



# INVESTIGATION OF WIND ENERGY POTENTIAL AND ELECTRICITY GENERATION FOR CHARGING THE BATTERIES OF ELECTRIC VEHICLES

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## ABSTRACT

Environmental pollution problems are increased and utilization of renewable sources is important. Moreover, the fossil fuels make the environment weaken and this will encourage providing an alternate energy resources. Wind energy is one of the popular renewable energy resource and this paper deals with a novel charging mechanism utilizing this resource for automatically charging the battery packs of electric vehicles (EVs). In this study, the wind speed is determined for Chennai city in India for four different seasons. The hourly average wind speed for one day has been estimated by Weibull distribution and it is compared with three different methods for the hourly averaged wind data. The results show that the power density method outperforms and the Weibull distribution fit with the wind data. The energy and power density for each season are calculated and the performance of four different small scale turbines has been evaluated. Automatic recharging can reduce the requirement of fossil fuels to generate electricity, as a result CO<sub>2</sub> related emissions are reduced tremendously and increase of the travelling distance is minimized. Hence it is not necessary to wait for recharging in various stations and the vehicle can move long distance after one full charge by this method. The simulation result shows that the performance of small scale turbine is satisfactory and the batteries are recharged without using recharging stations.

**Keywords:** electric vehicles, charging mechanism, wind energy, wind duct, Weibull distribution, wind turbine.

## 1. INTRODUCTION

The basic requirement of the human in day to day life is electrical energy which is generated in maximum through burning fossil fuels which will create acid snow and rain, regional mist, climate change, urban smog, number of tornados etc. It is necessary to replace current highly polluting energy sources with cleaner source. Renewable energy (solar and wind) has great potential importance due to presence in abundance and causes nil pollution. These sources show much concern to the environment. The vehicle that uses crude oil produces more pollutants which are pumped into the atmosphere. Fuel vehicles are the biggest contributors of Carbon monoxide (CO) and Nitrogen Dioxide (NO<sub>2</sub>). High levels of NO<sub>2</sub> may lead to Lung damage or respiratory disease. Recent survey shows that there is an increased admission in hospitals with patients suffering from asthma, respiratory problems and mortality. This is because, when a person inhales Carbon monoxide, it enters the blood stream and disrupts the supply of oxygen to the body issues. Electric vehicles typically have almost zero pollution than an internal combustion engine or the vehicle which uses crude oil.

Nowadays EVs are getting charged through roadside units, park stations and homes. For recharging the storage system present in the EV it takes couple of hours based on the capacity of the vehicle which increases the travelling time and thus limiting the usage of vehicles. To overcome this difficulty, an automatic recharging mechanism is introduced [1]. The control mechanism

automatically charges the storage system without the involvement of the driver. The performance of the system was studied and a comparison of CO<sub>2</sub> emission for different vehicles has been studied. The increasing greenhouse gas emissions can be reduced with the help of plug-in EVs. The traction battery packs are charged by using high frequency ac-dc converter. An electromagnetic interference (EMI) filter is interfaced with the high frequency transformer of dc-dc converter for suppressing the common mode EMI noise [2]. It is the responsibilities of everyone to adopt renewable technologies in residence for reducing global warming [3]. Swift *et al* [4], reported that more energy can be captured from the cold wind in winter season than other seasons.

Renewable energy (RE) based hybrid power generation becomes popular due to its concern over the environment. To eliminate the grid connection and reduce transmission loss, RE based power generation can be used to serve local loads in remote areas [5]. There is a maximum power tracking and control system for increasing the amount of power generated by the wind turbine [6]. The efficiency and life time of the turbine can be reduced if the design is improper and also creates fatigue to the turbine components. In addition, the other parameters such as yaw misalignment, wind shear, turbine imbalance and turbine shadow decreases the power quality of the turbine [7]. The fixed speed wind turbines are widely used because of its ruggedness, simplicity and less maintenance [8].



The wind condition in urban areas is weak and turbulent, due to the presence of huge and tall buildings. To overcome this difficulty vertical axis wind turbine (VAWT) is used in a turbulent environment [9]. A drag type VAWT is considered for its better starting behavior, simple fabrication and low cut-in wind speed. In a study conducted by Peacock et al there is an alternate approach to generate electricity at lower cut-in speed [10]. The VAWT can be mounted in lower height because of its generation capability. This feature makes it familiar to generate power in residents and it can be easily constructed on the top of a building [11]. A drag type VAWT is mounted on a roof of a building for renewable energy generation and the significance is reported by Grant *et al* [12]. The drag type wind turbine is surrounded by a guide vane to increase the performance of the turbine which is done by guiding the wind in an optimum flow angle. This will lead to prevent the negative torque [13].

The wind speed distribution can be efficiently determined by two parameter Weibull distribution function using the actual wind data. The potential energy of the wind in a particular region can be evaluated from the average wind power density at that region. Thirty years of wind data has been collected and the speed characteristics of three different locations through Weibull parameter estimation is studied [14]. The night and day time wind characteristics can be estimated using scale and shape parameters. The wind speed potential of seventeen places in Tunisia has been investigated by Elamouri and Ben [15]. The wind roses for various places of Malaysia have been studied by Islam et al. The two years wind data has been recorded at a height of 10 m and the Weibull parameters has been estimated for every month by using empirical method [16]. A software based wind rose in a particular direction has been estimated using Weibull parameters and the accuracy of the parameters has been evaluated by root mean square error [17].

