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Renewable Energy Use for Continuous Electric Vehicles Battery Charging Capacity in Mobile

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Abstract
This paper presents and studies on renewable energy use, by integrating solar and wind energy, for continuous electric vehicles battery charging capacity in mobility. Modeling of the solar and wind power extraction and vehicle's battery charging potential was performed using MATLAB. And the modeling result shows that the power output from the proposed renewable energy was desirable and appreciable for other researches. The average power gets from renewable energy, solar and wind combination, extract up to 2.5 kW, and it is 25 % power need of the, 10 kW use motor, vehicle. It can be used worldwide due to its high efficiency, free global warming and health issue, and charge time saving technology.
Keywords: Battery Charging, Charging Capacity, Electric Vehicle, Photovoltaic, Wind

1. Introduction

Now a day, suffering by the global warming, environmental pollution and oil price inflation are the common issue in any geographical location of our planet. The greater shares of the problem are vehicles, because they contribute 60 to 90 percent of the air pollution in urban areas (Anant et. al., 2011) and also consume huge amount of non-renewable energy. Although this non-renewable energy (or oil fuels) needs 150 years to vanish (International Energy Agency Report, 1997), it required millions of year for their formation. To retort over all issue, researchers have been trying to design oil fuel independent vehicles. Electric vehicles are the only way to improve the nations green economy growth policy and reduce the stress of universal issue. Renewable energy use vehicles are the most viable way to achieve clean and efficient transportation and it is crucial to the sustainable development of the whole world. In the near future, electric vehicles will dominate the clean vehicle market (Howell D. & Boulanger AG et. al., 2011) by reducing the GHG emissions and other environmental impacts of road transport (Gopalakrishnan D. et. al., 2011) though they have charging time and energy storage problems. Wind and solar energy are part of renewable (non-replenishment) energy, uses for electricity generation, has grown dramatically with decreasing costs and improved performance of wind turbine and solar panels and increasing fossil fuel costs and environmental concerns (W. Short and P. Denholm, 2006 & Gianfranco Rizzo et. al., 2010). Solar-wind powered electric vehicles use solar and wind energy to either power an electric motor directly, and/or use wind and solar energy to charge a battery, which powers the motor in the automobile. They have an advantage not only on the environmental aspect but also on the energy efficiency, performance benefits, and reduced energy dependence.

Even though electric vehicles have many advantages, driving range and recharge time (or charging system) needs an extra research. Maximum charge and discharge rates are depends on the battery design even though it takes the same time. The battery capable of a high power discharge in 30 minutes is also capable of a high power charge in 30 minutes. And similarly, a traction battery best designed to deliver its total energy over a period of three or four hours will need three or four hours to achieve a full charge with additional to the charging cost. So, the aim of the paper/research is to analyze and realize the possibility and capacity of electric vehicle charging during motion using renewable energy and to reduce the time taken to charge the vehicle for long distance motion. And the result of the research helps to reduce or halt global warming and climate change and assures an option for non- renewable energy and charging system.

2. Brief Description of The Design and Analytical Approach

Conventional electric vehicles have the difficulty of charging it after few kilometers because the time to charge and discharge is equal. Wind and solar energy use electric vehicles battery charging helps to simplify this problem, and it is the best solution for powering battery discharging during the motion of vehicles. The research paper proposes hybrid types of charging: plug-in charging uses grid and non-grid power station, and direct renewable energy use for electric vehicle charging during motion. In this designed powered electric vehicle is generated from wind turbines and solar cells and are directed to the battery for charging through the inverter to the electric motor for rotational power development to the differential shaft.

