European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'12)
Santiago de Compostela (Spain), 28th to 30th March, 2012

# Solar and wind generation to power medical facilities in Haiti

**Students:**
William Hafner-Burton and Peter Nelson
**Faculty Advisor:**
Dr. Ahmed ElSawy
[1] Department of Manufacturing and Industrial Technology
Tennessee Technological University
College of Engineering – 920 N Peachtree Ave Cookeville, 38501 Tennessee (United States)
Phone/, e-mail: **Waburton42@students.tntech.edu**; **Pwnelson21@students.tntech.edu; Aelsawy@tntech.edu**

**Abstract.** The main objective of this senior design project was to design, manufacture, and test a lightweight portable power generator utilizing wind and solar power. The intent of this system is to provide electricity to power the medical equipment in a small clinic in Haiti. Haiti is suffering from recent natural disasters and in urgent need of support from the United States and other countries. So far, about 100 million dollars in aid has been poured into Haiti as well as medical supplies/equipment and manpower including engineers, nurses, doctors, etc. With such a power generator system, Haitians will be able to economically supplement the power needed to run their clinic's equipment. Haiti is a prime spot for solar and wind generation, using its over 3000 hours of sunlight and trade winds to produce optimal amounts of green energy. This richness of natural resources was the main motivation behind developing this economical system, building it to set up a strong basis for green renewable energy into their economy, monitoring its setup, and learning from the findings. Powering a small clinic is just a small step into making Haiti a self-sufficient country in the area of power generation. The details of this wind and sun renewable energy system are described and discussed in this undergraduate research paper.

## Key Words

Wind power generation, solar power generation, Haiti medical facilities, and renewable energy

## 1. Introduction

Haiti has a large amount of solar and wind power generation potential. Haiti needs this potential to help it grow out of its economical hardship status as well as improve its living environment. A wind turbine/solar system is needed that incorporates these characteristics: economical and low maintenance cost, safe in the event of a transient excess of winds, lightweight and portable, and able to generate energy in low winds and survive high winds. This study aims to show the economic feasibility of installing small wind/solar power generators for medical facilities throughout Haiti.

After researching the type of wind turbine that should be used, the horizontal turbine had an easier time starting up because wind from any direction could be used to propel the blades as opposed to a vertical turbine where the blades need to be facing the wind in order to generate power. The horizontal turbine does not need any specific wind direction to generate power. Also, direct power generation is used instead of a gearing system to reduce inertia, friction, and improve efficiency. An alternating current generator is utilized in view of the fact that it has the highest voltage output in lower winds. A large battery bank powers the medical equipment and lights while the wind turbine and solar cells recharge the batteries. A charging circuit controls the power going into the batteries to charge them properly, preventing the batteries from overcharging. The circuit also regulates the load on the wind turbine which puts strain on the blades slowing them down in high winds; the higher the wind speed, the larger the load. Therefore, more power is generated while the blades are seemingly spinning at the same speed.

## 2. Materials and Methods

*A. Winds survey for the region of Haiti*

An analysis of wind currents and wind seasonality along eight years was carried out by weatherreports.com. The projected monthly averages of the winds were obtained from Port-Au-Prince, Haiti [2].

*B. Solar Survey for the region of Haiti*

An analysis of path of the sun was done by haitipassivecooling.tumblr.com in Santiago de Cuba which is in close proximity to Port-au-Prince, Haiti. An ecotect analysis was used to gather this information.

*C. Choice of wind power generator*

A low maintenance, high efficiency, high voltage output generator would be needed to produce enough energy to charge the battery bank. The generator would also need to be safe and reliable.

*D. Economic feasibility of the project*

The wind turbine and solar panels will need to be inexpensive to produce and small enough to economically ship to Haiti in a standard 45' dry container.

*E. Design of the turbine*

2D and 3D computer software was used to design and engineer the wind turbine. Programs like Autodesk Inventor, SolidWorks, AutoCAD, MasterCam, and Pro-E are acceptable programs to complete the design phase of the project.

*F. Materials to use*

All the materials used to build the system are corrosion resistant, strong, light-weight, and non-magnetic. Also, the materials used have good machinability and formability properties.

*G. Manufacturing the turbine*

The wind turbine needs to be easily manufactured and assembled. The design should be compatible with large scale production.

*H. Power demand profile analysis*

The wind turbine/solar generators need to be able to power lights, a suction machine, a cauterize machine, an anesthesia machine and a heart monitor without running out of power.