This paper deals with the new configuration of wind turbine which is used to recharge the battery banks of EV. The turbine simultaneously supplies power to the battery packs of EV under running condition and generate power under stable condition if wind speed is higher than the threshold level. The hourly average wind speed for a day has been derived for three different speed scenarios and the Weibull parameters has been calculated using two different methods for the hourly averaged wind data. Consequently, a series of experiments has been done for evaluating the effectiveness of the proposed system. This paper has been organized in six sections. The section 2 of the paper describes different types of EVs and the proposed configuration of present system; section 3 describes different methods of Weibull parameter estimation; section 4 presents the results of the experiments with discussions; finally conclusion is described in section 5.

## 2. ELECTRIC VEHICLE CONFIGURATION

### A. Types of electric vehicles

There are three types of electric vehicles such as 1) Hybrid electric vehicles 2) plug-in hybrid electric vehicles (PHEVs) and 3) full electric vehicles (FEVs) which are widely used. Table-1 shows the types of EVs and the corresponding charging of batteries. From Table-1 we can easily understand that the last two types do not have internal charging and the first two types has internal combustion engine.

**Table-1.** Various types of EVs.

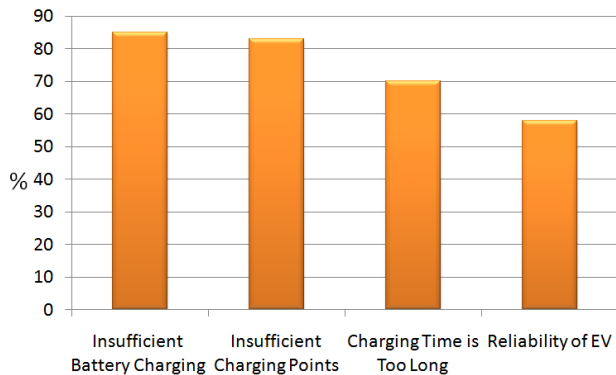
Type of Electric Vehicle	Battery Charging	Internal Combustion Engine
Plug-in Electric Vehicle	Internal (on-board) and/or external charging	Yes
Hybrid Electric Vehicle	Internal (on-board)	Yes
Full Electric Vehicle	External charging	No
Proposed	No External Charging	No

PHEVs received much attention in the transportation sector as a promising technology to reduce CO<sub>2</sub> emissions. It has more facilities like internal combustion engine (ICE), battery packs and the fossil fuel consumption can be remarkably reduced in PHEVs by including grid electricity. By using the external source for recharging the batteries (electric mode) it can be possible to cover a minimum distance of 16 km [18]. Gasoline is widely used fossil fuel in PHEVs and diesel or ethanol is also used in lesser extent. This vehicle has the capability to run through fossil fuel and electricity or the combination of both. It has enormous advantages like lower greenhouse emission, higher fuel economy; less usage of oil, high power efficiency and vehicle to grid technology [19].

HEVs are equipped with combination of two power sources such as electric motor system and an internal combustion engine. Full HEVs has the capability to perform either in conventional vehicle transmission mode or electric power mode [20]. The ICE and gasoline as fuel is used in conventional vehicle transmission mode and battery is used to drive the electric motor in electric power mode of operation. The HEVs has different features such as when it is used as motor, it turns the wheels of the vehicle and drive the vehicle and when it is used as generator, generates electric power required to charge the battery and starts ICE whenever it requires [21]. FEVs are new upcoming technology to reduce emission and other pollutants. These vehicles are powered by fuel cells or a traction motor or by an electric motor. Gasoline ICE or diesel engines are not used in this type of vehicle. Electricity is provided through rechargeable battery packs and in some cases flywheels or UCs is also used. Charging the battery pack can be made through external charging



stations or electricity points present in parks or standard home electricity outlets. FEV provides significant reduction in greenhouse gas emission compared with HEVs and PHEVs. The percentage of emission reduction is potentially much higher in FEV than PHEVs [22].



**Figure-1.** Factors affecting to purchase full EV [23].

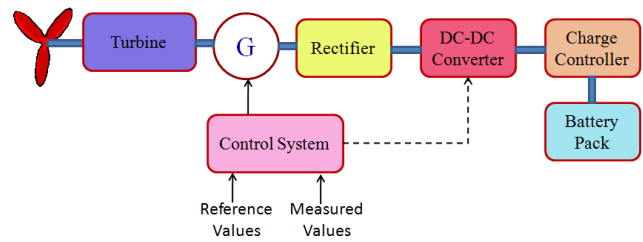
A global survey has been done for plug-in electric vehicles (PEV), the customer preferences and opinion about PEV and charging services has been done for 13 countries [23]. Analysis of price difference between PEV and conventional cars, different factors affecting purchase of EV, and switching from conventional car to EV has been made. Various factors affect the wide usage of EVs such as insufficient battery charging, huge charging time and insufficient charging points are shown in Figure-1. These factors motivate us to develop a new charging method for wide usage of EVs as a result green environment.

## B. Proposed EV configuration

The batteries present in the electric vehicles such as FEVs and PHEVs need to charge through dedicated recharging stations, standard household outlets and electricity grid. However, need of more charging time and long distance travel leads to construct public recharging stations [24]. To overcome these difficulties, a novel automatic charging mechanism is introduced for FEVs to increase the travelling distance and eliminating the need of recharging stations.

