Modeling and Analysis of Vehicle with Wind-solar Photovoltaic Hybrid Generating System

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Abstract. Through the analysis of the key issues of Wind-solar photovoltaic hybrid generating system (WPGS) and electric system, this paper proposes a WPGS method applied to pure electric vehicles. Establish a mathematical model of WPGS in the Simulink environment, make simulation analysis on the vehicle based on vehicle simulation software ADVISOR, this paper has proved the practicality of WPGS in terms of increasing car trip range.

Introduction

The concept of "Low-carbon Environmental Protection" is well known to everyone. However, traditional car was driven by fossil fuel, the auto emissions include large amount of harmful gases, such as CO, SO. Therefore, the car, as an essential component for modern society, facing the transformation due to its serious environmental pollution, and the research of green cars has become very popular. Because of its clean and pollution-free characteristics, the electric vehicle has been achieved widely attention in recent years. However, EV has its certain drawbacks, for example, short continuous range and long charging time. This would require the use of other renewable energy to make up for the electric car's deficiencies.

The Solar and wind power [1] comes as the gifts of nature, they are clean and powerful. These two kinds of energy could be used to generate electricity and stored in the battery because they are easier to obtain, they cost less and they have zero carbon emissions.

But no matter the solar or wind power, are bound by the natural environment. Currently the wind and photovoltaic hybrid power are used to complement the shortage of the both [2]. Using the solar energy to generate power during the day when the light is stronger, using the wind power when it is dominant advantage in the evening. Such complementarities, effective use of the green resources, but also increase the charge in a storage battery, in order to make up for the inadequacy of pure electric vehicles.

Brief Introduction of Wind-solar Photovoltaic Hybrid Generating System in Vehicle

Solar or wind power as a kind of clean energy, after recent years of booming development, its performance and reliability were greatly increased. The electric cars, gained vast popularity in recent years, have some quite mature power demand theories. Based on the existing vehicle simulation software advisor, add two modules of solar cells and wind turbines, we are going to make a simulation analysis of the vehicle's energy control system.

Overall Structure. The wind-solar photovoltaic hybrid generating system (WPGS) include wind turbine system, solar cell power generation system, energy storage system, energy management system and driving system. The structure diagram is shown in figure 1.The battery is supplied by solar cells and wind turbine energy through DC - DC converter. The battery can accept and store the electric current of solar, wind and electric supply. When the working condition of vehicle need high-power, the battery can supply energy for its drive system.
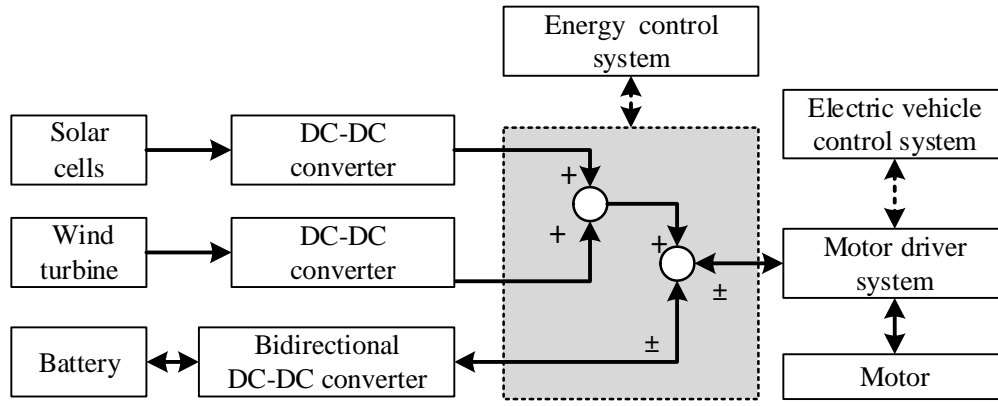
Fig. 1 Structure diagram of wind-solar photovoltaic hybrid generating system

Introduction of ADISOR. ADVISOR was developed by renewable energy laboratory in the US, it is the advanced vehicle simulation software developed within MATLAB and Simulink software environment. This software can make quick analysis for various performances of traditional car, pure electric cars or hybrid vehicles. The file structure mainly includes input scripts, output scripts, block diagrams and advisor control scripts [3]. The user can go through the GUI interface to set the parameters of the simulation model, choose a different simulation functions.

