ELECTRICAL VEHICLE POWERED BY SOLAR AND WIND SOURCES

Mr. N. NAGARAJU, MTech
Associate Professor
Electrical and Electronics Engineering
KKR & KSR Institute of Technology & Sciences(KITS)
Guntur,AP,India.

SK.JASMINE
Electrical and Electronics Engineering
KKR & KSR Institute of Technolgy & Sciences(KITS) Guntur,AP,India

N.RUPA KALYANI
Electrical and Electronics Engineering
KKR & KSR Institute of Technolgy & Sciences(KITS) Guntur,AP,India

T.PRAVALLIKA
Electrical and Electronics Engineering
KKR & KSR Institute of Technolgy & Sciences(KITS) Guntur,AP,India

B.PURNA CHAND
Electrical and Electronics Engineering
KKR & KSR Institute of Technolgy & Sciences(KITS) Guntur,AP,India

B.SUNIL KUMAR
Electrical and Electronics Engineering
KKR & KSR Institute of Technolgy & Sciences(KITS) Guntur,AP,India

Abstract—In this paper, the possibility of utilizing a wind turbine to recapture a portion of the kinetic energy losses of a car, irrespective of being a traditional car that is propelled by an internal combustion engine or an electric vehicle (EV) that is propelled by an electric motor, is appraised. To investigate the topic, a small wind turbine has been inserted at the back of the condenser of a car to recover a portion of the kinetic energy of wind passing through the condenser's crisscrossed bars. a novel built hybrid power generation system combining the wind-driven generator's output power with that of the car's battery have been embedded in an EV having a total weight of 1855 kg. Experimental measurements conducted under realistic operation of the EV are given that prove the traveling range of the EV and the power efficiency of the EV's power supply are enhanced by, 6.4 km and 0.2% respectively, by recovering only a portion of the kinetic energy losses of the EV. These two benefits also prove the novelty and contributions of this work in successfully recovering a portion of the kinetic energy losses of a car by using a small wind turbine embedded in the car. Wind power is clean and sustainable natural resources that has yet to be fully utilized in the automotive industry . Also the sun is probably the most important sources of renewable energy available today.

Index Terms—**Kinetic energy losses of cars, energy loss recovering, wind energy, car's battery.**

I. INTRODUCTION

OVER the years, the usage of renewable energy based sys-tems and devices have rapidly increased due to economy and environmental issues [1], [2]. Among renewable resources, Electric vehicles sales may increase fro 2% global share in 2016 to 30% by 2030.

1.1 Solar Energy

Solar energy has the greatest potential of all the sources of renewable energy. The solar power where sun hits atmosphere is 10^{17} watts where as the solar power on earth's surface is 10^{16} watts. The total world - wide power demand of all needs of civilization is 10^{13} watts. Therefore the sun gives us 1000 times more power than we need. So the technical utilization of solar energy can prove very useful. Utilization of solar energy is of great importance to India since it lies in a temperature climate of the region of the world where

sunlight is abundant for a major part of the year. The recent applications of solar energy in India, are the energisation of pump sets for irrigation, drinking water supply and rural electrification covering street lights, community TV sets, medical refrigerators.

1.2 Wind Energy

The potential of wind energy as a source of power is large. The energy available in the winds over the earth is surface is

estimated to be $1.6\text{x}10^{7}$ mw

which is of the same order of magnitude as present energy consumption on the earth. In India, high wind speeds, are obtainable in coastal areas of saurashtra western Rajasthan and some parts of central India. They are non - polluting and it has no adverse influence on the environment.The first power source is photo - voltaic solar cell. These cells convert sun

light directly into DC power without any emissions. The second power source is wind energy ie the kinetic energy of air in motion. The third one is shock absorber which is connected to suspension. It converts kinetic energy into another form of energy.

the popular attention mainly concentrates on solar and wind energies, so that, various solar and wind energy based systems are currently utilized in the different points of the world [3], [4]. Commonly used automobiles are mainly divided into IEC cars and electric vehicles (EVs), although, replacing IEC cars with [5],[6] EVs because of their benefits is the dominant tendency nowadays

