Transduction of highway winds into applicable energy sources

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Introduction

As the world attempts to "go green," renewable energy has become an ever-growing market. Not only do renewable resources allow for energy conservation, but the technology involved introduces new jobs into the economy. However, creating new means to harvest alternative energy involves a lot of creative thought. There are limitless sources of energy (wind, water, sun) for collecting energy, but the method to do so is not always a straight-forward or efficient approach. The purpose of this project was to design an alternative way to collect wind energy from an overlooked source: highways. Vehicular transportation is a staple of American society, so there is no doubt that this source of energy will not peter out in the upcoming years.

Research

Highways are an excellent source of wind energy because automobiles, especially trucks, are not 100% efficient when it comes to aerodynamics. These deficiencies cause vehicles to produce an incredible amount of wind as they travel along highways. Using highways as a source of wind energy eliminates the complaints of large wind turbine systems which are deemed noisy eyesores. Highways, by default, are already ugly and by no means quiet, thus addressing these problems.

Means for collecting wind energy must be cost-efficient, effective, and most importantly, safe. The well being of motorists cannot be compromised for a return in energy. Jersey walls/barriers or meridian barriers were chosen as the best fit for these criteria. Jersey walls are prevalent on most interstate highway systems and they are used as a means of protecting motorists. Concrete by design, the walls are durable and have longevity. A trip to Smith-Midland, a manufacturer of portable concrete barriers, revealed that the walls have a typical lifespan of seven years. Most of the damage inflicted to the walls occurs on the bottom, outer edges, and less than halfway up its face (M. Smith, personal communication, January 24, 2010). Also, electrical supplies for highway light fixtures often run through the center of the concrete barriers.

The next step was to determine if there truly was enough wind on highways to power a wind generator. After contacting the Maryland Transportation Authority, an anemometer was set-up to collect wind data at two different highway locations. Data showed that wind speeds decreased as the rig was moved farther away from the outer lane of traffic, that wind speeds peaked at a around two and a half feet off the ground, and the average wind speed was around 9 mph with gusts in the 23 mph range. This is very similar to the working conditions of large scale turbines.