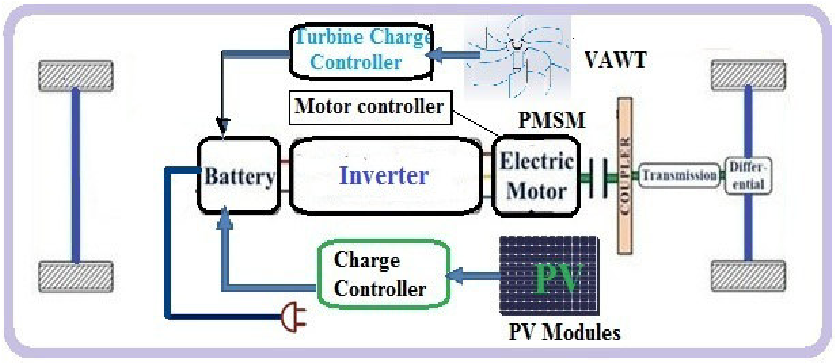


Figure 1: Block diagram of plug-in and renewable (or wind and solar) energy use electric vehicle charging system

The proposed block diagram shows that renewable energy use for continuous electric vehicles battery charging system (Fig.1). And this vehicle can charge using wind energy and solar energy during motion and plug-in and solar energy can also during immobility with parallel configuration.

2.1 Wind Energy

A wind driven generator (alternator) is based on the first law of thermo-dynamics (Daniel S. and Gaunden, 2001) which states that energy can neither be created nor destroyed and it can only be transformed from one form to another. And wind speed on the vehicle body is analyzed using Newton's 3rd law which states that action and reaction once body on another are equal and opposite. Using this analysis, the first stage is analyzing the wind speed that occurs at the top and front body of the vehicle, and it is defined in equation (1).

$$V_T = V_c + V_n \cos(\varphi) \tag{1}$$

In the second stage mechanical energy gets transformed into electrical energy which produces current and voltage. Power generated by wind turbine has directly proportional with these three factors: air density (ρ,), projected area of the turbine perpendicular to the approaching wind (A) and velocity of the wind (V_T) (Singh et. al., 2011).

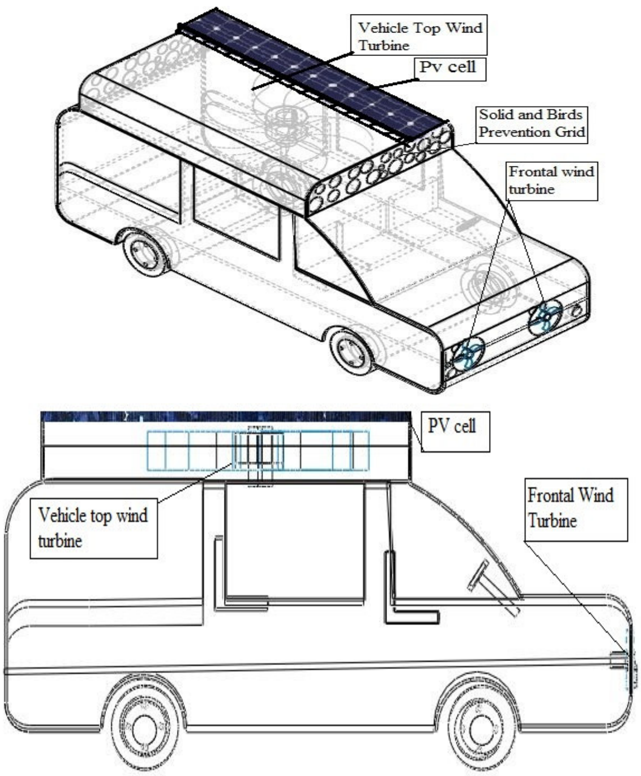


Figure 2: Wind and solar energy use electric vehicle charging (a) 3D view of the vehicle (b) side view of the vehicle