Power required to overcome the air resistance

$$Hp = \frac{\rho v^3 c\, dA}{1100}$$

ρ = air density. Slugs
v = car velocity . ft/sec
cd = drag coefficient
A= frontal area . ft^2

drag depending up on body of car

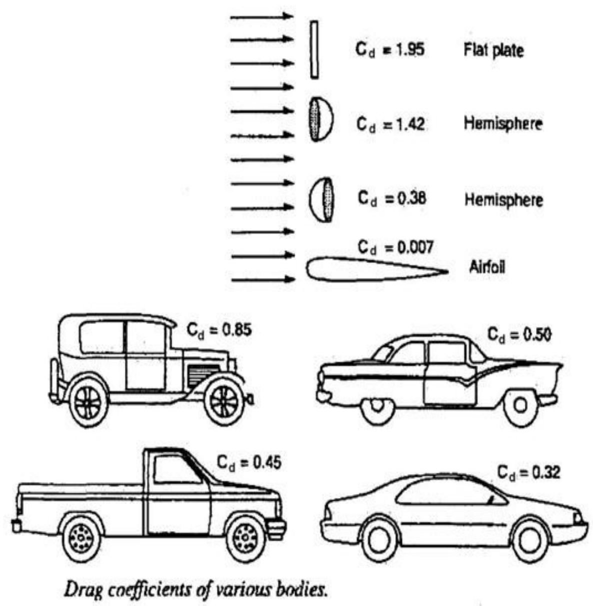


Fig 1

solar source

generating voltage	12v
current	0.3 A
rated power	20 watts
rpm input	100-1500 rpm
charging time	(1hr 30 min)

Wind source

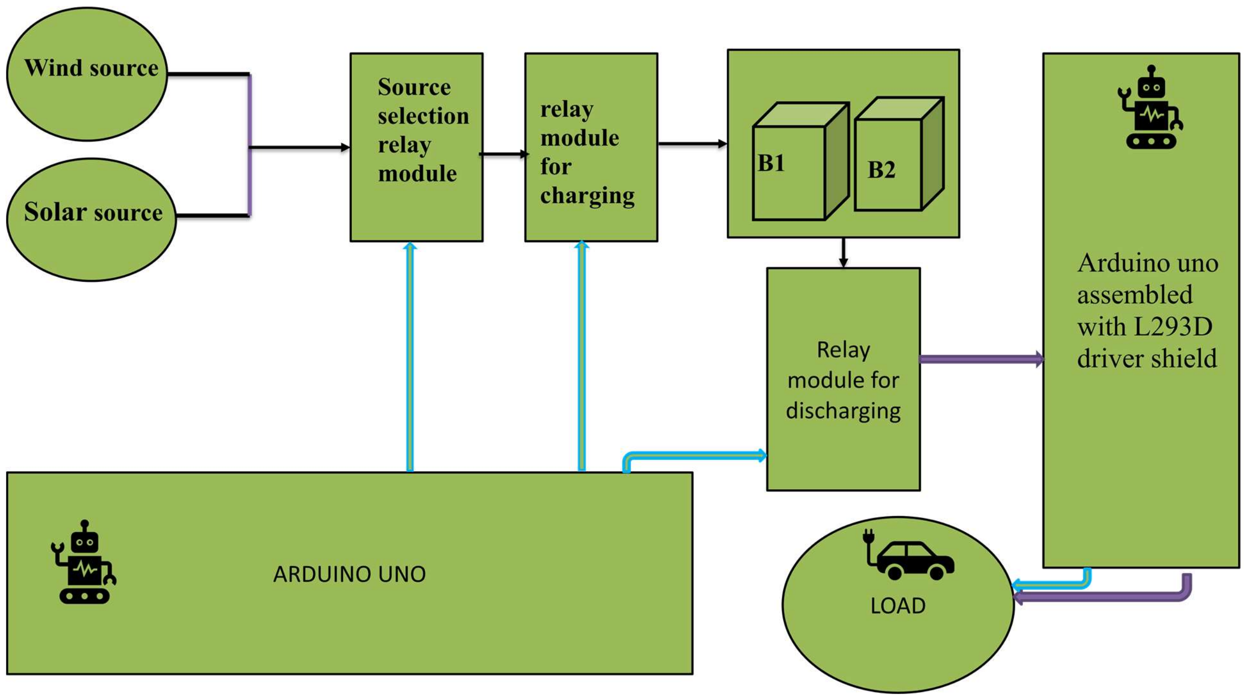
generating voltage	12v
current	0.3 A
rated power	20 watts
rpm input	100-1500 rpm
charging time	(2 hr 12 min)

