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Sustainability of Small Wind Turbines on Native American Tribal Lands

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Abstract

As part of the Tribal Energy Program we, as interns, are given the privilege to visit many tribal sites that employ renewable energy technologies. During a field visit to the Manzanita Tribe of Kumeyaay Indians and the Ramona band of Cahuilla Indians reservations in southern California, concerns were heard about the reliability of small wind turbines.

In an attempt to learn more about the reliability of these small wind systems, a field visit to the Navajo reservation (which lies in parts of New Mexico, Arizona, and Utah) was made. Since one of the services provided by the Navajo Tribal Utility Authority (NTUA) has been small wind systems, the Navajo Nation visit was considered a primary source for reliability data. In addition to wind systems, NTUA supplies photovoltaic (PV) systems and PV-wind hybrid systems to their customers in locations without access to electricity from a conventional distribution grid.

As the NTUA has allowed documentation of the installation procedures of their hybrid systems, their data is the primary focus of this paper, which will identify common

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reliability issues with small wind turbines. Recommendations to address documented reliability issues will be discussed and clarified with NTUA representatives at a later date, and are not a part of this paper.

Introduction

Tens of thousands of Native Americans live without the modern conveniences provided by electricity. This is especially true on the Navajo Nation, which is located in the southwest United States. It is the largest Native American reservation both in terms of population and land area spanning about 27,000 square miles with a population of nearly 250,000 people. To gain some perspective, West Virginia is about 24,000 square miles and has a population of about 1,800,000 people.

The largest towns in the Navajo Nation have a population of only about 8,000 so it can be seen that the population is sparse with most living in remote rural locations far from the electrical grid. It is estimated that 38% of the families on the Navajo Nation are without a grid connection.[2] The estimated cost of line extension is about $27,000 per mile.[3] Since some of the homes require many miles of grid extension, electrical line extension is not feasible and too costly to be implemented.

One approach that has been effective in providing electricity to rural customers is distributed energy systems--systems that generate power at the site where the power is consumed. In remote rural locations, these systems are ideal because they offer electricity to customers who would not otherwise have access to it. Once again, these

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[2] http://www.navajo.org/history.htm
[3] http://www.wapa.gov/es/pubs/esb/2004/august/aug045.htm

small wind systems on the Navajo Nation are a good example to examine for this research paper.

A distributed energy system can consist of renewable energy technologies (e.g. wind, solar, or geothermal), or it can be made up of fossil fuel technologies (such as propane or diesel generators). The renewable distributed energy systems (RDES) can provide essential electricity to remotely located Navajo people. Furthermore, the non-polluting systems are a good match with the cultural values of minimal impact to the environment held by many in the Navajo Nation.

During our intern field visits, it was discovered that some customers expressed that their small wind turbines were not performing up to their expectations, and in some cases, the system had completely broken down. Issues with the small wind turbines will be illustrated by installations observed during field visits to not only the Navajo Nation, but also visits to the Manzanita, Ramona, and Hopi tribal lands. An overview of small wind turbine technology will also be presented in order to further illustrate issues with small wind turbines.

Navajo Nation

NTUA is a non-profit enterprise established by the Navajo Nation Council to provide multi-utility services to the Navajo Nation and the Navajo People.[4] In 1993 NTUA was given a grant to institute a program to provide RDES to customers living in remote locations in the Navajo Nation. Since 1993, the program has grown to reach over 300 customers. Table 1 shows the progression of the program from 1993-2004.[5]

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[4] http://www.ntua.com/

[5] SAND Report 2004-5104 P "Navajo Tribal Utility Authority: Photovoltaic Hybrid Operation and Maintenance Process For a Sustainable Program"

From 1993-2004 the RDES have changed rather significantly. The first deployment of RDES provided customers with 240 watts photovoltaic (PV) power.

Table 1. Progression of NTUA Renewable Energy Program

	Power Output	Number of Units	Manufacturer
Phase I-1993	240 Watt 260 Watt	40	Solar Mart
Phase II-1999-2001	640 Watt	200	Photo Com./Kyocera
Phase III-2002-2003	880 Watt hybrid (Small Wind Turbine) 880 Watt Hybrid (Propane Generator)	44 total (40 Wind 4 Propane)	SunWize
Phase IV-2003-2004	880 Watt Hybrid (Small Wind Turbine)	63	SunWize

The latest deployment of the systems provides customers with 880 watts of PV, and a supplementary 400-watt small wind turbine. The small wind turbine in this system is complementary to the PV panels. That is, the PV panels produce electricity during the day when the sun is shining, but the PV panels do not produce electricity during the night. The wind turbine acts as a complementary source when the sun is not shining and when the wind is usually blowing.