Experimentally, it has been investigated that as the wind velocity gets doubled, the output power increases by eight times. So, it can be easily concluded that power output is proportional to cube of the wind velocity (Rizk and Nagriak, 2010). Using this explanation, the power generated by the impeller type wind turbine is calculated by the equation:

$$P_T = ½ * \rho * A * V_T^3 * \lambda * \cos(\theta) \tag{2}$$

Even though the density (ρ) varies with different factors (such as: temperature and altitude) and the paper uses an average value around 1.225 Kg/m^3, θ - vanes at the angle of rotation(θ=0 for vertical wind turbine and θ=45 for maximum acting area of impeller or VAWT). And the parameter λ is wind turbine efficiency that consists following factors and calculated by following formula (Qasim et.al, 2011):

$$\lambda = C_p * C * N_g * N_b \tag{3}$$

Lift (C_l) and drag (C_d) factors are depended on the shape and form of the blades or vanes and on orientation of the wind flow with respect to the object, the drag factor (C_d) can vary from 1.2 to 2.1 for impeller wind turbine and either of them equivalent with C; Ng- generator efficiency (80% or possibly more for a permanent magnet generator or grid connected induction generator); N_b - gearbox/bearings efficiency (95% for a good design).

2.2 Photovoltaic Energy

Solar panels are useful for powered electric vehicle by the energy that is radiated by the sun. Unlike solar thermal energy which converts solar energy to heat, PV cells directly convert sunlight into electricity. In a solar energy, all power has to go through the electrical power system before the solar power can be converted into mechanical power. The electrical system that carries the power consists of charge regulator unit, batteries and the drive train (George C.M. Arkesteijn, 2007).

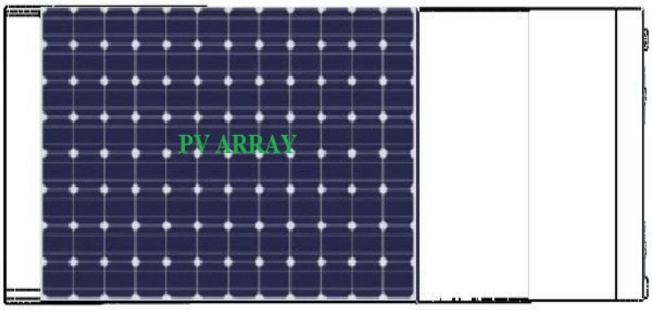


Figure 3: Top view of the vehicle solar energy converter for electric charging

The PV installation at the top of the vehicle is dynamic, does need tracking mechanism to get maximum power at any hour angle. The mathematical analysis of the photovoltaic cell, module or array described in equations (4) & (5) (Nema et. al,(2010), Chowdhury et. al. (2008), Jee-Hoon Jung and S. Ahmed (2010), and N. Pandiarajan and Ranganath Muthu (2011)). The PV cell photocurrent which depends on radiation and temperature according to equation (4):

$$I_{ph} = [I_{sc} + K_i(T - 298)]\frac{\beta}{1000} \tag{4}$$

To design the vehicle power need, it needs to know the electrical current and voltage that the panel generates. The current generated by a solar PV module can be approximated by:

$$I_{PV} = N_p * I_{ph} - N_p * I_o\left[\exp\left\{\frac{q*(V_{ph} + IphR_s}{NsAKT}\right\} - 1\right] \tag{5}$$

Practically, only about 35% of the solar irradiance is potentially available for conversion to electrical power (John Twidell and Tony Weir, 2006). And the output power from the PV modules can be determined using the equation:

