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Technology Advancements in Small Wind Turbines

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ARE442 10KW grid-tied wind turbine on a 142 ft freestanding lattice tower in Newberg, Oregon. Designed, manufactured and installed by Abundant Renewable Energy.

Advancements in wind turbine technology have been growing rapidly. In the shadows of multi-megawatt wind turbines is another growing sector within this industry: residential wind. Improved airfoil designs for maximum efficiency at low wind speed, high efficiency direct drive permanent magnet alternators, improved governing methods and highly sophisticated controls and inverters now allow home owners to interface directly with utility companies or design off-grid systems. These systems are increasing energy independence, competing with current energy prices and reducing environmental impacts.

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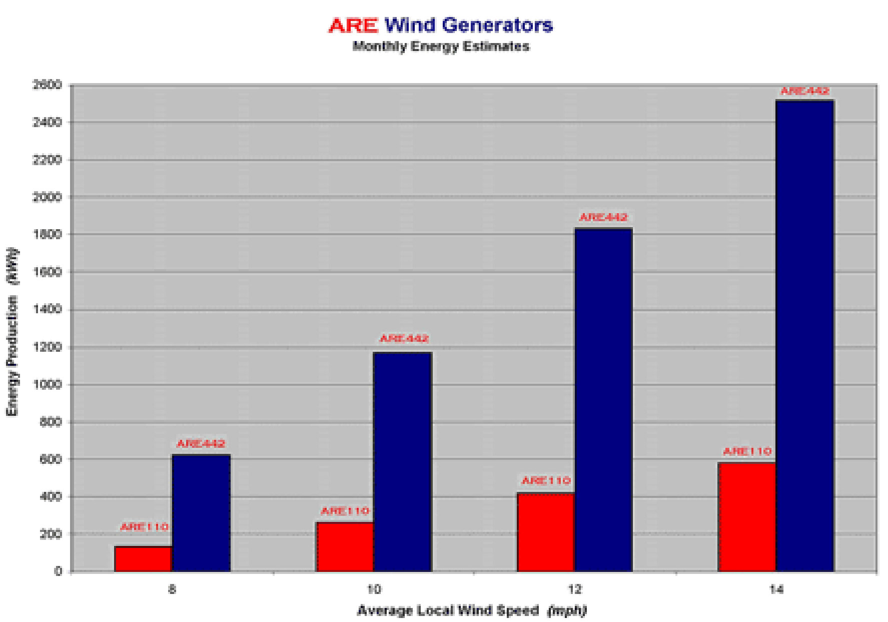
Small wind turbines are usually defined as any wind turbine with a rated capacity of less than 100KW. Many small wind turbines and wind turbine manufacturers have suffered from extensive criticism over poorly made machines, over stated energy production, and over estimating longevity. Abundant Renewable Energy has adopted a design philosophy that puts efficiency, long life and high-energy production in low wind speeds as the first priority of our engineering and manufacturing efforts.

Fig. 1. ARE110 2.5KW grid-tied wind turbine on a 127ft ARE tilt-up tower in Newberg, Oregon. Designed, manufactured and installed by Abundant Renewable Energy

The small wind industry has been growing in the last couple years, and with the advent of new and improved technology the efficiency and longevity of these machines are greatly improving. Now more than ever attention is being paid to the economic feasibility of these machines, and some manufacturers have taken this opportunity to increase overall quality and performance. Not many people live with in a class 3 or 4 wind site, and quite often lack the quality or quantity of wind needed for consistent energy production. This has lead to increasing effort to improve turbine efficiency in low winds.