## 3. Results

*A. Winds survey for the region of Haiti*

In Haiti, the wind speeds vary from 9.0 to 13.0 mph (Figure 1) with an average of 11 mph. Haiti's eastern blowing trade winds allow for almost constant winds along Haiti's coast and into its mainland.

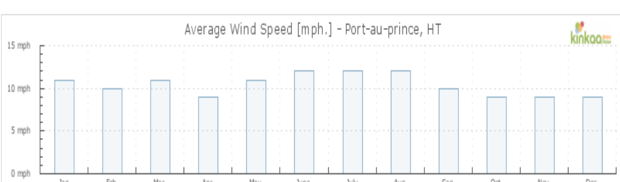


Fig. 1. Average wind speeds at Port-au-Prince, Haiti for a year. Provided by kinkoo

*B. Solar survey for the Region of Haiti*

In Haiti, there are between 7.9 hours per day in December and 9.1 hours per day in August on average. There are 3,115 sunshine hours annually and approximately 8.5 sunlight hours for each day (Figures 2 and 3).

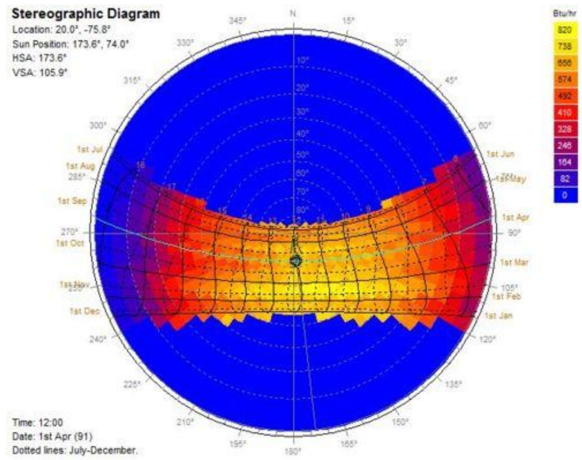


Fig.2. Picture taken from Ecotect Analysis 2011

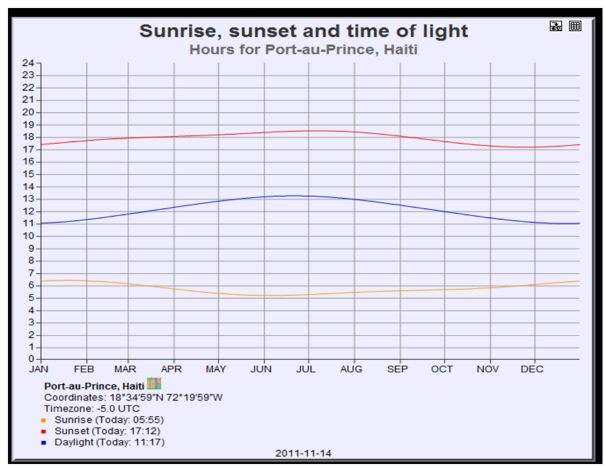


Fig.3. Graph of sunrise, sunset, and time of light in port-au-prince Haiti.

*C. Design of the turbine*

The first step in designing a wind turbine is deciding to use a horizontal-axis wind turbine (HAWT) or a vertical-axis wind turbine (VAWT). After comparing the two types of turbines, the HAWT was selected. The VAWT runs into problems with support, bearings, fatigue, startup, and speed control. The HAWT is safer, produces better energy, does not suffer from a hard startup and is easier to manufacture. A vertical design was conceptualized, and then engineered into AutoCAD and Autodesk Inventor. Three, four foot blades were designed using a wing shape to reduce wind resistance. Three blades are chosen over two blades because two blades lead to "blade chatter," a vibration that puts wear and tear on the whole machine. Three bladed machines do not have this issue. With three blades positioned 120 degrees apart, the direct imbalance that two-blade turbines are susceptible to is avoided. The three blades also run quieter because they move slower and are more stabilized, reducing vibrations. Deciding whether to choose a direct-drive or a gear-driven generator ended in picking out a direct-drive generator. Gear-driven generators face too many disadvantages; its gear, belts, and pulleys increase energy loss. The machine is also made more complex by adding gears, meaning more parts to buy, maintain, and replace. A direct-drive generator provides the most energy out of the wind in the simplest way. A custom- made three phase AC (alternating current) generator was designed for this purpose. Magnetic bearings were designed to reduce the amount of friction on the blade, helping the turbine to reduce startup time.

