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Efficiency Concept

According to Betz Law, no wind turbine can extract more than 59% of the energy of the wind

Source: Wikipedia from Introduction to the Theory of Flow Machines by Albert Betz

Wind speed increases as height increases by the equation $V/Vo = (h/ho)^{\alpha}$

Where V is the velocity of the wind, Vo is the initial reference velocity at some known height, h is the height at velocity V, and ho is the initial height at which velocity is Vo, and α is a surroundings coefficient, different for urban settings, flat land, tree surroundings etc. As an example, α=.25 for trees and bushes surrounding the area of a wind turbine. A usual α is around 1/7, meaning that wind speeds are double at 50 m height than at 10 m height.

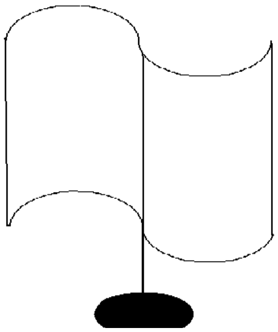
Source: Renewable Resource Data Center, National Renewable Energy Laboratories

Wind Collection

Vertical Axis Wind Turbine

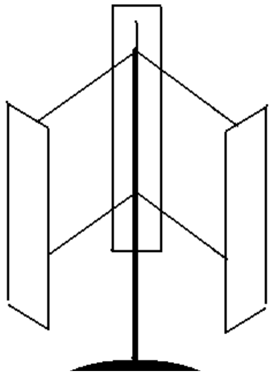
Savonius

- Vertical axis wind turbine which is somewhat crude.
- Construction usually involves two halves of a barrel offset and attached to the central shaft which converts energy to electrical energy at the base of the shaft
- Cheap to construct.
- High stresses in the vertical shaft. Stresses are often pulsating.
- Usually only 10% efficient.



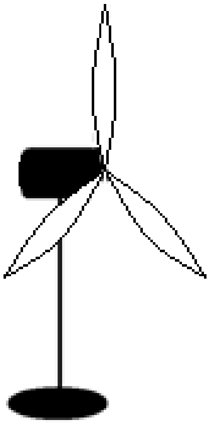
Darrieus

- VAWT which is sometimes referred to as an Egg Beater Design.
- Air foils around the radius of the machine function to spin the central shaft.
- High stresses in the central shaft, usually pulses.
- Usually 30% efficient.
- Air foil design and construction can be difficult and costly.



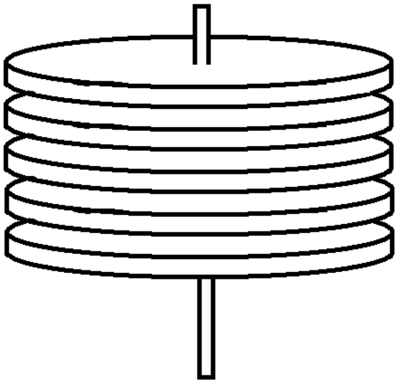
Horizontal Axis Wind Turbine

- Horizontal axis wind turbine where electricity is generated at the height of the rotor, often off the ground.
- Stresses are more even and less severe than in VAWT.
- Usually 35% efficient.
- Three blade design can be balanced well without external balancing.
- Efficient blades may be difficult and costly to produce.
- Packaging concerns of the generator being off the ground.



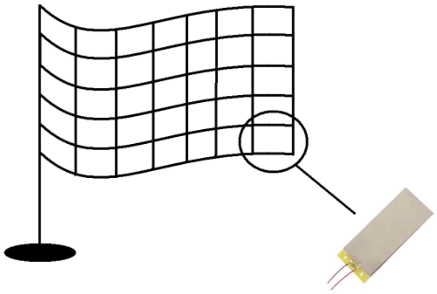
Static Electricity Wind Plates

- Plates that allow wind to pass through them generate static electricity from air friction.
- No moving parts.
- Plates usually made of glass.
- Plates can be cheap to construct.
- Tough to extract power, as static electricity is usually high voltage and very low current.
- Viability of amount of power generated could be a concern.



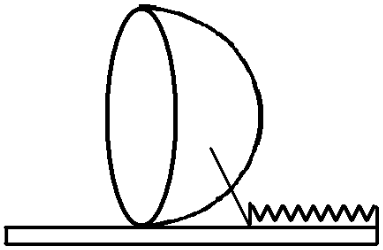
Piezo Plates

- Piezo plates generate electricity through mechanical motion by flexing elements in the plate that act as actuators.
- This application would be a blanket or flag of piezo plates that would generate electricity from fluctuations in the wind, much like a flag billowing.
- Very costly to buy.
- Not an established technology.