Wind-solar Photovoltaic Hybrid Generating System. The photovoltaic panels of solar power generation system can generate electrons and holes under the condition of light, so as to generate an electric current. At present, monocrystalline silicon and polycrystalline silicon photovoltaic cells are mostly applied. With the development of science and technology, the energy conversion efficiency is also gradually increasing. Photovoltaic battery output characteristic equation [4] is as follows:

$$I = n_p I_{ph} - n_p I_o \left\{ \exp\left[\frac{q(V + IR_s)}{n_s AKT} \right] - 1 \right\} - n_p \frac{v + IR_s}{R_{sh}}$$

(1)

I is the current through the load; I_{ph} is photo-generated current; I_0 is solar cells reverse saturation current; q is electron charge; I, V is the solar cell output current and voltage; K is Boltzmann constant; T is Solar battery's temperature; A is P-n junction ideal factor; Rs is equivalent circuit in series resistance; R_{sh} is equivalent circuit parallel resistance; n_p is the number of parallel in the photovoltaic cell; n_s is the number of series in the photovoltaic cell.

Wind generator is mainly consisted of the blade of wind turbine generators rectifier and controller. The torque of wind overcome the engine's internal resistance to produce kinetic energy, then converted it into electrical energy. According to the Colorado renewable energy institute fan model [5], the energy of wind is captured by the wind generator as follows:

$$P_W = \frac{1}{2} \rho \pi R^2 C_p(\lambda, \beta) V^3$$

(2)

Wind energy utilization coefficient C_p be determined by the following formula :

$$C_p(\lambda, \beta) = c_1 \left(\frac{c_2}{\lambda_i} - c_3\beta - c_4 \right) e^{\frac{-c_5}{\lambda_i}} + c_6\lambda$$

(3)

The λ_i satisfy the following formula:

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + b_0\beta} + \frac{b_1}{\beta^3 + 1}$$

(4)

ρ is air density; R is radius of fan; V is the current wind speed; λ is the fan blade tip speed ratio; β is pitch angle; c_1, c_2, c_3, c_4, c_5, c_6, b_0, b_1 all are constant that determined by the fan manufacturer.

Modeling and Simulation Analysis

Vehicle Model and Parameters. Based on the mathematical model, Simulink models of solar and wind energy are established respectively in Matlab/Simulink [6]. And then in the Advisor, pure electric vehicle model was secondary developed which was shown in Figure 3, reestablish the vehicle simulation model with solar cell module and wind power module.
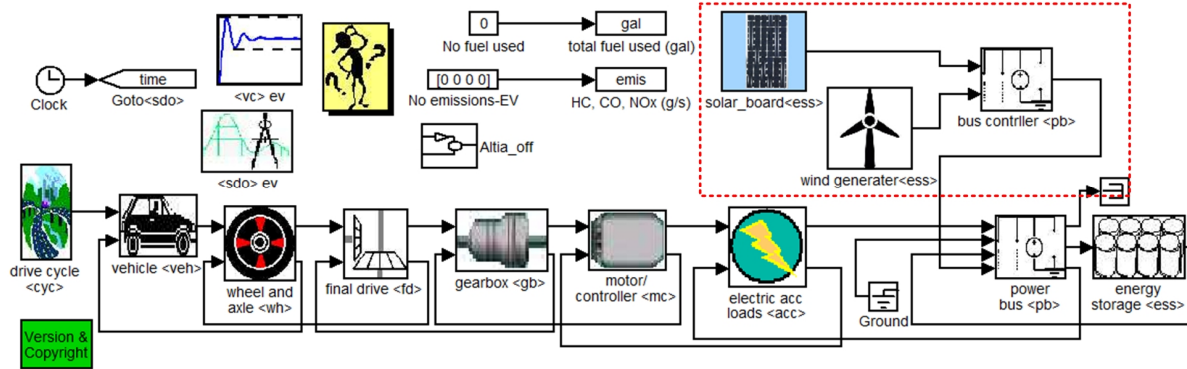