$$P_{OPV} = I_{OPV} * V_{OPV} \tag{6}$$

3. Result and Discussion

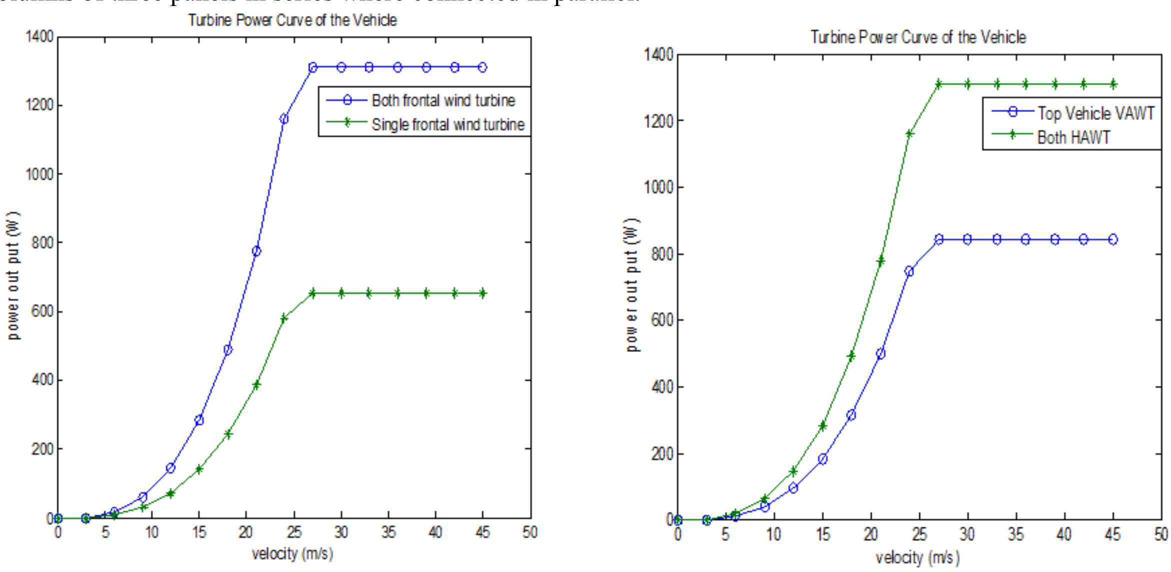
To reduce charging time of electric vehicle, it is necessarily to use renewable energy for direct charging. Availability of natural wind speed and solar intensity during the day motion of the vehicle is rich even though it varies according to the different geographical location of the world. Using the newton's third law, the average wind speed availability on the vehicle is the same to the speed of the vehicle as discussed in equation (1). Power output analysis of wind turbine and photovoltaic modules are directly proportional with wind speed and solar intensity respectively (Fig. 5(b) & 6(b)). Wind speed, unlike solar intensity, is available at any time (day and night) and place during motion of the vehicle. Even though solar energy is not available at the night, I propose to track incident radiation at the day to extract maximum power photovoltaic energy using the direction of the vehicle and hour angle.

3.1 Wind Energy Analysis

Availability of wind energy at the vehicle not depends on hour angle (or sun), it depends the vehicle speed and available 24 hours per day even though it has its own factor. Wind energy analysis from the movable vehicles, according its power and turbine diameter, is micro scale (Spera, 1994 and Gipe, 1999). Wind energy available at the top as well as frontal side of the vehicle is high since it is as function of the vehicle speed. In addition to the charging system, any energy extraction from wind during the motion of the vehicle does help to reduce drag force (aerodynamic loads) on the rear part of the vehicle (Ferdous et. al., 2011). Now a day due to high quality and efficient vehicle and high quality standard road, the rated speed of the vehicle can approach around 90 km/h. So, using PM machines we can fix the rated speed of the turbine around 25 m/s (Singh et. al., 2011), In order to develop optimum energy from the optimum vehicle's wind speed. Wind turbines were installed, for MATLAB modeling, at the front and top of the vehicle. Frontal wind turbine is a type of horizontal axis wind turbine (HAWT) with each of the turbine blade has 50 cm diameters. From this wind turbine, the power analysis shows that power extraction varies with the relative wind speed (V_T). And it varies an average from 300 to 600 W individually and from both of frontal wind turbines can extract up to 1200 W (Fig. 4 (a)). Top vehicle wind turbine also a type of vertical axis wind turbine (VAWT) and it has the capacity to develop 800 W rated powers; and this turbine blade also has 120 cm diameter with 20cm width. Therefore, overall wind energy from the moving vehicle can obtain up to 2.5kW rated power (Fig. 4 (b)).