Figure 1 shows an 880-Watt Hybrid System in Monument Valley, Utah and illustrates the most current system deployed in the field. At this location, the PV panels and small wind turbine produce electricity that is stored in a bank of batteries. The 880-watt PV cells will provide at least 2 kilowatt hours per day in the winter months, when the sun is least available. The power production of the small wind turbine is a function of wind speed. The manufacturers of the AirX wind turbine used by NTUA project a maximum power output of 400 watts. This maximum will occur when the wind speeds are at 28 miles per hour. There are four 6-volt battery units. When these batteries units are connected, the total battery system provides 24 volts of AC electricity to the user.[6]

Figure 1. 880-Watt Hybrid System in Monument Valley, Utah

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[6] Sunwize Handbook

Installation and Maintenance

It is the responsibility of NTUA electricians to install and maintain the RDES. The hybrid system shown in Figure 1 was installed by Vircynthia Charley and Melissa Parrish, two NTUA electricians. Vircynthia and Melissa conduct bi-annual visits to each RDES site to perform maintenance and to ensure the health of the systems. There is maintenance procedure in place for both the PV panels and the batteries, but not for the wind turbines. The bi-annual maintenance for the wind turbine includes checking to make sure the wind turbine is rotating in the wind, and making sure the light located on the wind turbine that indicates power production is illuminated.

During a field visit and as a result of telephone conversations with Vircynthia Charley, more information was obtained about how the turbines were installed and maintained. The turbines are installed on a utility pole that is 25-30 feet above the ground. Initially the electricians tried to install guyed towers to put the turbines on, but this proved to be a difficult task due to limited manpower and a lack of appropriate installation equipment in the field. During the summer internship field visit, the difficulty of getting to the site was observed. Before reaching the site, it was necessary to travel about 50 miles from the district office. Some of the unpaved roads were very rough, and getting large equipment through would be very difficult, especially in the winter time or after it has rained.

Small Wind Turbine Technology

In order to better understand issues that might be encountered with small wind turbines, it is important to understand some fundamentals of wind power. The term small wind turbine refers to a class of wind turbines whose electrical power output is less than 100 kW.[7] There are two different types of small wind turbines: vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT). The rotor of the VAWT rotates about a vertical axis; the rotor of a HAWT rotates about a horizontal axis. For the most part, HAWT turbines are preferred. Figure 2 shows the components a common small wind turbine.

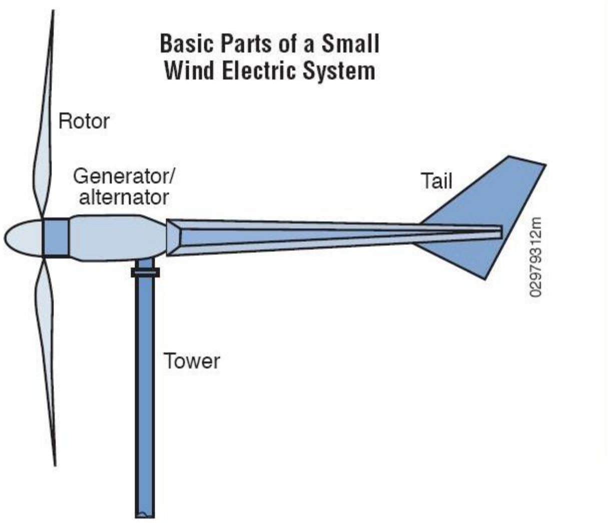

Figure 2. Basic Parts of Small Wind Electric Systems

Mechanical and Technical Issues Affecting System Reliability

A number of issues can make installing a small wind turbine either a success or a failure. These issues can be classified in one of two categories: mechanical or technical. Mechanical issues are classified as issues that are intrinsic to the wind turbine. Conversely, technical issues are those issues that are not intrinsic to the turbine. An

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[7] Small Wind Electric Systems: An Oregon Consumer's Guide

example of a mechanical issue would be the mechanical bearings wearing out. An example of a technical issue would be inadequate knowledge of the average annual wind speed of a particular site. Often technical issues can have implications that cause mechanical issues. Technical issues include but are not limited to: turbulence, turbine height, turbine location, and wind speed measurement.

Generally there are two types of winds: turbulent and laminar. Laminar flow is where there are parallel, undisturbed layers in the flow. Turbulent flow is where there is a sudden shift in both wind speed and wind direction.[8] Turbulence can have adverse effects on a wind turbine and can cause mechanical issues. Turbulence is caused by obstructions such as buildings, houses, trees, and local topography. If a turbine must be located in close vicinity to an obstruction, the following rule of thumb should be remembered: an obstruction will cause a turbulent zone within 20 times the height of the obstruction in the horizontal direction directly downwind of the obstruction, and two times the height of the obstruction in the vertical direction above the ground. The wind turbine should therefore not be placed in this turbulent zone. Figure 3 illustrates the rule of thumb.

