SMALL WIND GENERATORS

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INTRODUCTION

Electricity produced from small wind generation can be used directly, as in water pumping applications, or it can be stored in batteries for household use whenever it is needed. With a capacity in the range of 10-100 kW, they can provide the consumer and business side of the power grid with its electrical needs, often in combination with solar photovoltaic panels. They usually do not need gearboxes or transmissions like utility-scale generators. They do not need a yaw mechanism either, replacing it with a tail-rudder system. The Vertical Axis Wind Turbines (VAWTs) designs can be used in the urban environment. A 10 kW turbine, with a storage system, can provide the needs of an average household.

The $787 billion American Recovery and Reinvestment Act of 2009 provides a 30 percent investment tax credit to consumers buying small wind turbines. This could help this market to grow by 40-50 percent per year. The USA is the global leading manufacturer of small wind turbines with 2/3 of the market share and USA companies produce 98 percent of these turbines sold in the USA.

Small wind generators can be used alone, or they may be used as part of a hybrid system, in which their output is combined with that of solar Photo Voltaic (PV) electricity and/or fossil fuel (e. g. diesel generators). Hybrid systems are especially useful for winter backup of home systems where cloudy weather and windy conditions occur simultaneously. They have found a new use as a power source for small businesses and urban dwellings that are remote from the electrical grid.

Under unusual emergency conditions causing power failures, they can provide emergency power for extended periods of time.

Figure 1. Small wind turbines roof mounted on a commercial gas station and on an apartment building in the UK.

There is no precise definition of what is considered as a small wind generator, but it usually applies to machines under about 10 kW in rated power. In developing countries small wind turbines are used for a wide range of rural energy applications. Many off-grid applications are used in the industrialized nations as well, such as providing power for navigational beacons.

In this case, the wind generators are not connected to a grid. They use Direct Current (DC) generators and operate at a variable speed. A typical 0.1 W battery-charging wind generator has a shipping weight of just 15 kgs.

SITING CONSIDERATIONS

The most important decision when considering the installation of a wind power system is determining whether or not a chosen site has enough wind to generate the power needed, whether it is available consistently, and if it is available in the season when it is needed.

The power available from the wind is proportional to the cube of the wind speed:

$$P = \frac{1}{2}\rho S V^3 [Watts] \qquad (1)$$

where:

ρ is the air density $[\frac{kg}{m^3}]$,

S is the rotor swept area $S=\pi R^2$ $[m^2]$

R is the rotor radius [m],

V is the wind speed $[\frac{m}{sec}]$.

If the wind speed V doubles to 2V, the power of the wind or its ability to do work increases $2^3 = 8$ times. This means that a 20 mph wind has 8 times the power of a 10 mph wind

One of the effects of the speed cube rule is that a site which has an average wind speed reflecting wide swings from very low to very high velocity may have twice or more the energy potential of a site with the same average wind speed which experiences little variation. This is because the occasional high wind packs a lot of power into a short period of time. However it is important that this occasional high wind occurs often-enough to keep a bank of storage batteries charged without causing catastrophic failure of the wind installation.

For providing smaller amounts of power consistently, the use of a generator that operates effectively at slower wind velocities is usually adopted.

Wind speed data is available from local weather stations at airports, as well as the USA Department of Commerce National Climatic Center in Asheville, North Carolina. A site analysis can be done with an anemometer or totalizer and observation.

Installation of generators should be close to the energy storage batteries bank to minimize line losses, and should be located 30 ft higher than surrounding obstructions within a 300-ft radius. The structural tower should be electrically grounded as a protection against lightning strikes.

Figure 2. A 10 kW wind turbine on a 120 foot tower with guy-wires in a rural environment can provide the electrical needs for a typical USA household with energy storage.

WHISPER 500, 3 kW WIND TURBINE

Figure 3. Whisper 500, 3 kW wind turbine.

The twin blade, 3 kW of rated power Whisper 500 turbine, manufactured by Southwest Windpower costs about $5,000 (Fig. 3). It delivers in excess of 500 kW,hr of energy per month in a 12 mph wind. This machine has a 4.26 m or 14 ft rotor diameter providing 175 ft^2 of swept area. It has a strong and large yaw shaft, blade stabilizer straps and three spindle bearings for increased reliability.

It uses a fiberglass and foam core blade allowing a smooth, high efficiency operation and low wind start-up. It incorporates the angle governor design for quiet operation in high winds.

It is a machine for application to village power projects, farms, ranches, back-up power and remote homes with large energy demands.

WHISPER 200, 1 kW WIND TURBINE

The three blades, 1 kW Whisper 200 wind turbine costs about $2,000. It has a 3.1 m or 10 ft rotor diameter and an 80 ft^2 swept area that provides a reasonable output at low wind speed averages. It is suitable for areas with low to moderate wind speeds of less than 5.4 m/s or 12 mph (Fig. 4).