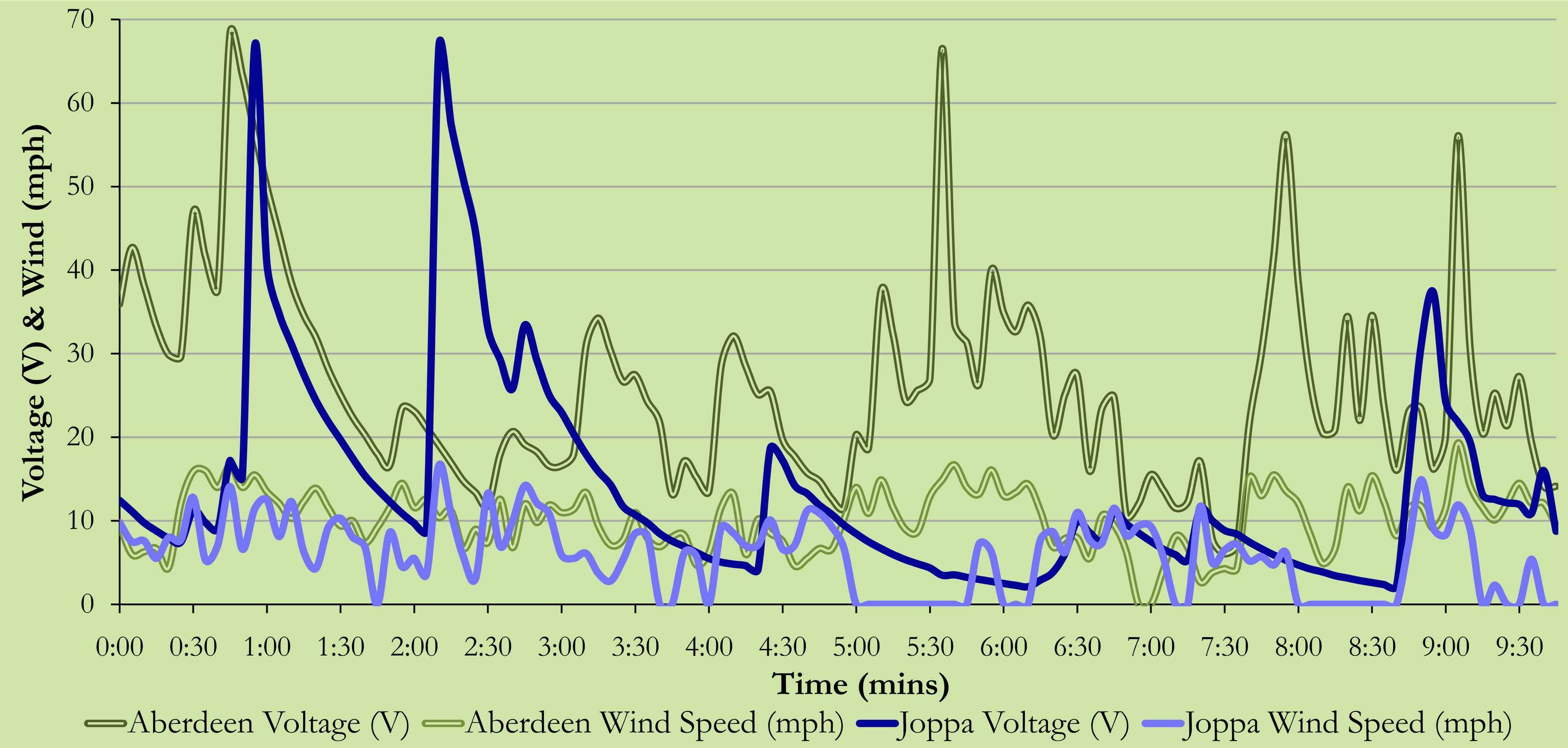
Smith-Midland revealed that there is a significant amount of room within barriers to attach fixtures without being obstructed by rebar and that barriers are cast upside down (M. Smith, personal communication, January 24, 2010). The first modified design internalized the entire energy-production system. Funnels fed into a central tube and ran the length of the wall. The main tube fed into the next wall and each wall contained its own wind turbine. However, instead of the expected increase in wind speed, the funneling of the wind caused an increase in air pressure, which is an unusable result.

Technology & Design

The final project features miniature AC brush fans that serve as miniature wind generators which are surface mounted to the face of the wall. The fans are placed high enough on the wall to be out of the typical damage zone, but not so high that they catch overdraft from opposing traffic (Photo 1). With this design, the safety of the wall and its structural integrity is maintained. The fans are designed to break easily upon impact. This minimizes the damage imparted upon vehicles and leaves them little chance to snag and yaw on generators. Repairs are not a major concern in the event of an accident. Replacement parts are cheap and the majority of components are surface mounted, allowing for ease of repair. However, internal circuitry problems would most likely result in a much more involved repair, and may require complete replacement of the wall.

Twelve VAC Mabuchi® motor and propeller sets are used as wind turbines. Because the motors are not brushless, they can be back-converted into alternators. However, the motors were not designed to serve as alternators, so voltage output is not optimal. This problem is solved by using

Aberdeen and Joppatowne Voltage and Wind vs. Time



Graph 1 – Shows the relationship between wind speed and voltage at two different testing locations

Photo 1 – Demonstrates the location of the generators in comparison to a standard vehicle. Notice bumper height.