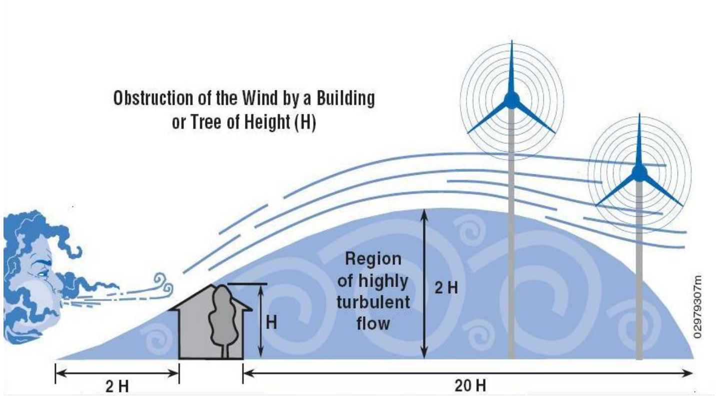

Figure 3. Turbulent Zone Caused By Obstruction

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[8] Wikipedia.com

Other obstructions that can cause turbulence include topography and surface roughness. While the regional wind conditions may be known, the local wind conditions can be quite different. Figure 4 shows how wind conditions can vary even on the same site. For example the wind conditions upwind of a topographical obstruction could be laminar, but on the downwind side of the obstruction the conditions might be turbulent. For this reason, it is crucial to know the prevailing wind direction on a specific site so the turbine can be sited upwind of any obstacles. It should also be noted that the ideal location for a wind turbine is at the top of a ridge because the maximum wind speed is at the top of a ridge.

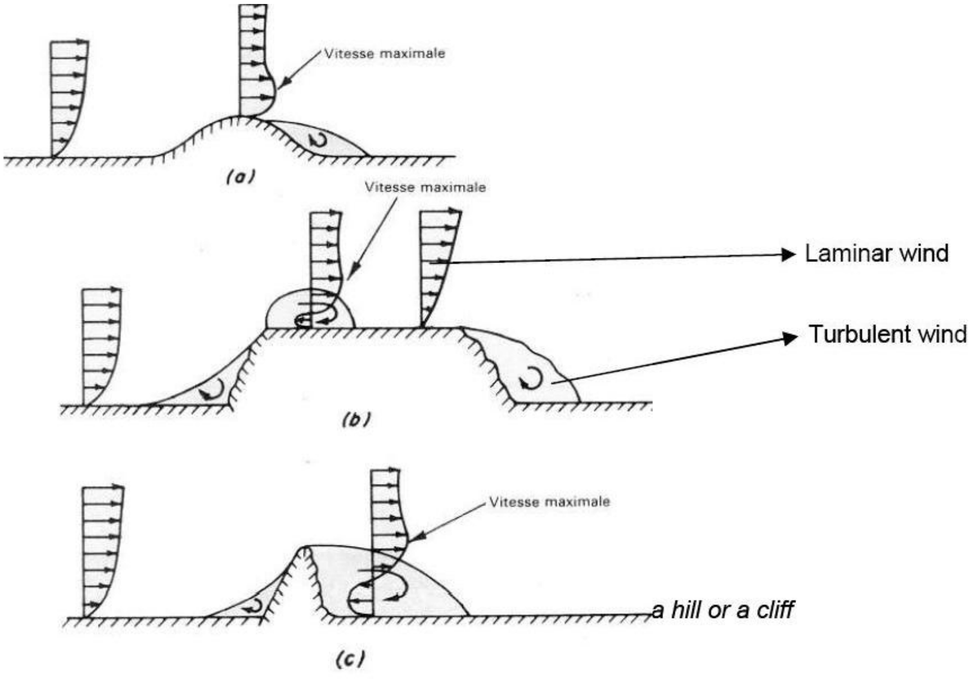

Figure 4. Topographical Obstructions

Turbine height is another important technical issue to be aware of. Wind speed increases with the distance above ground; it is therefore preferable to place the small wind turbine as high above ground as possible.

Wind speed as a function of height is given by **Equation 1**.

Equation 1:

$V_2 = V_1\left(\frac{H_2}{H_1}\right)^{\alpha}$, where α is the wind shear exponent, for most situations α is approximated as 1/7. The change in wind speed as a function of height has implications in the amount of power a small wind turbine is able to produce.

Power production by wind turbines is given by **Equation 2**.

Equation 2:

$$P = \frac{1}{2}\rho\pi R^2 V^3$$

Equation 1 shows that if the height were to increase by 2 times the initial height the wind speed would increase by 10%. Equation 2 shows that a 10% increase in wind speed would result in a 34% increase in power production.[9]

Another technical issue is wind speed measurement. For large wind turbine installations an anemometer study always precedes the installation of the turbine. The purpose of the anemometer study is to provide data of the actual wind speed at a given site. The anemometer study is usually conducted over the period of a year in order to get accurate average wind speed measurements for a specific site. Once the analyst has the average wind speed measurement for a given location, the average power that a wind turbine will produce, if placed at that particular site, is determined.