The vehicle which runs through the fuel produces more greenhouse emission and pumped into the atmosphere. The cost is increasing every day to control the pollution. Green energy utilization in EVs becomes popular to reduce the pollutants produced by fuel vehicles. The major disadvantage of EV is storage of energy and the distance to be travelled for the same charge. This study is mainly focused to solve this problem. The drive train assembly present in the proposed system automatically charges the battery packs. The wind turbine and the drive systems are used for producing power. The ARM-7 based controller with sensing system is communicated through the controller area network (CAN). A high power bidirectional converter is used to charge the storage

system present in the FEV. In this work, the performance of three different small scale vertical axis wind turbine has been studied.



**Figure-2.** Block diagram of proposed charging mechanism.

The control system is designed in such a way that proper operation of turbine is at start of the vehicle. If the vehicle moves, the turbine generates power and it is proportional to the speed of the vehicle. A variable speed wind turbine is used to increase the power quality and to reduce the mechanical stress. The battery management system is interfaced with the sealed battery packs via CAN bus communication. It also measures the battery SOC, load voltage and current under running condition. The block diagram of proposed system is shown in Figure-2. The SOC represents the amount of energy contained in the battery and it should be maintained between 20% - 95%. The controller always senses the SOC and maintain  $20 < SOC < 95$ . The advantages of the proposed system are given below:

- Energy stores through green energy harvesting which helps to eliminate pollutants.
- Recharging stations are not required for charging the battery packs of EV. As a result it reduces the travelling time.
- It works in such a way that it could overcome the future fuel crisis.

An automatic opening valve is incorporated at the end of the duct to release the pressure higher than the allowable pressure. The physical arrangement of the proposed system is shown in Figure-3. The outputs of proposed system depend on the speed of wind and the wind speed is proportional to the speed of vehicle. In this work, external forces which affect the wind turbine under running condition are not considered.

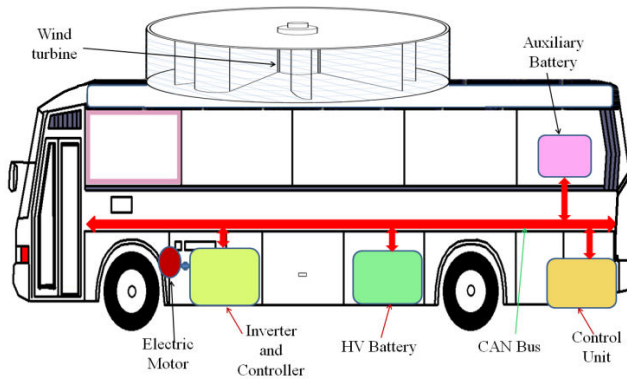


Figure-3. Structure of proposed charging mechanism.

### 3. WEIBULL PARAMETER ESTIMATION METHODS

The renewable wind energy generation mechanism is used to generate electrical energy for recharging the battery banks of EVs. Naturally, the wind energy varies every season and every day in a year. The stochastic behavior of renewable source can be done by probability distribution function (PDF) in a statistical manner. In this paper, the Weibull parameters, namely, shape parameter and scale parameter are represented by  $\beta$  and  $\alpha$  respectively. Appropriate values of  $\beta$  and  $\alpha$  of Weibull parameter estimation is important for choosing the range of turbine generator and study its performance. The wind speed is represented by the PDF  $f(v, \alpha, \beta)$  and the cumulative distribution function is represented by  $F(v, \alpha, \beta)$  and is given by [25]:

$$f(v, \alpha, \beta) = \frac{\beta}{\alpha} \left(\frac{v}{\alpha}\right)^{\beta-1} \exp\left[-\left(\frac{v}{\alpha}\right)^{\beta}\right] \quad (1)$$

$$F(v, \alpha, \beta) = 1 - \exp\left[-\left(\frac{v}{\alpha}\right)^{\beta}\right] \quad (2)$$

Where  $v$ ,  $\alpha$ ,  $\beta$  are the wind speed value, shape and scale parameters respectively. In order to calculate the Weibull distribution there are various methods has been used. In this work, the Maximum Likelihood Estimation, Least Square Estimation, Empirical method and power density methods are used. The root mean square error (RMSE) values for each season are calculated and the best fit wind data for each method is determined.

#### A. Maximum likelihood estimation

The Maximum likelihood estimation (MLE) of the Weibull distribution is given by

$$L(v_1, \dots, v_n, \alpha, \beta) = \prod_{i=1}^n \frac{\beta}{\alpha} \left(\frac{v_i}{\alpha}\right)^{\beta-1} \exp\left(-\left(\frac{v_i}{\alpha}\right)^{\beta}\right) \quad (3)$$

The shape parameter  $\alpha$  can be calculated in maximum likelihood estimation by using the following equation as:

$$\beta = \left[ \left( \sum_{i=1}^n v_i^{\beta} \ln(v_i) \right) \left( \sum_{i=1}^n v_i^{\beta} \right)^{-1} - \frac{1}{n} \sum_{i=1}^n \ln(v_i) \right]^{-1} \quad (4)$$

where  $n$  represents the total number of observation and  $v_i$  is the observed hourly wind speed. Initially the value of  $\beta$  is assumed and the numerical iteration is performed using (4) until the value of previous iteration is close to the new value of  $\beta$ . From the known value of  $\beta$ , the scale parameter can be estimated as:

$$\alpha = \left[ \frac{1}{n} \sum_{i=1}^n v_i^{\beta} \right]^{1/\beta} \quad (5)$$

