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Dual-Mode Solar and Wind Energy Charging System for Electric Vehicles: A Sustainable Approach

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Abstract -Electric Vehicles are now becoming part of our daily lives. The biggest challenge for complete adoption of electric vehicles is charging fo batteries. This paper explores a dual-mode charging system for electric vehicles. It proposes utilizing both solar and wind energy, aiming to address the challenge of battery charging and promote sustainable transportation. The study highlights the significant contribution of the transportation sector to carbon emissions and the growing demand for electric vehicles. Solar panels mounted on the vehicle can harness abundant sunlight, providing consistent energy throughout the year. Complementing this, wind turbines installed at the front of the car can generate electricity from airflow during motion, with power output increasing at higher speeds. The proposed setup allows vehicles to recharge while parked under the sun and while driving, reducing reliance on stationary charging infrastructure. The findings demonstrate the feasibility of integrating renewable energy sources for electric vehicle charging, paving the way for environmentally friendly solutions. Future work will focus on the practical implementation and performance evaluation of the system.

***Key Words*:**Sustainable energy, electric vehicles, charging, battery charging, solar power, renewable energy

1.INTRODUCTION

Mankind has achieved great success and development over the years and has become the leading species in the world. At the same time, we have been responsible for the degradation of the environment, which has resulted in climate change [3]. One of the prime factors responsible for the degradation has been the transportation system. It has been observed that 25% of the carbon gas contribution has been by the transportation sector only [2]. There has been great research and development in the transportation sector as well [8]. Along with this, there has been depletion of sources of petroleum, which has resulted in to decrease in the supply of petroleum-based fuels. This has resulted in increased demand for Electric Vehicles [1]. It is estimated that by the end of 2030, there will be a demand of more than 238 million electric vehicles [1]. The main challenge for the complete acceptance of electric vehicles is the availability of charging batteries of electric vehicles. Batteries are the main part of electric vehicles. There has been a lot of research going on in developing different types of batteries for electric vehicles [4]. The main goal of developing electric vehicles is to create sustainable and environmentally friendly solutions. One of the areas that has been explored is self-rechargeable vehicles using renewable energy [9]. One of the areas that has been explored is solar energy [9]. The problem with the use of dependency of solar power is the limitation of space for the use of solar panels. If solar power can be used along with wind energy, there will be a significant improvement in the availability of recharging for the electric batteries. This paper showcases of use of dual mode for charging. It shows how the two renewable energy sources can be utilized. This can be a good step in sustainability and environmentally friendly solutions. (https://pvwatts.nrel.gov/pvwatts.php)

Basic Idea:

Hummingbird is one of the great wonders of Mother Nature. It has the highest metabolic rate of any animals or birds. So, in order to supply energy for its survival, it must consume the food which is three times its body weight. The reason for this can be explained as follows:

1. Hummingbirds have the largest brain of all birds (4.2% of their total body weight). To function, this brain needs a lot of energy.
2. The giant hummingbird beats its wings 25 times per second, which is 1500 flaps per minute. Any medium-sized hummingbird will flap its wings 20 to 30 times per second, and small ones have been found to reach up to 100 flaps per second. Hummingbirds need to beat their wings to stay arial and at the same

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time consume the nectar of the flowers, which supplies them with energy.

3. During nighttime, when they are not flying, they lower their body metabolic rate by almost 95%. This stage is called the torpor stage. The next day, when they wake up, they need to have reserved energy, which will enable them to push their metabolic rate. If this energy is not available, they will die.

Thus, hummingbirds keep on consuming the energy that is being continuously used by their small bodies to sustain them. If equivalent energy were to be calculated for an average person, that person would be consuming around 285 pounds of hamburger or 370 pounds of potatoes, or around 130 pounds of bread in a day.

Another fascinating thing about hummingbirds is their aerodynamic body shape. The equivalent speed achieved by these tiny birds is almost 54 km/hr. This is because of the aerodynamic shape of their bodies.

This is the basic principle for redesigning the car, which will run on renewable energy. The car will be consuming the energy that will be made available by using the solar panels and the wind turbine. The detailed explanation of the same is given in the following sections.