Drag coefficient of different objects

Type of Object	Drag Coefficient - c_d -	Frontal Area
Dolphin	0.0036	wetted area
Subsonic Transport Aircraft	0.012	
Supersonic Fighter,M=2.5	0.016	
Streamlined body	0.04	π / 4 d2
Airplane wing, normal position	0.05	
Sreamlined half-body	0.09	
Bicycle - Streamlined Velomobile	0.12	5 ft^2 (0.47 m^2)
Airplane wing, stalled	0.15	
Modern car like a Tesla model 3 or model Y	0.23	
Toyota Prius, Tesla model S	0.24	frontal area
Sports car, sloping rear	0.2 - 0.3	frontal area
Common car like Opel Vectra (class C)	0.29	frontal area
Hollow semi-sphere facing stream	0.38	
Bird	0.4	frontal area
Solid Hemisphere	0.42	π / 4 d2
Sphere	0.5	
Saloon Car, stepped rear	0.4 - 0.5	frontal area

Table 3

Fig. 2. Structure of the system realizing the proposed scheme in an EV.



proposed scheme is discussed in Section II. Details of the built system realizing the scheme and experimental measurements are presented in Section III, and the paper is outlined succinctly inSection IV.

II. THEORETICAL BASIS OF THE PROPOSED SCHEME

The proposed scheme deals with inserting a small wind tur- bine at the back of the condenser of a car that can be eithera traditional car which is propelled by an internal combustion engine or an EV which is propelled by an electric motor. The wind turbine is coupled to a PMSG connected to a rectifier to form a wind energy conversion system (WECS) as depicted in Fig. 1. Thus, to realize the scheme, it is necessary to design
and build a novel hybrid power generation system combiningthe power production of the car's battery with that of the wind turbine embedded in the car. The structure of the system realizingthe proposed scheme in an EV is depicted with all specifics in Fig. 1. It mainly consists of a novel hybrid power generation system powered by the WECS and the EV's battery. The WECSand the EV's battery are connected to a dc bus via two dc/dc converters, respectively called "WECS converter" and "battery converter". A 3-phase dc/ac inverter converts the dc-link voltage (V_{dc}) to a 3-phase voltage fed to the EV's traction motor. In addition to these, a dc/ac inverter connected to the EV's battery provides the V2G technology for the EV. The electric circuit of the WECS converter is shown in Fig. 2. All technical and theoretical details of this type of converter have been reported in [20]. The WECS converter's gain is obtained as [20]:

NAMES, MODELS AND TECHNICAL DATA OF THE COMPONENTS OF THE BUILT SYSTEM

Battery		Maximum power	130
Type	Lead acid	Rated phase voltage (V)	12
Voltage (V)	48	Rated rotation (rpm)	690
Current capacity (Ah)	400	Magnet material	NdFeB
Capacity (kWh)	19.2	Weight (kg)	2.8
Series-connected batteries	4	**Battery converter**	
ESR ($R_{bat-esr}$ (mΩ))	2.9	IGBT switches: SW, Q1-Q2	STGY40NC60VD ×40
Wind turbine		$R_{L_{bat}}$ (mΩ)	10.8
Rated power (W) & speed(m/s)	100 & 10	**V2G**: Single-phase: ~110 VAC, 60 Hz	
Diameter (cm)	76	IGBT switches: Q9-Q12	STGY40NC60VD ×8

Table 4

microcontroller. Noting the system's electric circuit depicted in Fig. 5 demonstrates that the built system operates exactly based on Eqs. (2)-(9) discussed with all details in the previous section. Figs. 6(a)–(c) depict the detailed photographs of the wind turbine and PMSG used which have been surrounded by a frame attached to the back of the condenser. These figures clearly show how the wind turbine, PMSG and their frame are assembled and inserted at the back of the condenser. As depicted in Fig. 6(a), the wind turbine has been attached to the back of the condenser and gets its energy from the wind passing through the A portion of this wind is caused by the kinetic energy resulting from the car movement, and if wind exists outside the car, the other portion is caused by it. Solar and wind turbine are employed .