#### B. Linear Least Square Estimation

The linear least square estimation (LLSE) is a special case of least square method which consists of some linear functions and easy to use. The non-linear Weibull distribution function Eq. (2) can be written as:

$$\frac{1}{1-F(v)} = \exp\left[\left(\frac{v}{\alpha}\right)^{\beta}\right]$$

$$\ln\left(\frac{1}{1-F(v)}\right) = \left[\left(\frac{v}{\alpha}\right)^{\beta}\right] \quad (6)$$

The cumulative Weibull distribution function can be transformed in to linear function as:

$$\ln \ln\left(\frac{1}{1-F(v)}\right) = \beta \ln v - \beta \ln \alpha \quad (7)$$

Now, equation 7 can be written as  $bX + a$ , where  $Y = \ln \ln\left(\frac{1}{1-F(v)}\right)$ ,  $b = \beta$ ,  $X = \ln v$ ,

$a = -\beta \ln \alpha$ . By using linear regression formula

$$b = \frac{n \sum_{i=1}^n X_i Y_i - \sum_{i=1}^n X_i \sum_{i=1}^n Y_i}{n \sum_{i=1}^n X_i^2 - (\sum_{i=1}^n X_i)^2} \quad (8)$$

$$a = \frac{\sum_{i=1}^n X_i^2 \sum_{i=1}^n Y_i - \sum_{i=1}^n X_i \sum_{i=1}^n X_i Y_i}{n \sum_{i=1}^n X_i^2 - (\sum_{i=1}^n X_i)^2} \quad (9)$$

#### C. Empirical method

The mean  $\bar{v}$  and standard deviation  $\sigma$  of wind speed are required for Empirical method of estimating Weibull distribution. The mean and standard deviation can be written as [26]:

$$\bar{v} = \frac{1}{n} \sum_{i=1}^n v_i \quad (10)$$

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (v_i - \bar{v})^2} \quad (11)$$

The parameters  $\beta$  and  $\alpha$  can be found using the following equations [27]:





$$\beta = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086}, \text{ for } 1 < k < 10$$

$$\alpha = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{\beta}\right)} \quad (12)$$

where  $\Gamma$  is a gamma function,  $\Gamma(s) = \int_0^\infty x^{s-1} e^{-x} dx$ , ( $s > 0$ )

#### D. power density methods

The power density method (PDM) uses energy pattern factor ( $E_{fact}$ ).  $E_{fact}$  is defined as the ratio of mean cube of wind speed ( $\bar{v}^3$ ) to the cube of mean wind speed ( $\bar{v}^3$ ) and is given by [28]:

$$E_{fact} = \frac{\Gamma\left(1+\frac{3}{\beta}\right)}{\Gamma\left(1+\frac{3}{\beta}\right)^3} \quad (13)$$

In order to find  $\beta$  the approximate solution can be used [28]:

$$\beta = 1 + \frac{3.69}{(E_{fact})^2} \quad (14)$$

From the known value of shape parameter the scale parameter can be easily found by Eq. (12).

#### E. Determination of Weibull parameters

The Weibull parameters for four different seasons in Chennai city, India and wind speed for a day can be calculated using the four different methods discussed above. Matlab software is used to find the numerical calculations and the best parameters can be found from the seven calculated values of their RMSE. The RMSE can be calculated by the following equation [25]:

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (f^*(v_i) - f(v_i))^2} \quad (15)$$

where  $N$  is the number of observations and  $f^*(v_i)$ ,  $f(v_i)$  are the frequencies calculated from the observation and from Weibull distribution respectively. Since the wind turbine is placed in the top of the vehicle and the height is around 2.5 meters from ground, large scale turbine is not suitable for this application. Hence small scale wind turbines are taken into account. The electrical power generated by the turbine changes according to the wind speed and the vehicle speed. The most probable wind speed ( $w_p$ ) and wind speed which has maximum energy ( $w_{max,E}$ ) can be calculated by Weibull parameters as [26]:

$$w_p = \alpha \left(1 - 1/\beta\right)^{1/\beta} \quad (16)$$

$$w_{max,E} = \alpha \left(1 + 2/\beta\right)^{1/\beta} \quad (17)$$

The wind power density ( $P_d$ ) can be calculated using Weibull parameters based on [29] as:

$$P_d = \int_0^\infty \frac{1}{2} \rho w^3 f(w) dw = \frac{1}{2} \rho c^3 \left(1 + \frac{3}{\beta}\right) \quad (18)$$

where  $\rho$  is density of air. The energy density of wind ( $E_d$ ) can be found for a day as [29]:

$$E_d = \frac{1}{2} \rho c^3 \Gamma\left(1 + \frac{3}{\beta}\right) T \quad (19)$$

where  $\Gamma$  represents Gamma function and  $T$  represents temperature.

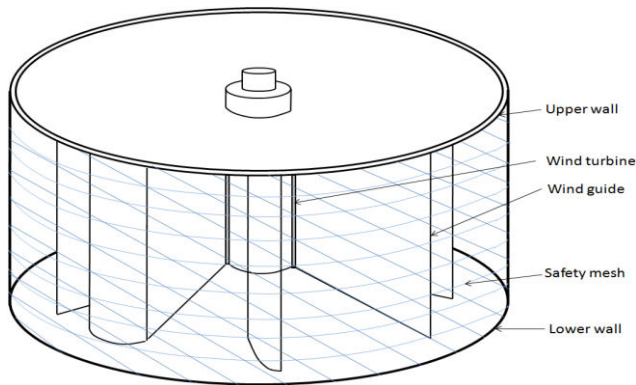
**Table-2.** Weibull parameters for four different seasons.