Photo 2 – Actual circuit board

Photo 3 – Side view

Photo 4 – Example of wall storage

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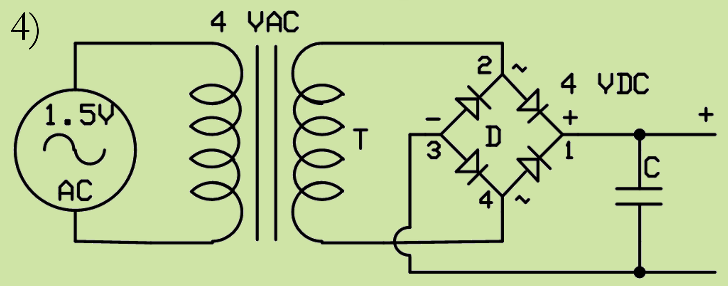
Technology & Design (Cont.)

the principles of electromagnetism and up-transforming the AC output voltage for each individual fan. The fans cannot be fed into a common transformer circuit because they will spin asynchronously and their voltages will cancel out, making them ineffective. After being transformed, the current is rectified from AC to DC. This proves extremely useful in two respects: First of all, DC power is more readily wired in series, allowing for additive output. Secondly, because the line current runs in DC, there is no back-loading of the alternators. That means that if one alternator is producing energy and another is not, the producing alternator will not power the non-producing alternator and cause it to spin as a motor. After the current has been rectified, it is fed into a capacitor. The capacitor flattens the output curve to give a more consistent voltage and eliminates zero-voltage points. In addition, capacitance serves as a mini storage terminal which allows for voltage out-put to continue into periods of low wind after large gusts, a discharge effect. These compound circuits (Figure 1) were joined in series (Photo 2) to allow for maximum voltage output.

While the alternators allow for a large amount of voltage, current is minimal. This shortage was overcome by coupling the alternator circuit in parallel with solar cells. The solar cells output 2.5 VDC at 8 Amps and are joined in a parallel-series circuit. They are protected with diodes to prevent back-loading and damage to shaded cells (Figure 2). The solar cells do not require any additional circuitry or current management. They can be directly hooked into the main power-line and utilized for energy. The solar cells are inset on the top face of the wall in order to avoid damage during storage (Photos 3 & 4)



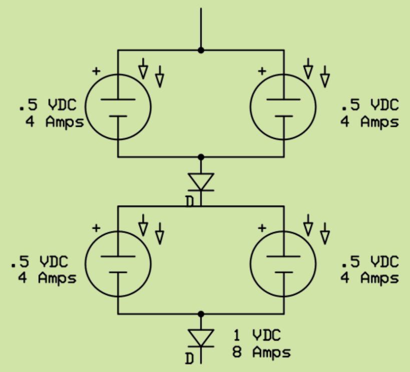


Figure 1 (Left) – Alternator-Transformer-Rectifier-Capacitor Circuit
Figure 2 (Right)– Solar panel series/parallel circuit w/ diodes

Results

Tests of the final product were conducted on live highways two feet away from the edge of the road during midday hours. Graph 1 compares the data from the two locations. The Aberdeen location had higher and more constant wind speeds than Joppatowne. Thus, the voltages from this location peaked higher and more often. A relationship can be visibly seen as to how a peak in wind speed translated into a peak in voltage. Using integration, the Aberdeen averages were determined to be 26 volts and 10 mph winds. Joppatowne averages were 14 volts and 6 mph winds. Thus, the average wattage for Aberdeen was 208 W while Joppatowne averaged 104 W. However, voltages noticeably peaked to the 50-70 volt range on various occasions. Also, it is important to note that these tests were conducted on a single wall. When an object generates wind it can be assumed that this gust will continue along with the object as it travels down the highway. The 60V peak that the object generates will continue along the whole wall, acting as an additive baseline. Only testing can confirm these hypothesized results. If found true, there would be a significant increase in output voltage.

Cost efficiency based on Aberdeen averages: Average of 208 W or 0.208 kW. With 8 hours of sunlight: 1.66 kWh/Wall or 732 kWh/mile. Sell back to grid at \$0.15/kWh = \$110/day/mile. Additional parts for wall cost \$200. Will take 2.2 years to pay off original \$200 investment. In 7 years, it is possible to make \$200,000+/mile.

Outlook

● Lower pitch on propellers and increase surface area to make more responsive. ● Upgrade to an actual alternator instead of back-converting a motor. ● Include larger fans that will be extended above wall to collect higher wind. ● Run a large number of walls together in series to collect from a larger area. ● Develop a saddle-type system that is independent of the wall which can be retrofitted to preexisting structures.