It incorporates a permanent-magnet alternator powered with an advanced airfoil, delivering 6.3 kW.hr of energy per day.

It is equipped with a controller that offers sufficient reliability and good control for battery charging with a safe cabinet design allowing easily settable voltage regulation points, load dump and load dump isolation from the battery bank.

Figure 4. Whisper 200, 1 kW wind turbine.

WHISPER 100, 0.9 kW WIND TURBINE

Figure 5. Whisper 100, 0.9 kW wind turbine.

The Whisper 0.9 kW wind generator, costs about $1,700. It is equipped with a controller for both wind and photo voltaic sources of power and designed to operate with medium to high wind speed averages of 5.4 m/s or 12 mph (Fig. 5). It can provide about 100 kW.hr of energy per month, or 3.4 kW.hr per day, in a 12 mph average wind speed location.

It has a 2.1 m or 7 ft. rotor diameter and 40 ft^2 of swept area, and is rugged enough for extreme environments. It uses 3 injection-molded blades with fiber reinforcement.

The turbine incorporates a permanent magnet brushless alternator, which combined with a composite airfoil blade design, delivers 0.90 kW peak power at 12.5 m/s or 28 mph. With a hybrid controller, it can be used as a stand alone wind generator or as a hybrid wind and solar generator for telecommunication applications, and remote home and ranch applications

It uses a side-furling angle governor which protects the turbine in high winds by turning the alternator and blades out of the wind, reducing turbine exposure.

It possesses a cast aluminum housing, and a sealed yaw bearings. Its operation was temperature tested over a range from –40°F (-40°C) to 110°F (43°C).

AIR-X 24, 0.4 kW, WIND GENERATOR

Figure 6. Air-X 24 wind generator.

