**Turbine Design**

Wind turbine should be designed by keeping some factors such as wind speed, blade design, number of blades and rotor diameter.   
  
**Wind speed:** Wind speed is defined as the amount of wind passing through a surface area. Higher wind speeds generate more power because stronger winds allow the blades to rotate faster. Normally, wind speed in Islamabad ranges between 3mph to 10 mph depending upon weather conditions.  
  
**Blade Design:** Along with wind speed, the design of blades for wind turbine is also important. Material that is commonly used for blades is PVC. It is quite easy to find raw PVC materials as they are relatively cheap.

The procedure to design blades is as follows:  
  
1.) First, assembly all the tools you may need during the actual procedure. Then, measure the PVC pipe's circumference; you can use either a paper or a string to do that. Then, measure the pipe's length using a tape measure. Then, using the length measurements, divide the pipe into equal parts. You can decide to come up with four pieces. If your pipe measured say 16 inches and you need 4 pieces it means that each piece will be 4 inch long.

2.) Then using the tape measure again, the pipe four times to show where the cuttings are to be made

3.) Next, wrap the pipe at one edge with a strip of paper that then make four marks around the paper to cover the circumference of the pipe. Armed with your hacksaw or jigsaw cut the pipe lengthwise using the marks you had previously made. Repeat this until you get the four pieces you had bargained for when you were marking the pipe. At the end of it all, you expect to come up with four pieces that have equal lengths, curvature and widths.

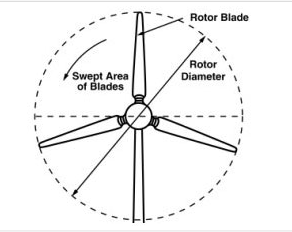
4.) Then from one corner of the four pieces, cut off about 2 inches and you will remain with a portion that is stable to mount the blade.

5.) Then starting from the corner that is on the opposite side of the cut corner, mark two inches. Next, create a straight line diagonally crossing the pipe from the place you marked to the other end of the pipe. Repeat this procedure for the other three pieces. On every pipe cut along the diagonal marks you made. With this, you will end up with triangular pieces that offer the windmill blade shape.

6.) Then, sand the blades to do away with the rough edges. Do this until all the four blades have smooth surfaces. With this, you will be ready to install into your wind generator. To create the surface, you will either need to bolt or screw the blades onto a hub preferably made of plywood. Alternatively, you can decide to use a car radiator fan and screw the blades onto the fan.

You may be required to coat the pieces with paint that is UV protective before installing the blades. Although the majority of PVC materials are strong enough to withstand a number of conditions, long exposure to UV rays will make them become brittle. The paint will ensure that the PVC material does not become brittle after some time of usage.

**Number of Blades:** Normally 2,3 or 5 blades are used for wind turbines. If we increase the number of blades, the more reliable and safer the wind turbine is.   
  
**Rotor Diameter:** By rotor diameter, we mean the turning diameter of blades.



**TSR (tip speed ratio):** Wind turbines should not rotate too fast or too slow. Because either of the scenarios are not ideal. So, for this reason, optimum tip speed ratio (TSR) is very important. Some TSR’s are as follows:

1. 2 Blades: 9 –10
2. 3 Blades: 6 – 8
3. 5 Blades: 4- 6

**The tip speed ratio** is given by dividing the speed of the tips of the turbine blades by the speed of the wind – for example if a 20-mph wind is blowing on a wind turbine and the tips of its blades are rotating at 80-mph, then the tip speed ration is 80/20 = 4.

**Basic Calculations:** Average wind speed and maximum wind speed must be taken into consideration before building a wind turbine. For Islamabad:

Average Wind Speed = 6 mph

Max Wind Speed = 9 mph

Reference: <https://weatherspark.com/y/107761/Average-Weather-in-Islamabad-Pakistan-Year-Round#Sections-Wind>

**Basic Power Formula:**

Blade length, l = x meter

Wind speed, v = x m/sec

Air density, ρ = 1.25kg/m3

Efficient, Cp = average 0.3 – 0.4

Ptotal=0.5 (x) ρ (x) 3.14 (x) I^2 (x) v^3 (x) Cp

**Rpm Calculation:** Rpm can be calculated from the following formula.

rpm = 60 \* V \* TSR / (Pi \* D)

where,

TSR = (Blade tip speed)/ (wind speed mph)

V = Wind speed

D = Rotor Diameter

**Betz Limit:** The Betz limit is the theoretical **maximum efficiency** for a wind turbine. Betz concluded that this value is **59.3%,** meaning that at most only 59.3% of the kinetic energy from wind can be used to spin the turbine and generate electricity. In reality, turbines cannot reach the Betz limit, and **common efficiencies are in the 35-45% range.**

<https://energyeducation.ca/encyclopedia/Betz_limit>

**Overall Design:**

