cut-in wind velocity and higher power efficeient resulting in higher system efficiency and energy yield.
    c. There are possibilities of using taller towers to tap the better wind potential available at higher elevations. This would be a distinct advantage at sites with strong wind shear where the velocity at higher levels could be significantly higher.
    d. There is greater control over the angle of attack which can be optimized through variable blade pitching. This results in better system output under fluctuating wind regimes.
    e. There is easy furling by turning the rotor away from the wind direction.
    f. The tall tower provides exposure to high wind speeds and hence increased energy production

Disadvantages:

a. HAWTs require yaw drives (or tail mechanism in case of small turbines) to orient the turbine toward wind.
b. The heavy units of generator and gearbox are to be placed over the tall tower, which requires stronger structural support. This makes the HAWTs more complex and expensive.
c. Taller towers make installation and maintenance more difficult and expensive.
d. Again, the taller mast height can make HAWT visible even from longer distances which may aggravate problems related to the visual impact of wind farms.
e. They are huge, so it is difficult and expensive to manufacture, transport, and install.
f. They are noisy, and disrupt the movement of birds and other animals.

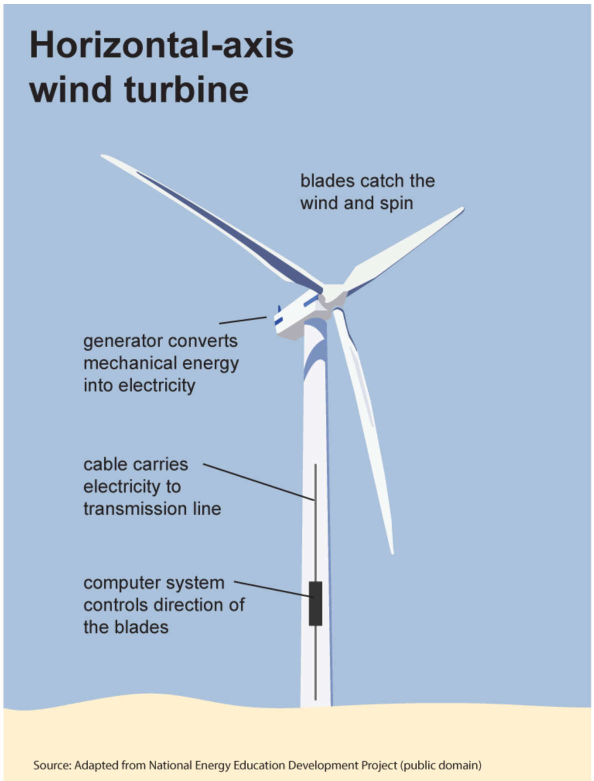
2. Vertical axis turbines:
    a. A vertical-axis wind turbine (VAWT) is a type of wind turbine where the main rotor shaft is set transverse to the wind.
    b. The main components are located at the base of the turbine. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair.
    c. A vertical axis wind turbine has its axis perpendicular to the wind streamlines and vertical to the ground. A more general term that includes this option is "transverse axis wind turbine" or "cross-flow wind turbine."

    Advantages:

    d. Gearbox replacement and maintenance are simpler and more efficient.
    e. VAWTs can be installed on HAWT wind farms below the existing HAWTs, supplementing power output.
    f. VAWTs may operate in conditions unsuitable for HAWTs.

    Disadvantages:

    a. VAWTs are less reliable than HAWTs and less efficient at converting wind to electricity.
    b. VAWTs often suffer from dynamic stall of the blades as the angle of attack varies rapidly.
    c. The vertically oriented blades can twist and bend during each turn, shortening their usable lifetimes.



Onshore and offshore wind:

1. Onshore and offshore wind power generation are among the most prominent technologies to provide clean energy for sources of energy and reduce the carbon footprint, providing clean and renewable energy for the grid.
2. Even though offshore wind turbines are larger in size than onshore turbines, both share the same mechanical principle to provide wind power generation.
3. In both cases, the turbines consist of rotor blades spinning around a horizontal hub. Passing wind through the blade, starts a lift motion that provides a rotating force used in a complex process by an asynchronous generator that finally generates energy.
4. While offshore wind farms cost more due to installation materials and other factors, materials used in both turbines are basically the same, with offshore turbines needing small variations to provide safety in the presence of higher wind speeds.
5. Onshore and offshore technologies could potentially provide the same energy, if two similar-sized turbines were exposed to the same wind speeds, with output
6. energy difference being close to none.