	MLE Method			LLSE Method			Empirical Method			PDM Method		
	$\beta$	$\alpha$ (m/s)	RMSE	$\beta$	$\alpha$ (m/s)	RMSE	$\beta$	$\alpha$ (m/s)	RMSE	$\beta$	$\alpha$ (m/s)	RMSE
Summer	2.267	4.375	0.0372	2.392	3.952	0.0382	2.305	4.372	0.0297	2.306	4.302	0.0275
Winter	1.483	3.738	0.0196	1.490	2.682	0.0199	1.682	3.831	0.0174	1.628	3.684	0.0157
Spring	1.436	3.481	0.0192	1.382	3.730	0.0203	1.692	3.489	0.0186	1.695	3.429	0.0178
Autumn	1.439	2.769	0.0217	1.472	3.274	0.0196	1.639	2.693	0.0193	1.652	2.683	0.0191

#### 4. WIND ENERGY SYSTEM

VWAT is the earliest wind harnessing machine based on drag. The efficiency of this machine is not satisfactory because of its tip speed ratio. The modern designs of VAWT applies aerodynamic principles and it has many advantages over horizontal designs such as no need of yaw mechanism, low cut-in speed and easier maintenance. On the other hand the aerodynamic efficiency of VAWT is lower than horizontal turbines [30,

31]. According to drag type wind turbine, a rectangular duct tunnel is used for adjusting the inlet mass flow which increases the output power of Savonius rotor and the power coefficient is 2.23 times greater than that of two bladed rotors and 2.5 times for 3 bladed rotors [32, 33].



**Figure-4.** Structure of sistan rotor.

The geometry structure of a Sistan rotor with three blade arrangement is shown in Figure-4. The wind turbine is placed at the center and the wind guide is surrounded with the turbine. The wind guide consists of upper and lower walls and a safety mesh is enclosed around it. The kinetic energy from the wind is converted in to mechanical energy by the drag principle of the blades. If the vehicle moves the wind gust with the velocity,  $V_w$  hit the surface  $M$ . The power  $P_M$  extracted for a single blade by the drag force  $F$  with the velocity  $V_M$  can be calculated as [34]:

$$P_M = FV_M \quad (20)$$

$$P_M = \frac{\rho}{2} K_d (V_w - V_M)^2 M V_M \quad (21)$$

Where  $K_d$  is the drag force coefficient and  $\rho$  is the density of air. Now Eq. (21) can be written in general form as:

$$P_M = \frac{\rho}{2} K_d (\vec{V}_w - \vec{V}_M)^2 \vec{V}_M \quad (22)$$

The average power  $P_{avg}$  can be calculated as:

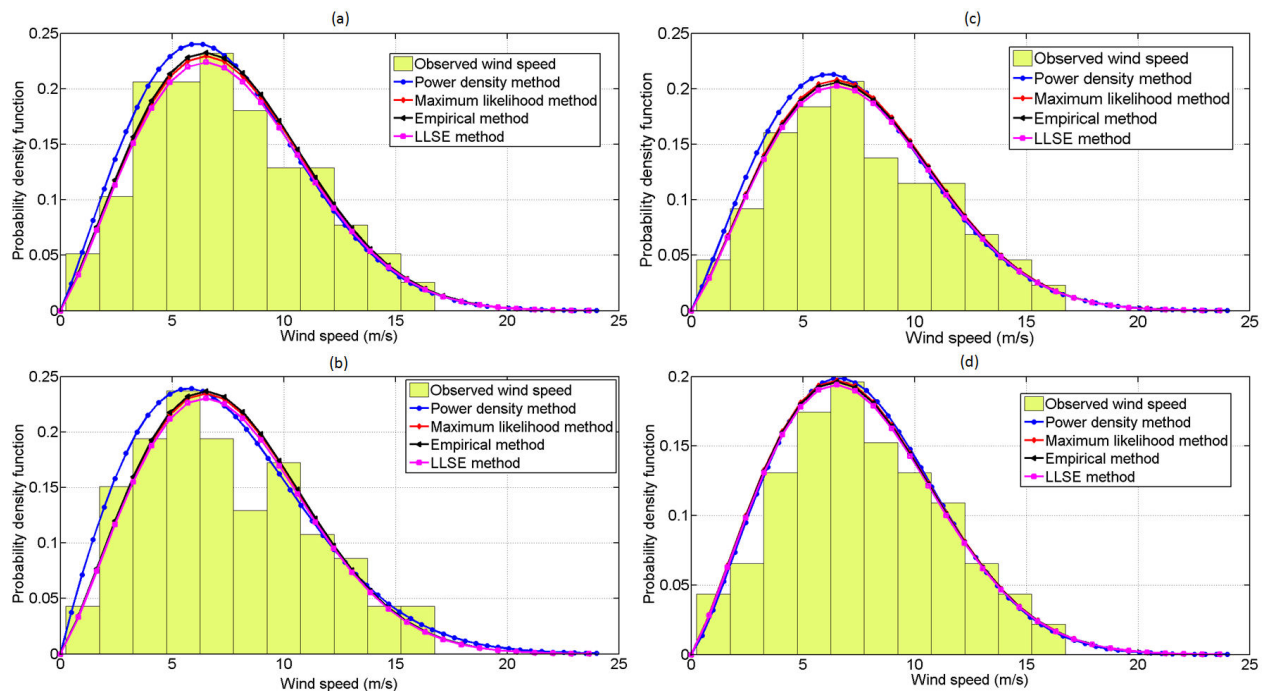
$$P_{M(avg)} = \frac{1}{2\pi} \sum_{j=0}^{2\pi} \frac{\rho}{2} K_d M (\vec{V}_{wj} - \vec{V}_{Mj})^2 \vec{V}_{Mj} \quad (23)$$