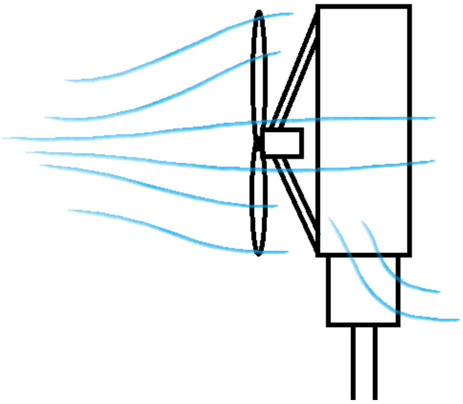
Linear Translating Magnet

- Bowl design attached to a linear slide, which moves a magnet through an electric field to generate electricity, similar to some flashlight designs.
- Compression spring returns the bowl to the neutral position.
- Relies on fluctuations in the wind to move the bowl back and forth.
- Not a proven technology, but could have some adaptations from tidal energy.
- Relatively cheap to build a prototype.
- Power generation could be too low.



Savonius-HAWT Hybrid with Dyson Booster

- Primarily a HAWT, with a booster mechanism.
- Booster uses a Savonius design to blow air around the outside ring of the HAWT.
- Similar to a Dyson ‘Bladeless’ Fan booster system.
- Efficiency increase needs to be weighed against the increase in cost and complexity.



Energy Storage

Battery
    Li-Ion, Na-Ion, Ni-Cd, Lead Acid, NiMH,
    Car, Motorcycle, Deep Cycle

Air Compressor

- Use the wind turbine to compress air in a tank, and release the air to drive a generator which would send energy to the storage bank.
- Efficiency would be lower with the additional energy storage step and losses with the compressor and air-driven generator.

Water Pump – Potential Energy Storage

- Use the wind turbine to drive a pump to move water to a higher storage container, then release the water to drive a generator.
- Increase costs with storage tanks.
- Efficiency would be lower with the additional energy storage step and associated losses with pumps and water wheels.

Flywheel

- Use the wind turbine to drive a flywheel, and use the flywheel to then drive the generator to generate electricity.
- Could even out electric charge rates over a period of time with wind gusts.
- Increase costs with the flywheel and associated systems.
- Losses due to friction in the flywheel assembly could lower efficiency.

Supercapacitor

- Use a supercapacitor much like a battery, where a charge is stored in the capacitor to the charge the LVE batteries
- Length of charge could be insufficient for the application
- Safety concerns with non-technical personnel working with a supercapacitor with a maximum charge.

Spring

- Use the wind turbine to compress or twist a spring to store energy, then release the spring to drive the generator.
- Eliminates losses from storing the energy in a battery.
- Size of the spring may be restrictive.
- Safety concerns of that much stored mechanical energy.

Motor/Generator

Brush vs. Brushless
Stepper Motor
Solenoid
Magnets
Linear Magnets
    Liner Magnetic Wind Capture

Turbine Brake

Progressive Clutch

- Use a clutch which would engage friction plates at a specified RPM, thereby limiting the maximum speed of the turbine.
- Allows the turbine to run safely in high speed winds and generate the maximum amount of power.
- Costs of the system could outweigh benefits of allowing the turbine to run in extreme conditions.
- Friction plates could wear out over time and need to be replaced.

Mechanical Brake

- Use a mechanical brake, disk or drum, activate either automatically at a set point or manually by the user, to slow the system down to a safe speed.
- Size of the system to slow the windmill mechanically could require a large cost.

  Disk Brakes
    Hydraulic
    Spring activated
  Drum

Dummy Electric Load

- During heavy winds, transfer the generator to a separate circuit which would place a heavy current draw on the generator, increasing the torque required to turn the motor and slowing the turbine down.
- Could be cheap to construct.
- System may not be as effective as needed in an emergency stop situation.

Driven Rotating Base

- Using a motor in the base of the stand, rotate the entire turbine 90 degrees to the wind direction, which then stops the blades.
- Torque required of the motor could mean the motor would have to be large and costly.
- System would require some type of sensing equipment for wind speed, and a microcontroller to turn the turbine until the wind speed was slow enough for operation.

Air Fin - HAWT

Passive

- Initially angle the fin on the back of wind turbine so it is offset from the main axis of the turbine. This then would push the turbine to an offset from the wind direction, and could slow down the turbine automatically.
- Extremely cheap and easy to actually implement.
- Effectiveness of the system may limit low speed operation.
- Angle of offset would have to be investigated to ensure that the maximum rotor speed would beacceptable.

Active

- Using an adjustable-offset air fin, turn the fin offset to the wind direction to angle the turbine out of the wind.
- Cost of the system could be too high.
- Motor driving the fin could fail and the rotor would spin dangerously fast.

Feather Blades

- Turn the blades relative to the rotor, such that the angle of attack of the blades relative to the turbine and wind direction slows the rotor.
- Extremely costly and complex.

Failsafe?

- In a situation where the wind turbine needs to stop immediately, some methods will not work.
- Wind turbine needs to stop quickly if operating in dangerous conditions or if the system becomes unstable, like a blade breaking off the main unit.
- Stop for assembly needs to be investigated. Could be simple, like a rotor pin to stop components from rotating.