Wind turbine inspection:

Due to the complexity of the design, production and operation of wind turbine blades, there may be many defects. It has good application prospects to use ultrasonic NDT on the flaw detection of blades.

1. Blade failures:
2. Gearbox failures:
3. Generator failures:
4. Internal damages, such as the foot of the rotor blade.
5. Inspection can cover all the components of wind power generation including in the rotor, nacelle tower foundation and electrical system.
6. WT noise measurement:
7. Delamination
8. Core defects
9. Balancing problem
10. Resin gaps
11. Bad bondings
12. Lightning strike/ flashover

Inspection carried out at any point during the fabrication, commissioning and operation of the equipment. Typically requiring inspection include:

1. Manufacturing components
2. Storage / transport equipments
3. Assembly of assets
4. End of warranty
5. Assessing assets performance and conditions during operations.
6. Investigating damages.
7. To extend the life of a wind farm.
8. Planning evaluating maintenance.

Inspection provide the completely objective information on:

1. The condition of wind turbines and assets.
2. The performance of maintenance and repairs.
3. Ability to see further
4. Clarity on sub-structural defected
5. Direct comparison with optical images
6. Actionable repairs can be visualize

The inspections help to reduce risks, reassure stakeholders and meet regulations.

Advantages of wind turbine inspection using drone:

1. Higher resolution visual inspection with drone technology.
2. Thermal imaging can be used to aid in inspecting and monitoring wind turbines.
3. A fraction of the cost with better data, faster speed and increased effectiveness of work.
4. Safety of persons
5. Real time images and videos feed cam transmitted to ground control stations.
6. Smarter datasets and actionable insight: drones collect the needed data for identifying and mitigating risks and increasing revenue.

7. Greatly reduce man hours and costs with effective drone inspection.
8. Increase efficiency due to data accuracy and reliability.

Disadvantages of traditional inspection of wind turbines:

1. It takes a long time to repeat this for all three blades.
2. The knocking system is very subjective and prone to error.
3. Often, wind nice makes it hard to estimate the condition of the blade.
4. The turbine is out of use for hours, and valuable income is cost.
5. Operatives are put at unnecessary risk by being forced to work at height.
6. Faulty and damaged WT can be catastrophic in terms of financial loss, but also in regards to the safety of personnel and the public.

Datasets:

Typically in a wings turbine pose the big data challenge:

1. Volume:
2. Velocity:
3. Variety:
4. veracity:

For handling the data we can use the cloud computing framework for big data ML.

For feature selection various methods are used.

1. Wrapper method:

   Prediction performance of a given model is used to assess the usefulness of a subset of features.

2. Embedded methods:

   perform features selection as part of the training of the ML model.

3. Filter Methods:

   Independent from the model, these methods perform significance tests between each feature and a dependent variable.

For data extraction:

1. Statistics:

   Statistical features such as max/min, standard deviation, mean, median are extracted from the signal and used as features.

2. Parameters of fitted time series models:

   Models are fitted and their coefficients are used as features.

3. Time frequency domain properties:

   Decompose a signal in time domain to its constituent frequency components. Unsuitable for-stationary signals.

Dilatation and translation of a “mother” function are convoluted with the signal resulting in a set of Wavelet coefficients that express the amount of similarity. between the two.
Signal decomposition method that finds a set of intrinsic mode functions at different frequencies that sum to obtain the original signal; suited for non-stationary, non-linear time series.

https://data.mendeley.com/datasets/hd96prn3nc/2

https://ieee-dataport.org/keywords/wind-turbine-inspectio

AI techniques used for this problem statement:

1. Neural networks
2. Support vector machine
3. Multiscale cnn
4. k-clustering

Tasks:
Turbine Performance assessment
Methods used:
Regression vs Unsupervised methods
Evolution:
GMM models exhibited more gradual health change, being more suitable than SOMs and NNs.

Tasks:
Generator bearing failure prediction, Power curve monitoring, Lubricant pressure monitoring, Generator temperature monitoring, Gearbox,
Method used:
Regression/Normal Behaviour Model
Evolution:
Nonlinear neural network approaches outperform the regression models.

Tasks:
Predict failures at different granularities, Detect several types of faults related to rotor blade imbalance and misalignment, Mechanical fault detection, Blade faults detection, Structural vibration errors; root cause analysis, Fault detection, diagnosis, and prediction of generator faults,Transmission system fault diagnosis, Generator Brush Failure prediction
Methods used:

Classification

Evolution:

NNs., SVM, Ensemble decision trees, mscnn, swcnn.

Conclusion:

I've studied briefly wind turbine inspection.