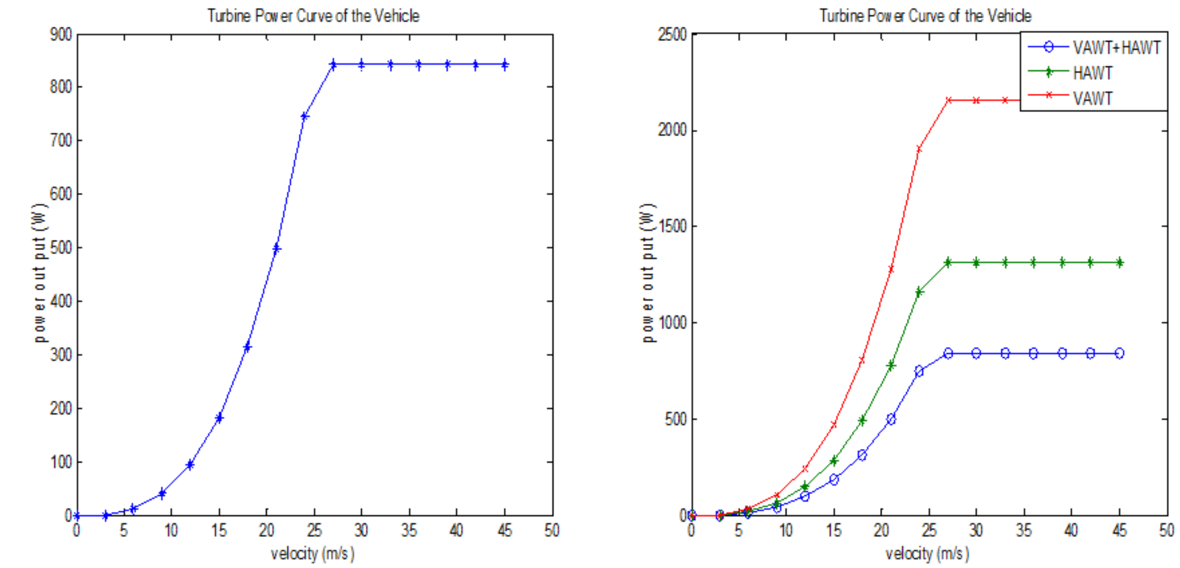
3.2 Photovoltaic Energy Analysis

Mathematical modeling of the vehicle PV modules is assumed clean sky, any PV cell not shaded and the photovoltaic cells at constant temperature. Using MATLAB modeling, it was possible to create a wide range of curves that interrelates current vs. voltage and voltage vs. irradiation conditions. During the modeling, Sanyo HIP-200BA20 photovoltaic cell specification data was selected for simulation. And, it shows that the power characteristic curve for each column in different current, voltage and irradiation conditions. In this research paper uses 6 photovoltaic modules and these modules contain 36 series photovoltaic cells. These modules are arranged according the available area of the vehicle (1.2 x 1.8 m^2) and the total top vehicles surface covered by PV arrays reaches 2.16 [m^2] with 100 cm^2 area of each photovoltaic cell. According to design restrictions two columns of three panels in series where connected in parallel.