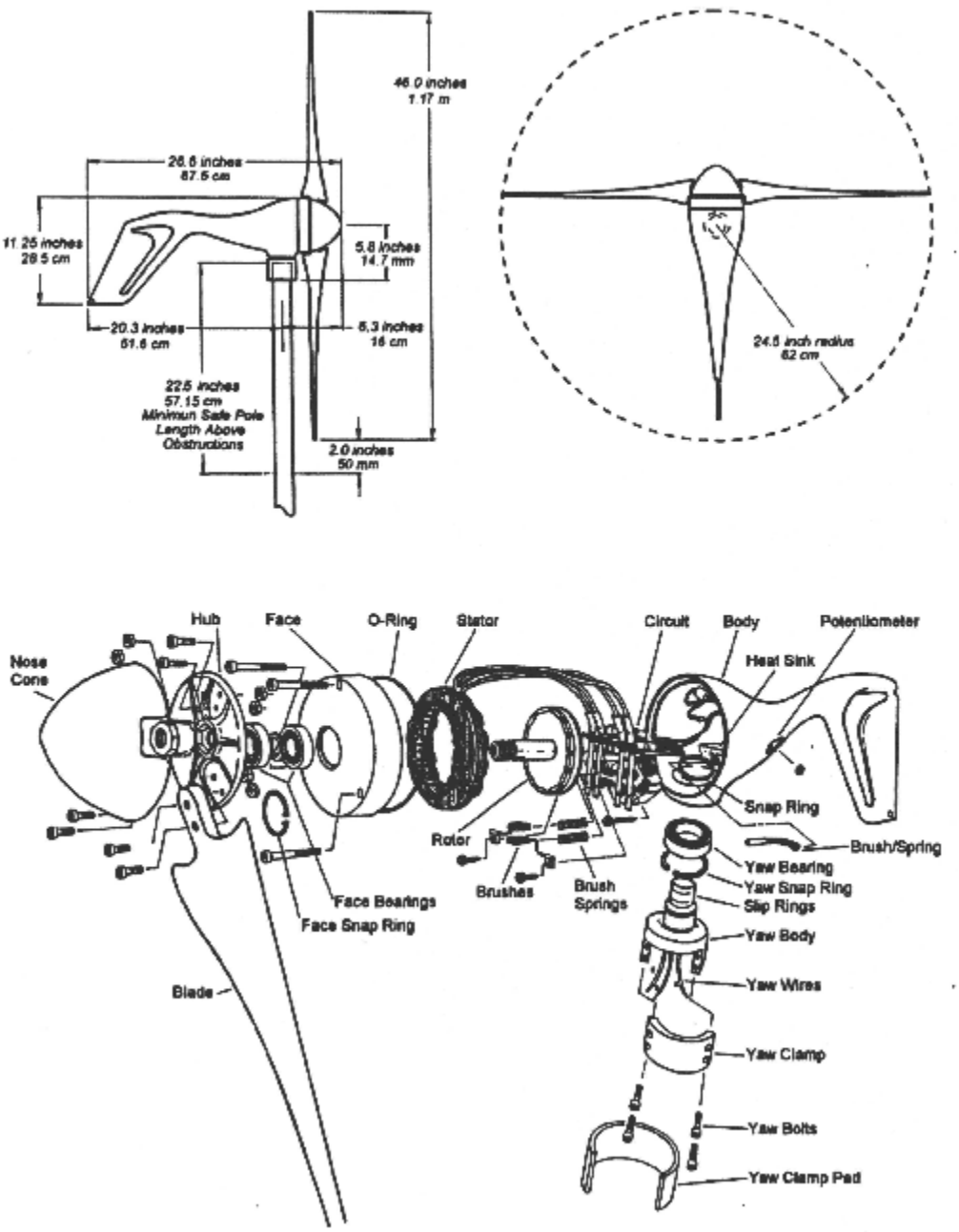

Figure 7. Exploded view of the components of the Air-X 24 wind generator.

At an appliance cost of about $500, the Air-X 24 is a small wind turbine with a micro-processor controller. It is primarily intended for charging batteries generating a 12 or 24 Volts Direct Current (DC) current output. Its controller continuously adjusts the alternator loading to maximize alternator and blade efficiency at all wind speeds and all states of battery charge.

It can control its rotational speed to prevent blade flutter in high winds which causes much quieter operation in all wind conditions. The technical specifications of the Air-X 24 are shown in Table 1.

Table 1. Technical Specifications of Air-X 24 small wind turbine.

Rotor diameter	1.15 m, 46 in
Weight	5.85 kg, 13 lbs
Mount	1.5 in schedule 40 pipe, 1.9" OD, 48 mm
Start up wind speed	3.13 m/s, 7 mph
Voltage	12 and 24 Volts DC
Rated Power	0.4 kW at 12.5 m/s, 28 mph wind speed
Turbine controller	Microprocessor based smart internal regulator with peak power tracking.
Blades	3 carbon fiber composite blades
Energy production	38 kW.hr/month at 5.4 m/s, 12 mph wind
Over-speed protection	Electronic torque control
Survival Wind Speed	49.2 m/s, 110 mph

It includes an internal charge controller, externally adjustable for any type of battery. Its electronics equipped with heat sinks improve reliability, increase output and offer better control. An automatic brake feature slows the blades to a silent spin when the batteries are fully charged

In its marine version it has a powder-coated aluminum body, all stainless steel hardware, marine grade wire, and a water-tight housing. It uses variable pitch aero elastic carbon fiber blades and a brushless permanent magnet alternator.

With only two moving parts, the marine version is simple to install, easy to use and requires minimum maintenance. It can be used for multiple purposes such as: refrigeration, autopilot, powering a fresh water maker, lights, navigational equipment, communication equipment, recreational boating, offshore beacons, remote monitoring equipment, ocean side homes and cabins, and battery charging in general.

ECONOMICS

As a niche market, small wind generators are the only alternative when the costs of energy from conventional sources can be excessively high as in desert areas or in cold climates (Fig. 7).

Figure 8. Bergey Wind Power Company small wind generator.

Small wind turbines are used in the Arctic, Antarctica, northern Canada, Alaska, and Finland. The USA Office of Technology Assessment (OTA) reports typical costs of energy sources at remote locations to wind energy for a 10 kW turbine as shown in Table 2. Electricity generated from wind power would be more advantageous than diesel or grid extensions.

Table 2. Comparison of energy costs for remote locations.

Alternative	Energy cost [$ / kW.hr]
Micro Hydro	0.21
Wind (10 kW rated power)	0.48
Diesel	0.80
Grid extension	1.02

HYBRID AUTONOMOUS SYSTEMS (CICLOPS)

The sun shines mainly in summer while during wintertime there is more wind. Sun shine and wind are anti cyclic. Photovoltaic solar panels generate electricity during daytime only and the bulk of energy during the summer period. Therefore solar panels and wind turbines are complementary, resulting in a more reliable and constant energy source.

Figure 9. Hybrid wind solar and diesel installation.

Figure 10. Control and energy storage of a wind-solar hybrid system.

Ecotécnia from Spain has designed the Ciclops system, as an integral system for managing hybrid autonomous wind-photovoltaic-diesel electricity generation for application in zones isolated from the electrical grid in a rated power range from 10-50 kW.

The system is a modular system that adapts to both the energy requirements of the installation and the availability of natural resources in the zone. A typical installation could consist of:

1. A wind turbine of about 10 kW rated power,
2. A photovoltaic solar plant of 2, 5 or 10 kW rated power,
3. A generator set,
4. A 120 V deep cycle battery,
5. The Ciclops system including a solar charger, wind, diesel and one or more 10 kW wave inverters.

This system is suitable for remote applications with consumptions of up to 100 kW.hr/day, suitable for applications such as remote farms, small villages, campsites, park shelters, applications in developing countries, aquaculture operations or telecommunication stations.