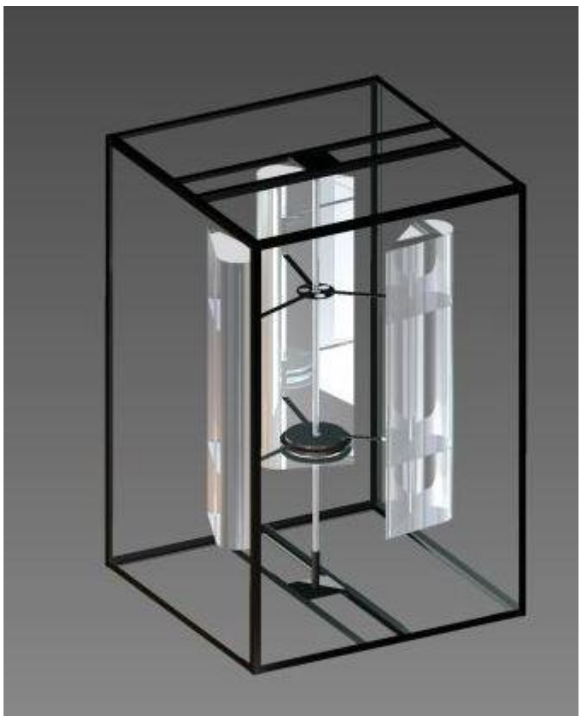

Fig.4. 3D cad drawing of the wind turbine

*D. Materials to use*

Aluminum (7075, used in aircraft blades) is used for the blades, generator and bearings; stainless steel is used for the axis. Coils are encased in a fiberglass resin to prevent them from being scratched.

*E. Choice of wind power generator*

The power generator is a three phase AC power generator. A three phase power generator achieves its high conductor efficiency and low safety risk by splitting up the total voltage into its three lesser parts. It converts the wind mechanical power into a set of three AC electric currents, one from each coil (or winding) of the generator. The windings are arranged such that the currents vary sinusoidally at the same frequency but with the peaks and troughs of their wave forms offset to provide three complementary currents with a phase separation of one-third cycle (120° or $^{2\pi}/_{3}$ radians).

*F. Manufacturing the turbine*

Each part is designed in Autodesk Inventor and transferred to MasterCam which produces G&M CNC (Computer Numerical Controlled) codes. These codes are used to produce each part to tolerance and specification as defined in the CNC code. Neodymium magnetic bearings are used to support and center the stator. These bearings are used in conjunction with centering thrust bearings to improve the magnetic bearing life expectancy. The stator coils are incased in fiberglass to protect them from being scratched, preventing a short. The solar panels are obtained from a third party.

Each CNC code is run through a wood dry run, and a final testing with aluminum. Each piece is processed through a series of finishing machining processes to smooth the edges and take out any rough spots in the product. The coils are wound sixty-four times with 15AWG Copper armature wire. This was done nine times. Then the coils are paired together and incased in fiberglass resin. 24, N42 grade neodymium magnets are used on the AC generator. Two magnet plates are CNCed out of aluminum with 12 place holders for magnets. The magnets are epoxy bonded into the place holders on each plate. The magnetic bearings are made using four N42 grade circular neodymium magnets. The advantages of magnetic bearings are that they are high speed, do not need lubrication, have no resistance, very low vibration, and experience minimal wear. They are centered onto the axis using a thrust bearing. A safety cage is built around the wind turbine to keep bodily harm to a minimum. The cage is made out of steel angle iron.

*G. Economic feasibility of the project*

This system is characterized as being environmentally friendly and economical. It does not produce any pollutants and it is feasible because it would be less expensive to manufacture and install the wind turbines and solar generators than to import fuels from overseas and run gas or diesel powered generators. The life of a wind turbine with magnetic bearings is 10-15 years. This allows for the power usage to pay for itself over this time period. With the use of magnetic bearings there is very little maintenance required. For a full cost estimate on parts and manufacturing refer to table 1. The total cost of materials and parts needed to build the wind turbine/solar power system is about $ 24,057.00. Also this cost will go down if the turbine is mass produced due to the fact that the manufacturer will be buying the materials in bulk reducing their cost. The main costs are in the batteries, shipping container, and solar panels.