The average power calculation is a tedious process so we are considering the drag force with the turbulence behavior and other external forces are not considered. In this work, three different small scale wind turbines such as Ropatec [35], Eurowind [36] and OY Windside [37] are considered.

## 5. RESULTS AND DISCUSSIONS

The experiment is carried out by using a Sistan wind turbine and the Weibull parameters, namely, shape parameter and scale parameter has been determined. The simulation was developed using MATLAB-Simulink version 2013, Intel core i5, 2.3 GHz with 8GB RAM computer. The speed of wind and the vehicle speed are proportional to each other. So the natural field environment wind stream was generated by using two industrial fans and it has turbulent and swirling. The test was conducted for four different seasons. The calculated  $\beta$  and  $\alpha$  parameters for four different seasons with their RMSE have been presented in Table-2.

From Table-2 one can easily understand that the PDM and empirical method provides best Weibull parameters for four seasons. It is observed that particularly the PDM provides best fit parameters for summer, autumn, winter and spring seasons whereas empirical method provides best fit parameters for autumn and spring seasons. The Weibull distribution graph for each season is shown in Figure-5. The Weibull parameters with hourly wind speed for four different methods are presented in Table-3. The best parameters are evaluated by their RMSE value among the four methods. It is noted that from Table-3 the PDM provides better Weibull parameters than MLE for the wind speed data. The PDM provides best result for first six hours and the MLE is best for three hours only. From the calculated results one can observe that the parameter calculation for one day using PDM provides more consistent result than MLE.



**Figure-5.** Weibull distribution of wind speed for four different seasons and determined using four methods.

**Table-3.** Weibull parameters for one day wind speed using four different methods.

Hours	MLE Method			LLSE Method			Empirical Method			PDM Method		
	$\beta$	$\alpha$ (m/s)	RMSE	$\beta$	$\alpha$ (m/s)	RMSE	$\beta$	$\alpha$ (m/s)	RMSE	$\beta$	$\alpha$ (m/s)	RMSE
5	1.9573	4.1672	0.03763	2.0356	4.3025	0.02973	2.0735	4.1672	0.03263	2.1436	4.3849	0.02284
6	2.2478	4.4190	0.02992	2.3638	4.5278	0.02386	2.3267	4.4190	0.02672	2.4482	4.5271	0.01745
7	2.5023	4.3175	0.03974	2.6583	4.4290	0.03396	2.6288	4.3175	0.03702	2.7391	4.4963	0.02740
8	1.8261	3.2937	0.03627	1.9638	3.8493	0.03026	1.9269	3.2937	0.03359	2.1037	3.9390	0.02496
9	1.5286	2.8378	0.02437	1.6366	3.1065	0.01846	1.6105	2.8378	0.01902	1.6972	3.1937	0.01184
10	1.4275	2.7386	0.01937	1.5185	2.8369	0.01275	1.5199	2.7386	0.01639	1.5827	2.9172	0.00735
11	1.7205	3.9146	0.02375	1.8364	3.9972	0.01849	1.7927	3.9146	0.01963	1.8924	4.1047	0.01284
12	1.5219	2.5935	0.02475	1.6193	3.0475	0.01835	1.5982	2.5935	0.02025	1.6923	3.1394	0.01249
01	1.7269	3.9248	0.02311	1.8153	3.9926	0.01903	1.8024	3.9248	0.01903	1.8832	4.1036	0.01368
02	1.7846	4.0375	0.02784	1.8739	4.1205	0.02294	1.8308	4.0375	0.02362	1.9352	4.2304	0.02638
03	1.5282	2.8295	0.02415	1.6241	2.8837	0.01938	1.5924	2.8295	0.02018	1.6823	2.9739	0.01385
04	2.4285	4.6268	0.03205	2.5278	4.7153	0.02836	2.4829	4.6268	0.02864	2.5803	4.8036	0.02184
05	2.2842	4.4577	0.03103	2.3155	4.5288	0.02739	2.2925	4.4577	0.02743	2.3826	4.6294	0.02046
06	1.4683	2.8136	0.01954	1.5386	2.9036	0.01427	1.5189	2.8136	0.01482	1.5930	3.0732	0.00683
07	1.3753	2.2753	0.01742	1.4584	2.3276	0.01280	1.4296	2.2753	0.01382	1.5392	2.4194	0.00648
08	1.5385	2.9326	0.02610	1.6295	2.9937	0.02036	1.5924	2.9326	0.02287	1.6935	3.0836	0.01382

The maximum energy carrying wind and the most probable wind speed for a day is presented in Table-4. For this calculation, the scale and shape parameters for each hour with the minimum RMSE value are taken. From the calculated values one can easily understand that the minimum and maximum probable wind speed occurs in 5-6 and 10-11 hours respectively.

