

# Wind Energy Harvesting for Low Power Applications

Edward Dawidowicz  
US Army

## ABSTRACT

A study was made to determine the effectiveness of low power wind energy harvesting for mobile applications. Experimental and simulated data has shown that harvesting of alternative energy resources is viable for potential mobile applications. This conducted study incorporated a mobile configuration consisting of a wind-photovoltaic hybrid in concert with a vehicle generator. The study has demonstrated an improvement in overall efficiency of the power generation system.

## INTRODUCTION

Effective utilization of alternative energy resources depends on environmental conditions specific to the geographic area where these devices are expected to be deployed. The wind and solar resources frequently compliment each other well. For instance, during the

months of May through September in southern New Jersey the incident sun radiation is on average at its highest level (Figure 1), while the wind speeds diminish during about the same period

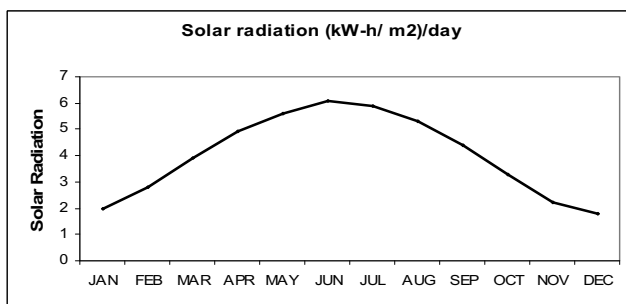
The design of a wind generating system is also dictated by the application's requirements for stealth, efficiency, portability; light weight, reliability, ease and speed of system deployment, disassembly as required for relocation. These operational constraints should yield an optimal design that is well suited for a particular application.

Known as Betz limit the efficiency of wind energy conversion  $C_p$  is the ratio of energy captured by a turbine to the kinetic energy of the wind. When efficiency of capturing the wind energy is secondary to ease of deployment and becoming mobile quickly, the vertical-axis wind turbine (VAWT) is the better choice than its more efficient counterpart the horizontal-axis wind turbine (HAWT). Based on the Betz limit a HAWT reaches its maximum efficiency of theoretical  $C_p=16/27$  (~59%) when the tip speed to wind ratio  $\lambda=5.8$  while Savonius drag VAWT type reaches  $8/27$  (~30%) with  $\lambda=0.8$  [1, 2].

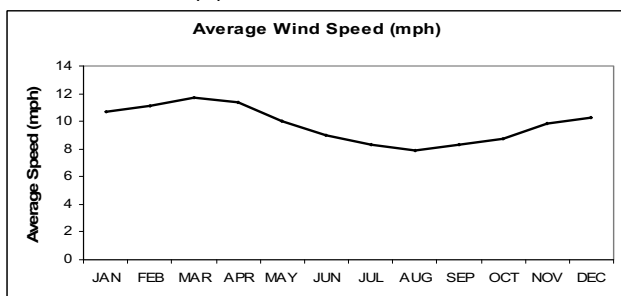
While the Savonius type VAWT turbines have both lower  $C_p$  and lower  $\lambda$  they are less sensitive to turbulent flow, easier to fabricate and more robust in the field environment. However due to their low speed the drag type VAWT are poorly suited for generating electricity. One needs both efficiency of power transfer coupled with high tip to wind ratio.

The Darrieus VAWT has a slightly higher efficiency than Savonius, however being a lift type it has a tip to wind speed ratio  $\lambda$  closer to the HAWT ( $C_p = 0.32$ ,  $\lambda= 5.5$ ) and therefore is more suitable for generating electricity. The Gorlov turbine, a variation on Darrieus, is a worthwhile contender since it offers an improvement in both efficiency and vibration stability over the natural frequencies range [3]. The Darrieus VAWTs have also been known to require starting however it has been shown [4] that self starting can be achieved by several design considerations.

At first, in terms of energy production, an under 200W power plant does not seem significant, however, is particularly suitable for the energy needs of devices that form the bulk of critical battlefield systems. These



(a) Solar Radiation



(b) Wind speed

**Figure 1. A sample set of data collected by WBAN (Weather Bureau Army Navy) station number 93730, Atlantic City NJ, (a)Solar radiation data, (b)Wind speed data**

systems incorporate communications, battlefield sensors, situational awareness-visualization systems and other auxiliary devices.

