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Analysis of Hybrid Electric Vehicle operated by Wind and Solar Energy

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Abstract – One of today's most pressing challenges is the energy crisis and pollution brought on by car emissions. This work evaluates a wind-solar hybrid system designed exclusively for power generation in hybrid electric vehicles (HEVs). The primary objective is to utilize wind and solar energy effectively in order to optimize the hybrid system. Further, a foundation is established for future research, highlighting the importance of incorporating renewable energy into transportation networks. A Battery Management System (BMS) uses solar panels, wind turbines, converters and electrical outlets to charge HEV batteries. The Simulation and analytical results demonstrate that the system can successfully producing electricity by utilizing wind and solar resources, providing a sustainable source of power for hybrid electric vehicles.

Keywords – Hybrid Electric Vehicles, Battery Management System, Electric Vehicle

I. INTRODUCTION

At present, vehicles are regarded as vital fundamentals in daily existence for personal transportation and mobility of goods, as expressed by the continuous request for fuel. Laterally with such a request, rising fuel prices and growing environmental worries due to climate change and air pollution have raised concerns. Because of this, several governments have pressured automakers to offer environmentally responsible and low-emission transportation solutions [1]. Reduced reliance on fossil fuels has resulted in lower releases of greenhouse gases and other contaminants thanks to the deployment and development of electric vehicles (EVs) in this climate. [2]

In addition to the adverse effects of pollution, fossil fuels are becoming scarce. Therefore, it is necessary to find innovative technologies to optimize petroleum-based goods' usage. Regarding transportation, researchers are working to develop cutting-edge, environmentally friendly energy systems. In contrast to unconventional energy sources, petroleum products provide many benefits despite the apparent drawbacks of shortage and pollution. For instance, petroleum goods have a very high energy density compared to batteries, fuel cells, etc.

Moreover, replenishing the gasoline tank takes only a short time compared to battery charging, which might take many hours. Fuel cells produce electricity rather than storing it, in contrast to chemical batteries, and their ability to do so depends on fuel availability. Longer driving range is provided by this primary difference for fuel cell-powered vehicles. But to achieve a higher energy concentration for fuel cells, highly flattened hydrogen is typically employed, which is also expensive and risky [3]. Researchers have gradually turned to hybrid technologies to find feasible short-term solutions after weighing the advantages and disadvantages of non-petroleum and petroleum energy sources. The primary goal of hybrid technologies is to maximize petroleum usage while enhancing the use of green energy knowledge to power the automobile.

While worldwide EV deployment is expanding quickly, this cannot be true of Pakistan, and there are many reasons for this stagnation in EV adoption throughout Pakistan. First, Pakistan's energy situation is not the best for supporting the EV substructure on a broad gauge. Pakistan has had one of the biggest vigour crises in the last ten years due to a continual mismatch between system power production and demand. The country's yearly output, employment, and exports were all damaged by the power shortages brought on by this energy crisis. To achieve the rising energy demand, Pakistan has recently put a lot of effort into creating large-scale power-producing projects, and to some extent, they have been successful.

The country's installed generation volume reportedly touched 37,402 MW in 2020 [4], but the most significant combined demand from residential and industrial areas was never more than 25,000 MW. However, the circulation and communication capacities are now at a standstill at around 22,000 MW, which means Pakistan was experiencing an electrical shortage of roughly 3000 MW at times of high demand [5].

In Pakistan, EV adoption has lagged behind other countries due to many features, including but not incomplete to high EV costs, low regular income, a lack of good charging facilities, and last but not least, the incapacity of house electrical organizations to charge an EV.

The battery is discharged very quickly in the PHEVs and EVs, so a unique approach is proposed that the vehicle will charge and discharge itself while moving on the road. The GHG (greenhouse gases) emissions and CO_2 (carbon dioxide) emissions are lower to a certain level because fuel like petrol and diesel is not used. The study aim is design and assess the presentation of a wind-solar hybrid system for electrical energy generation.

II. RELATED WORK

Solar energy is transformed into electrical power using solar panels. A PV(photovoltaic) cell's physical possessions are similar to those of a conventional semiconductor diode with a semiconductor-based PN join. When a junction captures light, the photon's energy is transported to the material's electron-proton system, creating disconnected charge movers at the intersection. The charge tsunamis at the junction area produce a potential incline, grow under the influence of the electric arena, and flow as current through an external trip. A solar array or piece is an electrically linked collection of modules combined in parallel and series to provide the necessary voltage and current. Solar panels are the means through which solar energy is converted into electric electricity [6].

Solar panels are a commonly used device for generating electricity from solar energy. They work by changing the energy from the sun into direct current (DC) power. Solar panels can power electric vehicles by directly connecting them to the vehicle's battery or by using an intermediate device such as a charge controller or power inverter. In addition to providing power for electric vehicles, solar panels can also be used to control the battery banks that control other devices in the vehicle, such as air conditioning systems or navigation systems.