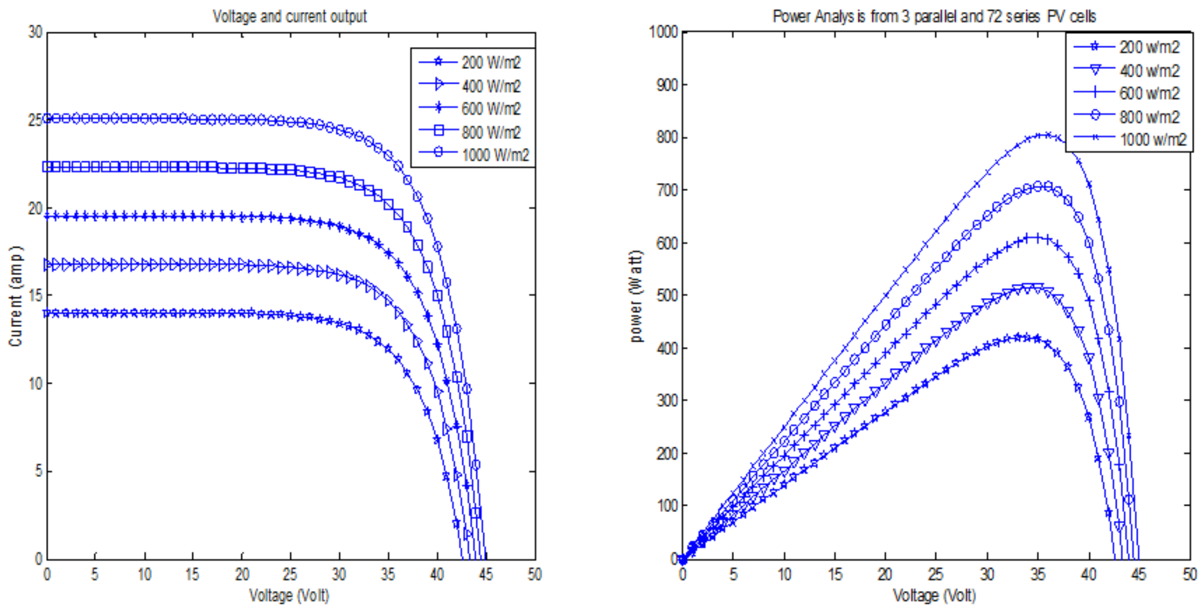
(a) (b)

Figure 4: Power Extraction using wind speed variation (a) Frontal wind power analysis (b) Total power analysis from HAWT



(a) (b)

Figure 5: Power Extraction using wind speed variation (a) Top vehicle VAWT (b) VAWT and HAWT combination



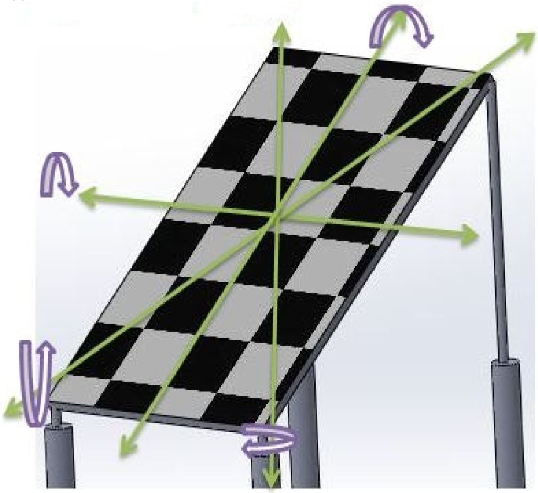
(a) (b)

Figure 6: Photovoltaic simulation (a) Current vs. Voltage (b) Power Extraction Using PV at solar intensity variation

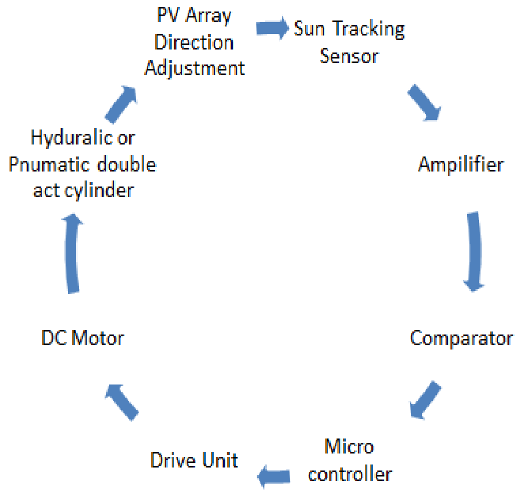
The power that get from the 216 photovoltaic cells varies according the solar intensities and varies from 400 - 800 watt (Fig. 6). This configuration delivers an average output current of 20 A with a nominal voltage of 44 V.