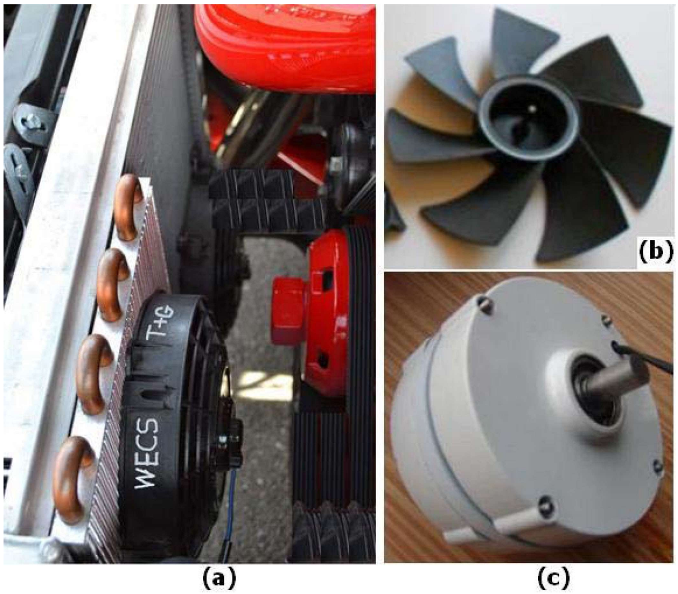


Fig. 3 (a) Wind turbine.

It is also reminded that when the car is parked (there is no kinetic energy resulting from the car movement), even a small flow of wind existing outside the car is converted into electricity stored in the car's battery. To add the WECS to an existing car, there is no need to make any change in the car. The only work that should be performed is to locate the wind turbine and the generator (PMSG) connected to it in a frame, and attaching the frame to the back of the condenser of the car as shown in Fig. 6(a). Experimental measurements showing the waveforms of the dc-link voltage, voltages and currents fed to the traction motor are depicted in Fig. 7 and Fig. 8, respectively. The switching frequency of the battery and WECS converters is 25 kHz as outlined in Table I. The waveforms of the duty cycle D_{we} produced by the microcontroller (power controller) and fed to the MOSFET switch of the WECS converter and also the dc-link voltage are depicted in Fig. 9. These two waveforms prove highly accurate regulation of the dc-link voltage to the assigned voltage (+400 V) caused by changing D_{we} executed by the microcontroller. To determine the power efficiency of the built system, the ratio of power fed to the EV's traction motor to the sum of the battery's discharge power and WECS's output power was calculated point by point using the measured values.

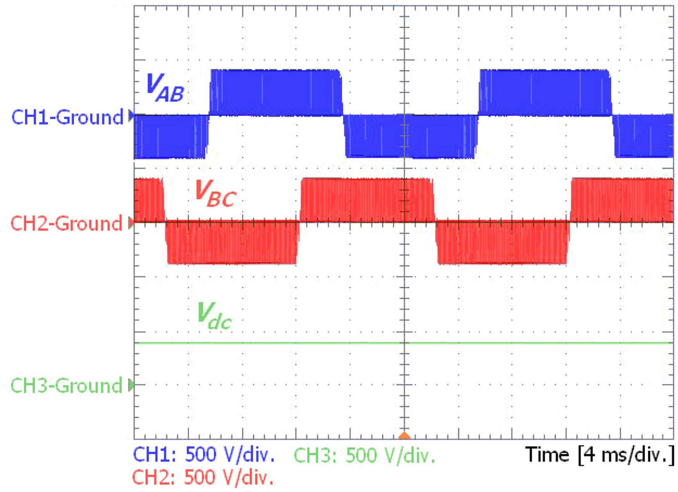


Fig. 4 Voltages fed to the traction motor and dc-link voltage.