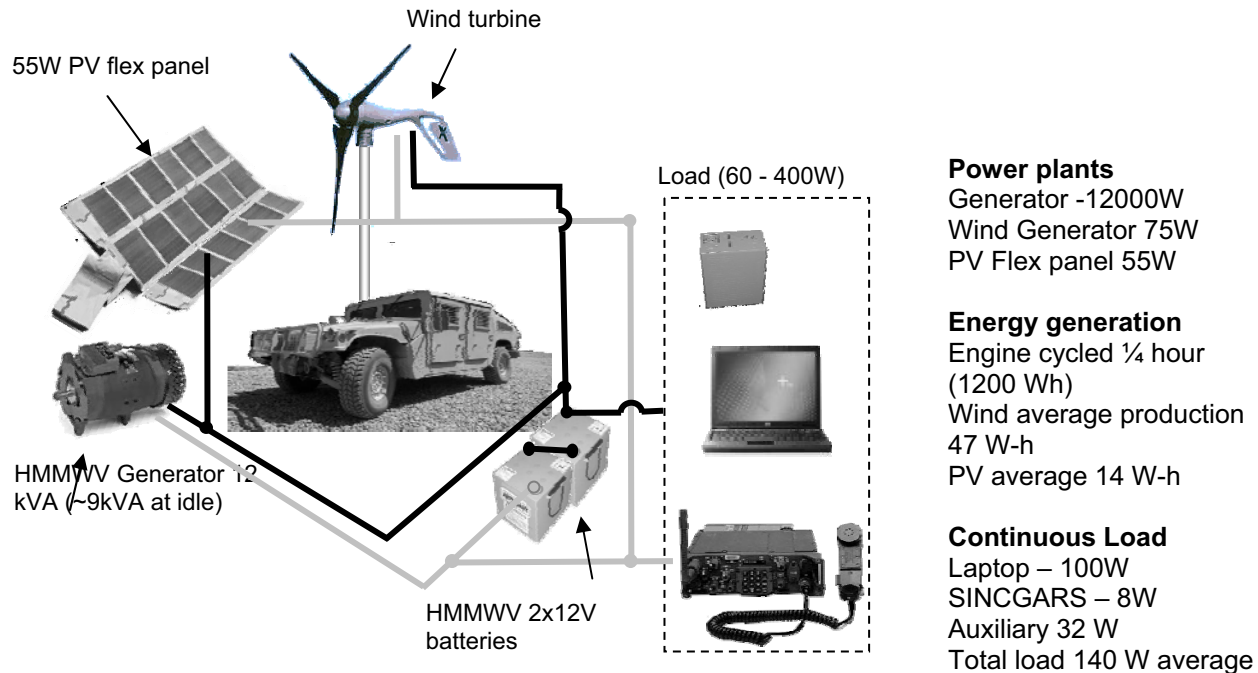


Figure 2 HMMWV configuration

## CONFIGURATION

Since the vehicles serve as platforms for mission relevant electronic a continuous supply of energy is required to run these devices. Since vehicles are providing the energy for these devices a power plant consisting of a small wind turbine, and PV array was used to compliment the vehicle's generator.

A HMMWV is a well suited platform for hybrid energy harvesting study. The vehicle's generator is estimated to provide 1200 W-h of energy during a 15 min charge cycle. The balance of the energy comes from a 200 watt wind turbine and one 55 watt photovoltaic flexible panel. The harvested energy contribution is averaged over a 24 h period for wind and solar as 47-W-h and 15-W-h respectively, or total of 62-W-h. An average load consisted of a laptop, SINCGARS radio, and additional auxiliary load of 32W totaling 140 W was estimated. Modeling of hybrid power plants is well described in [5, 6, 7].

## RESULTS AND DISCUSSION

For the test a 24-V Air-X HWAT [8], mounted 18 feet (5.5 m) above ground, was used to harvest wind energy. Its 46" diameter rotor sweeps an area of approximately 1m<sup>2</sup>. The data collected is shown in Figure 3. The total power of wind energy of an air mass moving through area A is expressed as:

$$P_t = \frac{1}{2} \rho A V^3 \text{ where:}$$

$P_t$  - Total wind power

$\rho$  - Density of air (1.2 kg/m<sup>3</sup>)

$A$  - Effective area the wind is passing through (the area swept by the rotor)

$V$  - Velocity of the wind

According to the manufacturer the turbine is rated at 400 watts at 28 mph (12.5 m/s). The maximum wind speed available for measurements was less than 20mph (9.0 m/s). The power output at a wind speed of 19 mph (8.5 m/s) was 85W (Figure 3). The collected data was in agreement with measurements made by NREL in 2003[9]

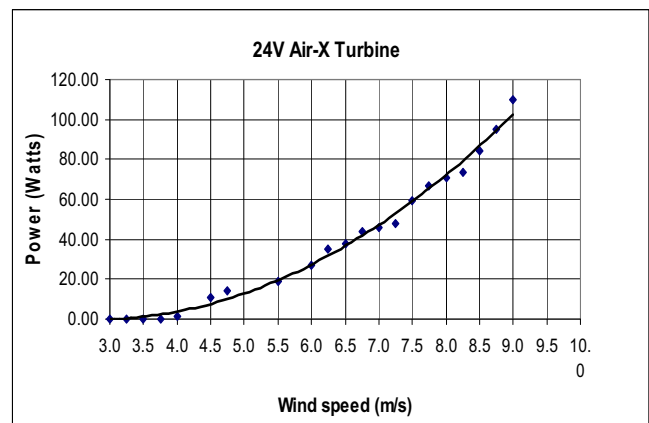


Figure 3 Wind turbine performance