Fig. 2 Electric vehicle model based on advisor

As shown in figure, the vehicle model mainly includes the power module, the wheel module, battery module, accumulator module, control module and the marked wind and solar complementary power generation system module [7]. Each module delivered and transformed the corresponding torque requirements. It also delivered and transformed the torque and speed which can be reached actually. The wind and solar complementary power generation module is mainly used for storing the electric energy in storage battery, and then recharge the battery as it was consumed. It can maintain the best working status of the battery and prolong the service life.

Table.1 Parameters of electric vehicle

Item	Velue
Kerb weight	1210kg
Rated load	11*65kg
Length*width * height	4370*1430*1940（mm）
Wind resistance coefficient	0.35
Rolling resistance	0.02
Electric motor(wheel hub motor)	4*4kw

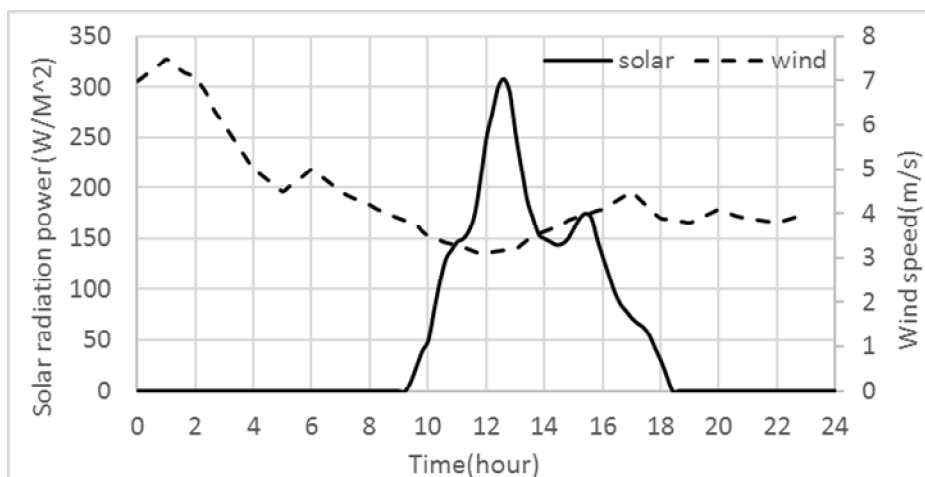**Statistical Results of Solar and Wind**.

Fig. 3 Example of solar and wind energy in one day of Luoyang

Taking one day of Luoyang (112°16' east longitude, 34°32' north latitude) as an example, the Fig. 3 above shows the wind speed within 24 hours and the solar radiation per square meter. According to the figure, before ten am and after seven pm, the electricity mainly generated by the wind, at other times it mostly depends on the solar cell. In summarize, the solar radiation power can be 1.25 kW per square meter. Combining with the design parameters in table 2, the solar cells used in this paper will get 1.4067 kWh per day. Using the formula (2) presented above and the wind turbine parameters in table 2, the wind turbine will gain 0.316 kWh per day. As a result, the WPGS presented in this paper can produce 1.7227 kWh electricity in one day.