Renewable resource 1: Solar Power

India is blessed with an abundance of solar energy. Sunlight is available throughout most of the year except during the monsoon season. During the monsoon season, there are many days when the sun is visible. Solar energy remains one of the most promising sources of renewable power for vehicular applications due to its high theoretical potential and scalability [10]. Solar energy can be converted to electricity by using solar panels. A solar panel is made up of several photovoltaic cells. Usually, the cells are very thin. They are square in shape of 3 to 4 inches, and have a thickness is about 1/100th of an inch. Around 200 photovoltaic cells are assembled to form a solar panel. The modules are encased in glass and aluminium panels so as to make them weather resistant.

To utilize solar power in the car, the solar panels will be mounted on the car. The top of the car is usually exposed to sunlight. This area is ideal as it would not affect the visibility of the driver. The figure of a car with having solar panel mounted is shown in Figure 1.

Fig 1: Car with solar panel mounted

The availability of solar power for the charging of the battery The average power per month that can be generated using the 4 solar panels mounted on the car for the city of Vadodara is shown in Table 1.

Table 1: Average Power Generation Using Solar Energy Per Month

Month	Daily Average POA Irradiance (kWh/m2/day)	DC Array Output (kWh)	AC System Output (kWh)
January	6.144	580.211	554.383
February	6.724	557.288	532.653
March	7.056	620.778	593.1
April	7.075	597.303	570.191
May	6.781	614.601	586.434
June	5.776	519.303	494.719
July	4.743	451.35	428.984
August	4.656	446.327	424.21
September	5.759	521.362	497.52
October	6.354	579.237	553.306
November	5.817	522.752	499.016
December	5.701	532.083	507.829

The sunlight varies from month to month. Also, there is a change in the intensity from morning to evening. The panels will generate electricity based on the intensity. Table 2 to Table 13 show the hourly electricity generated from January to December for the 15th day of each month. The time frame considered is from 7 am to 5 pm.

Table 2: Hourly Electricity Produced for January

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Volume: 03 Issue: 10 | Oct-2025
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Month	Day	Hour	DC Array Output (W)	AC System Output (W)
January	15	7	7.707	0
	15	8	962.796	912.826
	15	9	1766.734	1688.278
	15	10	2293.458	2196.337
	15	11	2657.544	2547.523
	15	12	2751.498	2638.147
	15	13	2640.288	2530.878
	15	14	2359.287	2259.834
	15	15	1824.423	1743.922
	15	16	1086.134	1031.794
	15	17	208.906	185.65

Table 3: Hourly Electricity Produced for February

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
February	15	7	90.452	71.392
	15	8	1139.556	1083.323
	15	9	1977.201	1891.287
	15	10	2539.52	2433.68
	15	11	2863.913	2746.579
	15	12	2970.21	2849.109
	15	13	2866.233	2748.816
	15	14	2553.483	2447.149
	15	15	2054.576	1965.92
	15	16	1324.908	1262.107
	15	17	482.771	449.81

Table 4: Hourly Electricity Produced for March

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
March	15	7	303.354	71.392
	15	8	1196.547	1083.323
	15	9	1855.56	1891.287
	15	10	2290.29	2433.68
	15	11	2691.204	2746.579
	15	12	2771.892	2849.109
	15	13	2667.926	2748.816
	15	14	2407.624	2447.149
	15	15	1933.794	1965.92
	15	16	1313.703	1262.107
	15	17	522.161	449.81

Table 5: Hourly Electricity Produced for April

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
April	15	7	569.135	276.751
	15	8	1396.474	1138.294
	15	9	1984.473	1773.955
	15	10	2253.416	2193.281
	15	11	2430.178	2579.99
	15	12	2464.763	2657.818
	15	13	2366.596	2557.537
	15	14	2229.37	2306.458
	15	15	1790.693	1849.418
	15	16	1202.183	1251.299
	15	17	515.825	487.804