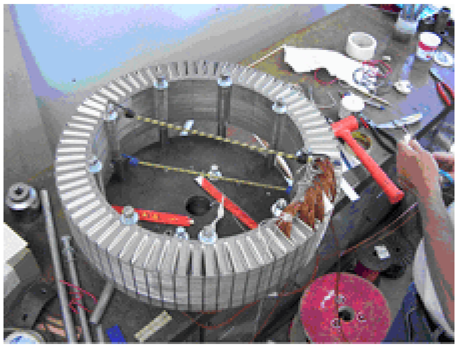
Figure 2. Energy produced in kilowatt hours in a given month in relation to wind speed for the ARE110 and ARE442



One important consideration in designing a wind turbine is matching the tip speed ratio (TSR) of the airfoils to the alternator/generator. The TSR is the speed of the tip of the airfoil relative to the velocity of the wind. Although having a high TSR might be advantageous in keeping airfoil cost down due to the requirement of thinner blades as well as the need for a smaller alternator due to a higher rpm rotor, this usually results in machines with shorter life cycles and noisier airfoils. Designing wind turbines with low TSR means that chord width of the airfoil can be increased making them more efficient at low wind speeds and lower rpm resulting in a quiet, longer lasting turbine. This aids in maximizing low wind start-up speed and increases energy production at the low end of the power production curve.

In addition to airfoil design advancement, alternators have also been advancing in their efficiency and capabilities. Neodymium magnets are now being used in most every modern alternator design for small scale wind turbines. These high strength rare earth alloy magnets consist of neodymium, iron and boron ($Nd_2Fe_{14}B$) plus other doping ingredients to increase coercivity and improve oxidation characteristics. These magnets are resistant to demagnetization, and have a much higher flux density than plastic, ceramic, or alnico magnets. This results in alternators with a higher flux density that can produce more power then an alternator of an equal size using Ferro or other magnets. Other improvements such as high quality laminate to reduce iron losses, tight air gap tolerances and low induction winding configurations to reduce cogging torque all add to increasing alternator efficiency.

Figure 2. Hand winding of the prototype ARE442 high efficiency permanent magnet alternator.



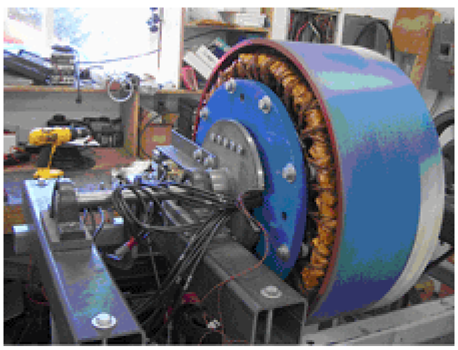


Figure 4. Bench testing the ARE442 prototype alternator.Instantaneous power production and peak rated capacity in relation to wind speed for the ARE442 and the ARE110. Power curves show passive self regulation at 25mph to govern rotor rpm.

Controlling a wind turbine's power output and rotor speed can be one of the largest challenges for designers and manufacturers. Without proper controls wind turbines are not able to achieve their maximum efficiency and run the risk of over speeding in high winds and damaging the equipment. Electronic controls load the alternator to keep the rotor at peak power for the wind speed unless the desired maximum power level has been exceeded. Controllers also enable as much power as possible to be put into the batteries, consistent with preserving battery life in battery charging systems. The power that exceeds available battery load will be diverted to a heat load, which can be a standard water-heating element allowing end users to utilize energy that would otherwise be dissipated as waste heat. Charge controls can be temperature compensated and have adjustable set points for extreme environments and custom charging capabilities. These controllers are using pulse-width modulation to control the amount of power sent to a diversion load.

Advanced control enable small wind turbines to interface directly with the utility grid without the use of a battery bank. Several inverters are now available to directly interface with a machine's controller and synchronize with utility voltage and frequency with very little conversion losses. Both SMA and Magnetek have been on the leading edge of manufacturing high voltage inverters designed to interface with small wind turbines. This required inverter manufacturers to provide power control algorithms suitable for small wind generators. These grid connect inverters provide maximum power point tracking in a highly efficient battery-less system ideal for net metering applications. This enables consumers utilizing the utility grid to sell their excess energy back to the utility for the same price the utility charges their consumers.

Combining several or all of these advancements in wind turbine technology can result in quieter, longer lasting and more efficient turbines. Implementing these technology advancements is not without it's price. As blade and alternator sizes increase so does weight. This leads to more expensive manufacturing costs, more robust tower requirements and higher shipping expenses. Sophisticated controllers and inverters also come with a slightly higher price tag than their predecessors. The end effect results in a more expensive machine. I guess it is true what they say: you get what you pay for.