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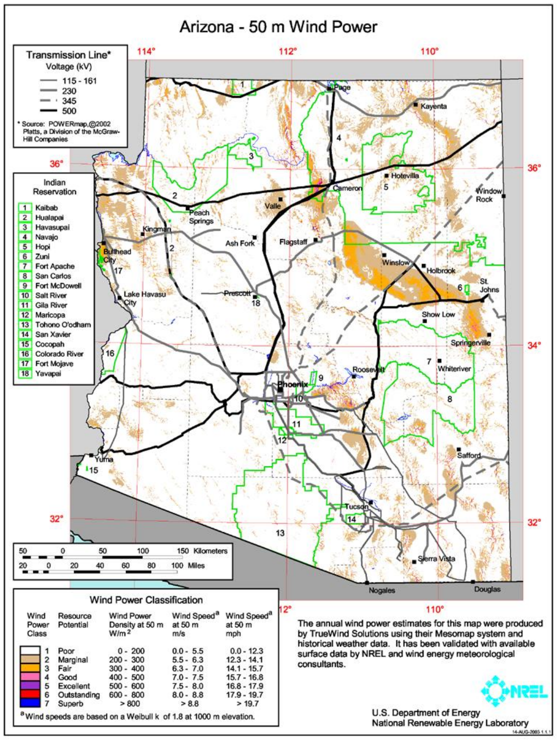
[9] http://en.wikipedia.org/wiki/Wind_power



The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

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National Renewable Energy Laboratory

Figure 5. Wind Resource Map of Arizona

For most cases, an anemometer study for a small wind turbine is not necessary and is cost prohibitive. Instead, the installer of a small wind turbine must rely on regional wind data. This can be in the form of wind resource maps like the one shown in Figure 5. By not properly siting the small turbine as previously illustrated, NTUA cannot easily quantify how much energy the small wind turbine can produce because the wind conditions are site specific. Knowledge of the regional wind resource allows for an economic feasibility analysis to be conducted on a larger scale. For NTUA, it is important to understand the economics of the project; but the necessity to deploy of the supplementary wind turbine in addition to a solar system for more residential electricity production might be an overriding factor. However, it is important to point out that correct siting of a small wind turbine is possibly one of the most important factors to a successful installation. Placing a wind turbine in a turbulent area or in an area with lower than desirable wind speeds is like placing a solar panel in the shade.

Mechanical issues with small wind turbines include but are not limited to blade fatigue, bearings failure, and generator over-speeding. Blade fatigue occurs when the wind turbine blade is subject to cyclic loads. The cyclic loads are a result of non-uniform loading of the blade. These non-uniform loads can be in the form of turbulence, a chipped blade, or a foreign substance on one of the blades. These cyclic loads decrease the expected lifetime of the wind turbine blades, and lead to increased operation and maintenance costs.

Most small wind turbines have bearings that allow the small wind turbine to rotate about the vertical axis. These bearings are known as yaw bearings. Bearings, as with all mechanical parts, have a finite lifetime. That is, they will fail at some point. Factors such as wind turbulence greatly reduce the expected lifetime of the bearings by causing the wind turbine to seek the wind, therefore introducing unnecessary fatiguing to the bearings.

Over-speeding is a major issue with any turbine. Over-speeding is a phenomenon that occurs when the wind speed is too high, and the generator of the wind turbine spins so fast that it burns out. Most, if not all, of the newer small wind turbines have some sort of over-speeding defense mechanism, such as braking or furling. Breaking occurs when the small wind turbine stops itself from spinning by shorting its circuit. Furling is when the rotor of the wind turbine turns itself out of the wind, thereby reducing the area exposed to the wind, and reducing its speed.

Intern Observations

Tribal student interns were fortunate to be able to learn about installations and maintenance of small wind turbines on Native lands, and also given the opportunity to talk with tribal members about some of the reliability issues they experienced while using these systems.

During any maintenance checks, a visual inspection of the turbine blades for foreign materials adhered there might prove useful. Additionally blades could be checked for fractures or breaks. While overly simplistic, it is possible that a “fly the kite” method of determining wind direction could prove useful during installations, as improper siting can lead to reliability issues. Installations in overly turbulent sites could certainly lead to reliability issues. Finally, upgrading the current small wind turbines from 400 watts to a 1000-watt capability might help resolve some reliability issues and provide more electricity to the customers.

Reliability issues of small wind turbines discussed herein are applicable not only to the NTUA systems, but to systems installed throughout Indian Country. It should be stressed that NTUA is a leader among Native renewable energy system installments and should be commended for its years of dedicated efforts to the Navajo people.