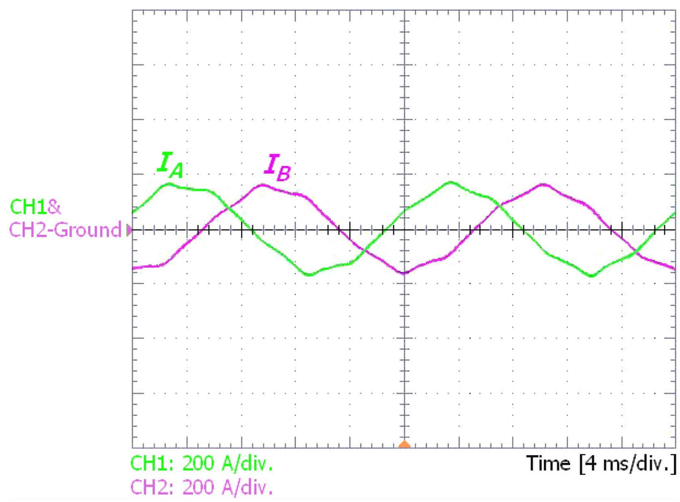


Fig. 5. Currents fed to the traction motor.

TABLE 5
EV's Parameters With and Without the Wind Turbine

Case	Test number	Traveling range (km)	Maximum velocity (km/h)	0-100 km/h acceleration (sec)	Maximum efficiency (%)
With wind turbine	Test 1	11	121	8.2	90.4
Without wind turbine	Test 2	13	121	8.6	90.2

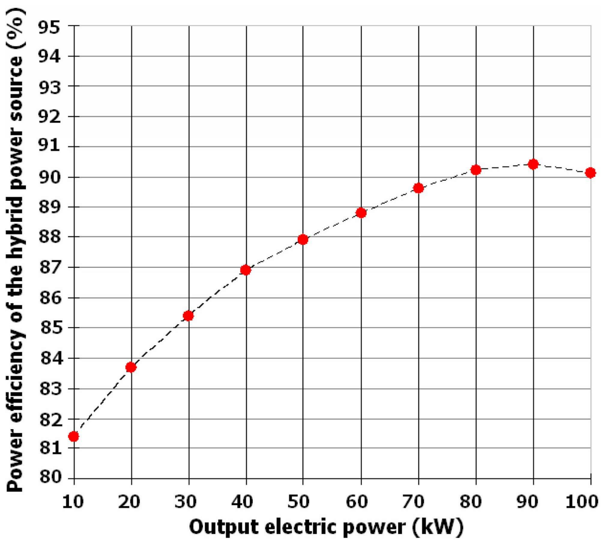


Fig. 6. Power efficiency of the built system.

The power efficiency curve is depicted in Fig. 10 that shows an efficiency of more than 90% at the traction motor's rated power which is 80 kW as reported in Table I.

To assess the contribution of the wind turbine to power pro- duction, the power flows of the built system were measured hour by hour over two sequential days (48 hours) that is depicted in Fig. 11. The power provided by the battery (battery discharge power) is shown with red color, while the power production of the WECS is depicted with blue color. It can be seen that when the car is parked, for instance, during 9:00-14:00, there is no kinetic energy resulting from the car movement, but the flow of wind existing outside the car has been converted into electricity stored in the car's battery. Moreover, the traveling range, maximum velocity and acceleration of the EV along with the maximum power efficiency of the built system were measured during two road tests (Test 1 and Test 2) in presence and absence of the wind turbine that are reported in Table II. The measurements of the two road tests were conducted under same conditions referring to the normal operation of the EV with a fixed weight of 1855 kg.

CONCLUSION

In this study, the possibility of inserting a small wind turbine at the bumper of a car to recover a portion of the kinetic energy losses of the car was evaluated. To realize the proposed scheme, a 100 W wind turbine, a PMSG coupled to the turbine and a novel built hybrid power generation system combining wind power production with the power production of the car's battery have been embedded in an EV with a total weight of 1855 kg. Experimental data obtained from the operation of the EV under realistic conditions showed that utilizing the wind turbine improves the traveling range of the EV and the power efficiency of the EV's power supply by, respectively, 6.4 km and 0.2%. These advantages outline the novelty and contributions of this research work in realizing the proposed scheme dealing with recapturing a portion of the kinetic energy losses of a car.

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