In comparison, the cost of running a gasoline generator to power the same facility for the same duration of time as the wind turbines is estimated to be 2.5 million dollars in a worst case scenario (the gasoline in Haiti is around $6.14 a gallon.). This as compared to $30,000 ($6,000 in maintenance costs over 15 years) for buying and building the wind/solar generators is much smaller.

*Table 1 - Description, quantity, unit cost and total cost of all materials.*

| Line # | Description | Qty. | Unit Cost | Total |
|---|---|---|---|---|
| 1 | Multipurpose Aluminum (Alloy 6061) .032" Thick, 24" X 48" | 9 | $63.55 | $571.95 |
| 2 | Multipurpose Aluminum (Alloy 6061) .063" Thick, 48" X 48" | 3 | $162.26 | $486.78 |
| 3 | Architectural Aluminum Tube (Alloy 6063) Square, 3/4" X 3/4", 1/8" Wall, 6' Length | 6 | $12.30 | $73.80 |
| 4 | Architectural Aluminum (Alloy 6063) 1/4" Thick, 1/4" Width, 8' Length | 12 | $4.58 | $54.96 |
| 5 | Multipurpose Aluminum (Alloy 6061) .125" Thick, 12" X 12" | 3 | $29.05 | $87.15 |
| 6 | Precision-Cast Multipurpose Aluminum (MIC 6) 1/2" Thick, 12" X 12" | 6 | $63.99 | $383.94 |
| 7 | Multipurpose Aluminum (Alloy 6061) Tube 1-1/2" OD, 1" ID, .250" Wall Thickness, 1' Length | 3 | $18.09 | $54.27 |
| 8 | Perma-Lube Steel Ball Bearing - ABEC-1 Double Sealed, NO. R16 for 1" Shaft Dia, 2" OD | 6 | $22.29 | $133.74 |
| 9 | Multipurpose Stainless Steel (Type 304/304L) 1" Dia, 6' Length | 3 | $75.67 | $227.01 |
| 10 | Vinyl-Coated Polyester Fabric 0.022" Thick, 61" Width, White, 10' Length | 3 | $48.20 | $144.60 |
| 11 | 1.5 In Angle Iron 24' | 18 | $31.00 | $558.00 |
| 12 | Surrette S530 6V 400 AH Wet Battery | 30 | $389.37 | $11,681.10 |
| 13 | Solar Panel Array - 800W w/ 2.5 kVA Inverter | 1 | $6,999.99 | $6,999.99 |
| 14 | Standard 45' Shipping Container | 1 | $2,000.00 | $2,000.00 |
| 15 | Miscellaneous Cabling Supplies | 1 | $400.00 | $400.00 |
| 16 | Miscellaneous Painting Supplies | 1 | $200.00 | $200.00 |
| 17 | Magnets-N42 Neodymium | 1 | $576 | $576 |
| | *Note Medical Equipment is not Included | | | $24,057.29 |

*H. Power generation profile analysis*

A typical medical service station is comprised of the following: a light source, an intermittent suction machine, a cauterizing (electrosurgical generator), an anesthesia machine, and a heart monitor. For more information on the power usage for the medical equipment refer to Table 2.

It is determined that we have a 2.52 kw draw on average per day (assuming a 100% duty cycle per day). Using simple conversions a 3.15 kVA UPS (Uninterruptable Power Supply) for a 24-hr period equates to a 6,000 AH battery bank at 12 volts. An industrial grade battery rated at a service life of 10-15 years was selected and chosen for the application. Due to these batteries being 6V and 400 AH a series of 15 batteries is connected in parallel with a twin bank of batteries which will satisfy the requirements for our design.

*Table 2:- Medical equipment with their respective power usages*

| Equipment | Volt (AC) | Amperes | Watts |
|---|---|---|---|
| Cree Toffer | 120 | 0.18 | 44 |
| GE Intermittent Suction Pump | 120 | 3 | 360 |
| Digital Electrosurgical Generator | 120 | 1.14 | 250 |
| Datex Ohmeda S/5 ADU | 120 | 15 | 1800 |
| Dash3000 | 120 | 2 | 75 |
| -Total- | 120 | 21.32 | 2529 |

For power generation three six foot diameter by eight foot tall wind turbines and supplemental solar arrays allow for a continuous operating time of eight hours with a max run time of 32 hours. After this time the battery bank and power generation systems will be depleted. The power output range of a wind turbine is 96-288 watts according to the following equation and average wind speeds.