Table.2 Parameters of energy system

Item		Velue
Solar cells	Area	6.25m^2
	Energy Conversion Efficiency	18%
	Weight	80kg
Wind turbine	Rated power	300w
	Blade Diameter	1m
	Start-up wind speed	2.5m/s
	Weight	13kg
Storage battery	Single section voltage	12V
	Battery capacity	90A.h
	Battery cells	25

Simulation Analysis of whole Vehicle. Using the simulation of vehicle with WPGS model based on Advisor, the output result was shown in Fig. 4. The curve in the upper left area of the figure shows the simulation output given working condition of typical urban demand for electric cars speed curve. The bottom left area shows the electric cars' battery remaining power curve under the condition of the given speed. The figure simulation results shows that the electric car model in a typical city condition run 35.9 km under the condition of power can consume the electricity of 9.45 kWh (31.5Ah), and the driving distance can meet the user's average transport demand mostly.
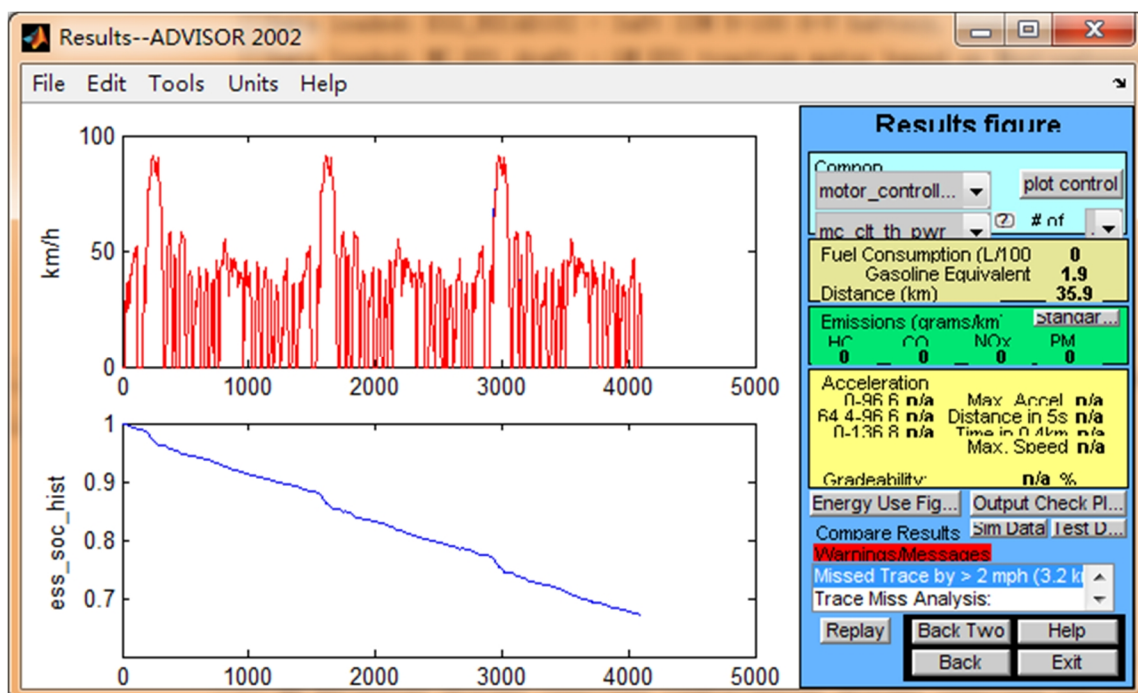

Fig. 4 Simulation results of electric vehicle

According to the normal weather conditions in Luoyang described in the previous section, using the proposed WPGS can result in the total energy of 1.7227 kWh. Therefore, when the weather condition is desirable, the energy generated system provides about 18.2% of the transportation energy for an average user.

Conclusion

This paper analyzes the resource condition of wind and solar energy in Luoyang, and then makes a simulation of vehicle with WPGS based on Advisor. By comparing the energy of WPGS and electric vehicle model simulation result, the WPGS can provide about 18.2% of the energy for the car, which has a certain practical significance.

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