The average air density and pressure for a day and the estimated wind power density and wind energy density is presented in Table-5. The power generated by the three wind turbines such as Eurowind, OY Windside and Ropatec has been presented in Table-6. It is noted that

the Ropatec is most efficient among the three small scale wind turbines. The energy production of OY Windside wind turbine is lower than that of other two small scale turbines.

**Table-4.** Most probable wind speed and maximum energy carrying wind for one day.

Hours	$\beta$	$\alpha$ (m/s)	$W_p$ (m/s)	$W_{max,E}$ (m/s)
5	1.9573	4.1672	2.8917	5.9710
6	2.2478	4.4190	3.4010	5.8653
7	2.5023	4.3175	3.5211	5.4598
8	1.8261	3.2937	2.1332	4.9385
9	1.5286	2.8378	1.4167	4.9052
10	1.4275	2.7386	1.1768	5.0584
11	1.7205	3.9146	2.3603	6.1287
12	1.5219	2.5935	1.2837	4.5011
01	1.7269	3.9248	2.3780	6.1274
02	1.7846	4.0375	2.5476	6.1525
03	1.5282	2.8295	1.4119	4.8920
04	2.4285	4.6268	3.7186	5.9254
05	2.2842	4.4577	3.4643	5.8707
06	1.4683	2.8136	1.2920	5.0525
07	1.3753	2.2753	0.8850	4.3707
08	1.5385	2.9326	1.4822	5.0393

**Table-5.** Average air density, wind power density and wind energy density for one day.

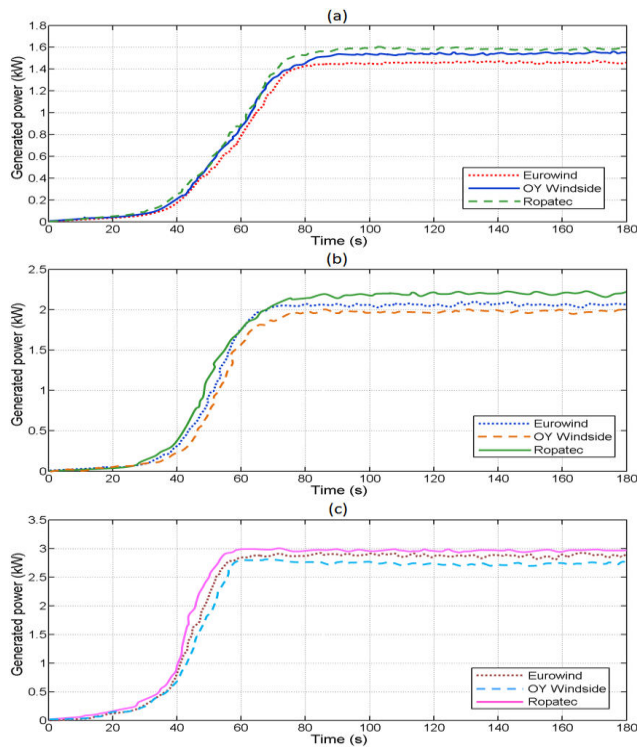
Hours	Pressure (mbar)	Average air density (kg/m <sup>3</sup> )	$P_d$ (W/m <sup>2</sup> )	$E_d$ (kWh/m <sup>2</sup> )
5	881.85	1.085	18.268	13.537
6	881.39	1.114	20.835	15.548
7	880.74	1.127	25.758	17.390
8	880.29	1.141	32.268	22.586
9	879.83	1.150	37.492	26.842
10	879.31	1.161	43.963	31.963
11	879.18	1.170	50.046	36.952
12	878.82	1.178	59.185	38.921
1	878.41	1.188	67.295	49.486
2	878.17	1.196	76.738	53.974
3	879.06	1.177	69.749	49.287
4	879.92	1.164	62.853	42.265
5	880.42	1.153	58.399	38.386
6	880.96	1.142	54.730	36.268
7	881.31	1.130	50.963	35.037
8	881.86	1.083	48.396	54.274

**Table-6.** Comparison between three small wind turbines.

Hours	Average power generation (W)		
	Eurowind	Ropatec	Oy Windside
5	292.67	406.57	310.49
6	305.49	450.95	319.37
7	316.47	520.48	327.92
8	304.50	504.90	316.64
9	115.35	237.57	127.61
10	319.31	590.46	334.82
11	326.35	639.73	338.30
12	317.06	580.94	330.19
1	323.84	622.63	337.93
2	132.49	387.96	146.02
3	324.38	636.90	338.92
4	318.15	589.35	331.90
5	316.74	549.46	330.84
6	116.03	342.55	129.74
7	314.63	538.43	327.61
8	310.23	526.29	321.78

Here the performance of three different wind turbines has been investigated for three different speed scenario of wind such as 5, 10 and 15 m/s. The experiment is carried out for varying the wind speed and the results are shown in Figure-6. The rotational speed of rotor for different speed scenario is taken for 180 seconds after it reaches the steady state.