$$P = 0.00508 * (D * H) * W^3 * (S * T)$$

Where: P = Power (Watts)
D = Diameter (Feet)
H = Height
W = Windspeed (MPH)
S = Stator Efficiency
T = Wing Efficiency

wind turbines can be mounted on top of the container along with the solar panels. This allows for minimum setup and takedown time and reduced the length of electrical wire needed from each power generator. Having this mobile capability allows for the medical facility to become mobile in cases of economic emergency. The facility can be moved with its power generators to areas that need its help. Once the truck has reached its destination the turbines and solar panels are setup on top of the container and the batteries are hooked up to the medical facilities power grid. The cargo container also protects the wind turbine and solar panels from damage caused by hurricanes. When a hurricane or large storm is coming into the path of the medical facility the turbine and solar panels can be disassembled and placed into the container until the danger has passed. This helps to keep repair and replacement costs to a minimum.

## 4. Discussions

Wind and solar energy would be the best option for Haiti at the moment. With 80% of Haiti being powered by domestic biomass fuel and some Hydro-electric sources it is facing a severe energy crisis [5]. Factors leading to problems are server deforestation and land degradation due to burning wood and coal for power. With the use of Solar and wind power Haiti could supply its power usages while reducing greenhouse gasses and restoring its forests. The main strategy of this project is to start on a smaller scale and just focus on the smaller medical facilities. Upon successful completion of this concept, it is possible to build larger scale units to serve larger buildings.

## 5. Conclusions

This study shows that it is possible to design and build a cutting edge green power generator using solar and wind power that can sustain a small medical facility in Haiti without the aid of any external power sources. Wind turbines and solar panels also offer a low maintenance power source that does not rely on non-renewable resources. Haiti has the potential to become an example of how renewable energy generation can change a country from fossil foil energy to green renewable energy.


## Acknowledgements

The authors would like to express sincere gratitude to Robert Nelson (BS/MS in Electrical Engineering) and Tana Hafner-Burton (BS in Nursing, MS in Healthcare Administration/ MS in Nursing C) for their help during the course of this study. Also, they grateful to all the help and assistance received from the Department of Manufacturing and Industrial Technology at Tennessee Technological University' faculty, staff and fellow students.


## References


[1] Weather Reports and Forecasts for Haiti. http://www.weatherreports.com/Haiti/Port-au-prince.

[2] Haiti Passive-Cooling January 7th 2011. http://haitipassivecooling.tumblr.com.

[3] Port-Au-Prince, Haiti Climate Guide to the Average Weather & Temperatures with Graphs Elucidating Sunshine and Rainfall Data & Information about Wind Speeds & Humidity: July 22nd 2011 http://www.climatetemp.info/haiti.

[4] http://www.allaboutcircuits.com/vol_2/chpt_10/2.html.

[5] Ministry for Public Works, Transportation and Communications Bureau of Mines and Energy Electricity of Haiti, November 2006 http://www.bme.gouv.ht/energie/National_Energy_Plan_Haiti_Revised20_12_2006VM.pdf.

[6] http://www.conserve-energy-future.com/VerticalAxisWindTurbines.php.

[7] Harrison, Robert, E. Hau, and Herman Snel. *Large Wind Turbines: Design and Economics*. Chichester: Wiley, 2000. Print.

[8] Fox, Brendan. *Wind Power Integration: Connection and System Operational Aspects*. London: Institution of Engineering and Technology, 2007. Print.

[9] Khaligh, Alireza, and Omer C. Onar. *Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems*. Boca Raton: CRC, 2010. Print.

[10] Woofenden, Ian. *Wind Power for Dummies*. Hoboken, NJ: Wiley Pub., 2009. Print.

[11] Lubosny, Zbigniew. *Wind Turbine Operation in Electric Power Systems: Advanced Modeling*. Berlin: Springer, 2003. Print.

[12] Manwell, J. F., J. G. McGowan, and Anthony L. Rogers. *Wind Energy Explained: Theory, Design and Application*. Chichester, U.K.: Wiley, 2009. Print.

[13] Ragheb, Adam, and Magdi Ragheb. *Wind Turbine Gearbox Technologies*. International Nuclear and Renewable Energy Conference, 21 Mar. 2010. Web. 14,Sept.2011. https://netfiles.uiuc.edu/mragheb/www/Wind%20Power%20Gearbox%20Technologies.pdf.