3.3 Four –Axis Tracking Mechanisms

The vehicle's photovoltaic modules propose to use maximum incident ray tracking mechanism. This tracking system is an automatic system to track the sun ray to extract solar intensity at the optimum angle of incident ray. The PV array tracking mechanism can track 360 degree rotation of the vehicle and 30-150 degrees (or 3-9 hour angle) of the sunrise (or sunset), and it is the best solution to maximize the power output from the photovoltaic panels. Because, when the irradiation increases, the current and voltage output increases as the result in net power output increases. Four axis trackers are considerably more complicated than one and two axis mechanisms. This electromechanical structure has four degrees of freedom, motorized by four DC motors to control movement of the double act hydraulic cylinder. The materials help to track the PV system: light dependent resistor (sun tracking sensor), amplifier (to amplify the LDR signals), DC Motors, Comparator (compares the signals), oil or air reservoir, double acting pneumatic or hydraulic cylinder and microcontroller. Microcontroller is the control unit, which gives the control command to the driver unit based on the comparator output. The driver unit controls the input to the dc motor. When the driver unit drives the dc motors and drives the four hydraulic and pneumatic cylinders for up and down ward motion (Bhuvaneswari et. al., 2013 and Choi et. al (2010)).



(a)



(b)

Figure 7: Tracking mechanism (a) four-axis (b) block diagram

Generally, the combination of wind and solar energy can extract up to 2.5 kW during the motion of the vehicle. And this power can decrease battery discharge by 25 percentages for 10 kW use electric motor of the vehicle. So, using the renewable energy can cover or extend up to 25 percentage of the transportation without changing the shape and smartness of the vehicles.

4. Conclusion

This paper is presenting the integrated renewable energy resources for continuous charging system was simulated. This will help to understand the capacity of continuous power output from the alternative fuel during motion of the vehicle. The results obtained from the model shows desirable and appreciable. The proposed system would be well suited for implementation in an enterprise environment where a large number of electric vehicles could be aggregated to substantially impact peak load alleviation and act as a significant energy resource.

Nomenclature

A = B is an ideality factor = 1.6
C_p - coefficient of performance (=0.35 for a good design)
C - C_l or C_d (or resulting of them) - are lift and drag factors respectively
$\cos(\varphi)$ - Direction of natural wind speed (varies from +1 to -1)
HAWT – Horizontal Axis Wind Turbine
I - the current generated by the photovoltaic effect
I_1 - the `reverse saturation current' (the small electric current that flows through the cell when it is not illuminated, and an external power source such as a battery applies a negative voltage across its terminals). The value of $I_1 \approx 30\ \mu$ A
I_{OPV} –photovoltaic current output
Isc - the PV module short-circuit current (3.5 A),
k - the Boltzmann constant $1.380\text{x}10^{-23}$ J/K
K_i = 0.0017 A/^{0}C - is the cell's short circuit current temperature coefficient and
n - a dimensionless constant that depends on the number and characteristics of the photovoltaic cells in the module;
N_b - gearbox/bearings efficiency (95% for a good design)
Np - Number of photovoltaic cell in parallel
N_g - generator efficiency (80% or possibly more for a permanent magnet generator or grid connected induction generator);
Ns - Number of photovoltaic cell in Series
Rs - the series resistance of a PV module

β - the solar radiation (W/m2).
q - the magnitude of the charge of an electron 1.609 $x10^{-19}$ C
T - the module operating temperature in Kelvin,
P_{OPV} –photovoltaic power output
V_{OPV} –photovoltaic voltage output
V - the voltage across the cell (this will depend on what is connected to the cell)
V_T - Total wind speed on the vehicle
V_c - speed of the car
V_n - Natural wind speed of the location
VAWT – Vertical Axis Wind Turbine

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