Table 6: Hourly Electricity Produced for May

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
May	15	7	693.673	533.114
	15	8	1440.063	1331.137
	15	9	2043.431	1898.301
	15	10	2420.947	2157.714
	15	11	2615.522	2328.213
	15	12	2637.124	2361.572
	15	13	2500.142	2266.884
	15	14	2210.164	2134.52
	15	15	1737.915	1711.387
	15	16	1135.923	1143.73
	15	17	504.176	481.693

Table 7: Hourly Electricity Produced for June

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
June	15	7	684.147	653.24
	15	8	1345.324	1373.182
	15	9	1881.761	1955.17
	15	10	2176.86	2319.309
	15	11	1705.316	2506.99
	15	12	2319.388	2527.826
	15	13	1905.334	2395.698
	15	14	2064.029	2115.995
	15	15	1603.279	1660.48

	15	16	265.696	1079.819
	15	17	192.394	470.457

Table 8: Hourly Electricity Produced for July

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
July	15	7	477.824	445.039
	15	8	876.891	829.965
	15	9	1851.344	1769.889
	15	10	1397.08	1331.722
	15	11	1812.714	1732.628
	15	12	2544.925	2438.894
	15	13	2454.638	2351.806
	15	14	1922.54	1838.562
	15	15	1650.672	1576.328
	15	16	779.845	736.358
	15	17	554.395	518.896

Table 9: Hourly Electricity Produced for August

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
August	15	7	388.324	644.051
	15	8	1092.747	1281.799
	15	9	1451.474	1799.229
	15	10	2097.801	2083.871
	15	11	1872.104	1629.036
	15	12	2821.65	2221.348
	15	13	2602.969	1821.966
	15	14	2391.301	1975.038
	15	15	1909.349	1530.614
	15	16	1174.821	240.427
	15	17	349.33	169.723

Table 10: Hourly Electricity Produced for September

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
September	15	7	509.24	358.71
	15	8	1385.989	1038.173
	15	9	2019.691	1384.188
	15	10	2449.568	2007.613
	15	11	2683.673	1789.913
	15	12	2728.631	2705.814
	15	13	2590.732	2494.881
	15	14	2127.375	2290.714
	15	15	1712.014	1825.839
	15	16	1080.786	1117.339
	15	17	100.631	321.097

Table 11: Hourly Electricity Produced for October

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
October	15	7	526.497	475.342
	15	8	1408.04	1321.024
	15	9	1962.043	1932.271
	15	10	2305.004	2346.916
	15	11	2564.663	2572.726
	15	12	2578.407	2616.091
	15	13	2427.539	2483.078
	15	14	2187.085	2036.14
	15	15	1639.484	1635.496
	15	16	902.606	1026.635
	15	17	156.31	81.211

Table 12: Hourly Electricity Produced for November

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
November	15	7	310.525	491.987
	15	8	1313.306	1342.293
	15	9	1997.461	1876.666

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	15	10	2422.975	2207.475
	15	11	2632.416	2457.933
	15	12	2643.916	2471.19
	15	13	2460.486	2325.667
	15	14	2005.698	2093.734
	15	15	1478.673	1565.536
	15	16	749.249	854.769
	15	17	48.325	134.917

Table 13: Hourly Electricity Produced for December

Month	Day	Hour	DC Array Output (W)	AC System Output (W)
December	15	7	57.771	283.667
	15	8	946.012	1250.916
	15	9	1826.765	1910.829
	15	10	2297.734	2321.265
	15	11	2420.751	2523.285
	15	12	2454.987	2534.377
	15	13	2323.771	2357.447
	15	14	2011.283	1918.774
	15	15	1558.186	1410.423
	15	16	821.499	706.846
	15	17	20.769	30.759

From tables 1 to 13, it can be easily understood that solar power is available throughout the day, almost throughout the year. The peak time of available sunlight is from 10 am to 5 pm. The electricity will be generated during this time. The electricity generated at this time will be used to recharge the battery of the car.

The cars parked in the sun will keep on charging and will provide partial recharging of the batteries of the electric vehicle. The other way of charging the batteries will be using the wind power which is explained in next section.