**Figure-6.** Power generated by three wind turbines at different wind speeds (a) 5 m/s (b) 10 m/s (c) 15 m/s.

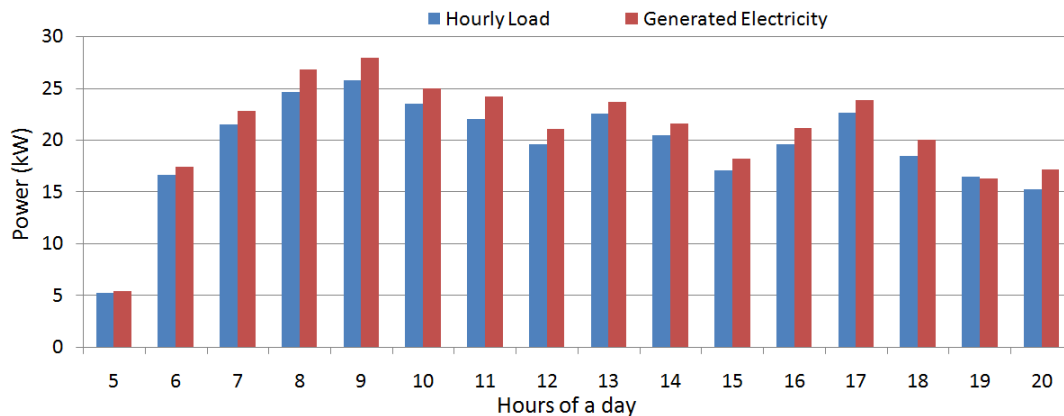
Figure-6 (a) shows the rotational speed of three wind turbines for 5 m/s wind speed. From Figure-6 (a) one can easily understand that after certain speed of the vehicle the wind speed will increase as the movement of wind

rotor increases. To attain this speed it takes some time as because the rotational speed of wind turbine has not been started from zero point. The rotational speed of rotor fluctuates due to the variation present in the wind speed. If the wind speed varies (vehicle speed is not constant), the output of the proposed method fluctuates. Figure-6 (b) and (c) illustrate the rotational speed of three wind turbines for 10 m/s and 15 m/s respectively. In some cases namely for hour 8, 11, 2 and 7 the vehicle speed is reduced to 40 percentage of its maximum speed and the corresponding speed variation obtained for each speed variation is also shown in fig. 6. It is noted that both the wind speed and the rotational speed of rotator are proportional. The on-coming wind speed increases from 5 m/s to 10 m/s then the rotational speed of rotor increases from 82 rpm to 92 rpm and the percentage of increment is around 24.5%. In the same way the rotor speed increase to 105 rpm if the incoming speed is increased to 15 m/s as a result the percentage of increment is about 24%.

The hourly generated electricity during a day time from 5 A.M to 8 P.M is considered. The electricity generated by the renewable source and the hourly load is shown in Figure-7. So the energy storage system (ESS) simultaneously charges the battery both in the running and non-running conditions. The discharging of battery is less than that of the charging of battery because the charge is produced automatically when the vehicle starts to move. The ESS automatically charges the battery under running condition of vehicle.

**Table-7.** Comparison of travelling distance of different EVs with the proposed method.

Name of EV	Battery Type	Distance per hour	Charging Time	Charging Voltage/Current	Distance covered after 10 hours travel	
					Existing Method	Proposed Method
BMW Mini E	Lithium ion with Air cooled.	96 miles	3 hours	240V/48 A	312 miles	960 miles
Chevy Volt	Liquid cooled. Lithium manganese cells from LG Chem.	40 miles	4 hours	240V/24 A	12 miles	400 miles
Ford Focus EV	Lithium ion tri-metal cells from LG Chem.	75 miles	7 hours	230 V/32 A	159 miles	750 miles
Smart Fortwo ED	Lithium ion	85 miles	4.5 hours	220V/24 A	224 miles	850 miles
Tesla Model S	Standard (larger premium batteries optional)	160 miles	4 hours	220V/70 A	448 miles	1600 miles
Tesla Roadster	Lithium cobalt (Liquid cooled)	220 miles	3.5 hours	220V/70 A	660 miles	2200 miles
Think City	Lithium ion batteries	99 miles	8 hours	110V/48 A	198 miles	990 miles
Volvo Electric C30	Lithium ion batteries	93 mile	8 hours	230V/16 A	186 miles	930 miles



**Figure-7.** Hourly load versus generated electricity by the proposed method.

Comparison of travelling time required for different electric vehicles such as BMW Mini E, Chevy Volt, Ford Focus EV, Tesla Roadster, Volvo Electric C30 and Nissan LEAF are compared with the proposed system is presented in Table-7. Assume that all vehicles are initially fully charged and each electric vehicle has different capacity and travelling distance is covered after first charge. Here 10 hours travel time is considered and the corresponding distance is calculated including the waiting time required for charging. We have taken the technical data given by the manufacturer and compared with the proposed system. The comparison result shows that the proposed system reduce the travelling time compared with other type of EVs.

## 5. CONCLUSIONS

In this paper, a novel charging mechanism using renewable source is used for electrical vehicles. One of the major issues for EV is the present charging system. For longer drive recharging is needed and recharging stations are familiar in few countries and it will increase the travelling time. The proposed recharging mechanism overcomes this difficulty and it automatically recharges the battery packs of EV without the involvement of the driver. The Weibull parameters has been calculated using four different methods such as Maximum likelihood, power density method, LLSE method and empirical method for estimation the speed of wind in a day. The estimation was performed every hour of one day and the best parameters were chosen according to their RMSE values. From the obtained results we conclude that the power density method performs better than maximum likelihood method. From the output generated by the proposed system, we strongly confirm that this system can be used in EVs with small scale wind generator. This is capable to utilize high speed wind and generate more power. It is now clear that this approach reduces the total travelling time and increase the efficiency of EVs. As a result, our proposed model effectively reduces fossil fuel consumption and decreases environmental pollution.

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