Renewable Resource 2: Wind Power

When the car is moving, the car experiences the wind in the opposite direction with the same velocity. So if the vehicle is moving at the speed of 60 kmph, it is going to face the air in the reverse direction with the same velocity. This velocity can be used to drive the wind turbine. The wind turbine can drive the generator, which will generate electricity. This electricity can be stored in the electric batteries. There will be two wind turbines which would be placed on the front side of the vehicle. These turbines will be placed at the place where generally internal combustion engine is present. Figure 2 shows the schematics of the car bottom with turbine placement.

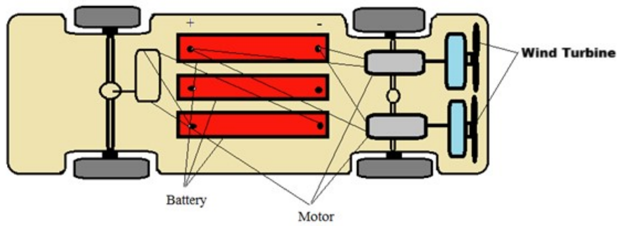

Fig 2: Schematic Diagram of Car with Wind Turbine

Table 14 gives details of the wind turbine particulars.

Table 14: Wind Turbine Particulars:

Number of Blades	04
Width	0.0889 m
Blade length, $l = r$	0.254 m
Wind speed, v	12 m/s
Air Density, ρ	1.23 kg/m^3
Power Coefficient, Cp	0.4

Swept Area $A = \pi r^2$

Power $= 0.5 \times Air\ Density \times Swept\ Area \times Velocity^3 \times Cp$

Inserting the value of blade length as the radius of the swept area, L = r= 0.254 m

$A = \pi \times 0.254^2 = 0.2026$ m^2

The power converted from the wind into rotational energy in the turbine can be calculated using the following formula:

$$P_{avail} = \frac{1}{2}\rho A v^3 C_p$$

There will be two turbines used. The power available at different velocities is shown in the Table 15.

Table 15: Power Generated at Various Velocities

Sr. No.	Velocity (km/hr)	$P_{available}$ (watt/hr)	Power available with 40% efficiency (watt/hr)	Total Power Available (2 turbines) (watt/hr)
1	20	8.52	3.408	6.816
2	30	28.84	11.53	23.06
3	40	68.34	27.34	54.68
4	50	133.56	53.42	106.84
5	60	230.88	92.35	184.7
6	70	366.15	146.46	292.92
7	80	546.77	218.71	437.42

The power available is low at lower speeds of the vehicle. As the speed increases, there will be an increase in the power output. Just like a hummingbird gains energy from flower nectar while spending energy in flying, the vehicle will be generating energy while driving. The power output will be better at higher speeds.

How Setup Will Work?

Case 1: Car is in the parking lot under the sun:

The solar panels will produce the electricity which will be stored in the battery. Even when the car is not connected to the main electric charging point, the battery will continue to charge.

Case 2: Car is moving

When the car is started, it will be having the required battery to run which was charged when the car was parked. As the car gathers speed, the wind turbines will start moving, the wind turbines will start producing electricity. This electricity will be sent to be stored in a battery. On the highway, there will be a consistent speed, which will also result in consistent electricity generation. Along with wind power, the solar cells will be generating electricity, which will be stored in the battery.

Case 3: Nighttime

The solar panels would not be of any use during the night. When the car is moving during the night, the wind turbines will generate electricity. Thus, during nighttime, the source of power will be only wind power.

Thus, the car will be charged during the motion. During the day, sunlight will aid in charging the car even when the car is not moving. The wind turbine will aid whenever the car is moving. Thus the overall dependency on the stationary charging points will be reduced.

Conclusion:

Electric vehicles are going to be used everywhere in the near future. The biggest challenge for the adoption of electric vehicles is the charging of the batteries, which are the heart of electric vehicles. There have been many methods suggested for solving this challenge. This paper presents the idea of using renewable energy resources for generating electricity, which will charge the electric vehicle. Solar energy is available in abundance in India. Taking Vadodara, Gujarat as a reference, it has been shown that battery charging is viable using solar power. Further, the use of wind power has also been suggested. As a part of future work, the practical setup needs to be prepared and explored to see the actual results.

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