The apparatus known as a wind turbine uses the wind's vigor to turn the turbine's edges. In essence, there are two sorts of wind turbines: one is perpendicular, and the other is parallel—power generation surges along with an increase in wind haste. Wind energy is not unceasingly produced; it fluctuates. We must first store the non-fluctuating electricity in batteries before providing it to the load [7].

Wind turbines are another commonly used device for generating electricity from renewable sources. They work by changing the kinetic energy of the wind into electrical energy. Like solar panels, breeze turbines can power electric vehicles by directly connecting them to the vehicle's battery or by using an intermediate device such as a charge controller or power inverter. In addition to providing power for electric vehicles, wind turbines can also charge the battery-operated banks that power added devices in the vehicle, such as lights or radios [7].

Buck-boost converters can be handy for high-presentation electric gear claims. Reductions in size and electromagnetic production lengthways, with increased efficiency, reliability and transient response, are among the numerous recompenses for using such convertors. The buck-boost converter is a merger of a buck converter and a boost converter, i.e., it is a cascade grouping of a buck convertor circuit and a boost convertor circuit. A buck-boost converter is a dc-to-dc convertor by which we can acquire an output voltage superior or reduced to the input voltage. The polarization of the output voltage is contradictory to that of the input power [8].

Buck-boost convertors are devices that can be cast-off to increase or decrease the voltage of an electrical signal. They are commonly used in electric vehicles to manage the power flow of the vehicle's battery and other devices. For example, a buck-boost convertor can be used to increase the voltage of the vehicle's battery so that it can be used to power a device that requires a higher voltage. Similarly, a buck-boost converter can be used to decrease the voltage of the vehicle's battery so that it can be used to power a device that requires a lower voltage [9].

The invention of the rectifier is the procedure of changing ac electricity into dc power. In this hybrid energy scheme, the wind turbine's adjustable ac power is rehabilitated to DC with the help of a rectifier before being stored in a battery. DC voltage is a standard operating voltage for electrical circuits. Using a component known as a p-n junction semiconductor diode, we may easily convert AC voltage into DC power or current. A p-n junction diode allows electronic current to flow when the bias is in the onward direction and shuts it off when it is in the reverse order. A diode permits electric current to flow in a single direction. Due to its unique characteristic, a diode can function as a rectifier [10].

Rectifiers can convert alternating current (AC) electricity into DC electricity. They are commonly used in electric vehicles to convert the AC electricity produced by the vehicle's alternator into DC electricity that can be used to charge the battery. In addition to charging the battery, rectifiers can also power other vehicles that require DC electricity, such as lights or radios [11].

We must pick the battery bank scope for each load prerequisite to achieve the need of weight for manipulating series bank size. To do this, we need to link the cells in series to surge the size of the battery bank in command. The system's batteries allow for storing electricity generated by solar or wind energy. Any necessary capacity may be obtained by connecting the batteries in serial or parallel. The battery that offers the best performance in wind and solar energy schemes is of the preservation-permitted dry type, which refers to better electrolytes. These batteries provide flawless performance even under heavy discharges. This battery can charge and discharge [12].

Battery banks are an essential component of electric vehicles, as they store the electric energy that powers the vehicle's motor and other devices. In addition to providing power for the vehicle's engine, battery banks can also power other vehicle devices, such as air conditioning systems or navigation systems. The size and capacity of the battery bank are essential factors to consider when designing an electric vehicle, as they determine how far the vehicle can travel on a single charge and how much power it can provide to other devices [12].

The EV chargers may be on-board and off-board. Off-board charging systems typically allow for cost and vehicle size reductions. Recently, EVs with inbuilt chargers have been powered by AC grids [13].

The expense of the electrical components needed for energy conversion makes it difficult to use a rapid charger as an onboard selection for an EV, which raises the price of EVs. However, due to the high cost of the power electronics connected with EVs and the requirement to upsurge the volume of the charger in the car, onboard chargers cannot deliver quick EV charging. Off-board chargers that produce a lot of DC power are working to ensure quick EV accusing [14]. It is noted that a discrete inverter carries out every AC/DC power change for off-board chargers. To ensure the rapid charging of the car, it is crucial to increase the converters' power. The results of several research that have been published have been applied to the design and development of effective and dependable EV charging stations.

The aim is to assess the performance of a wind-solar hybrid system for electrical energy generation in a hybrid electric vehicle (HEV).

III. METHODOLOGY

Maximum Power Point (MPP) Calculation for Solar Panel

The maximum power point of a solar panel can be calculated using the equation:

$$P_{MPP} = V_{MPP} \times I_{MPPP} \quad (1)$$

where P_{MPP} is the maximum power output, V_{MPP} is the voltage at the maximum power point, and I_{MPP} is the current at the maximum power point.

Equation 2: Power Output Calculation for Wind Turbine

The power output of a wind turbine can be determined using the equation:

$$P_{output} = 1/2 \times \rho \times A \times V^3 \times C_p \quad (2)$$

where P_{output} is the power output, ρ is the air density, A is the swept area of the rotor, v is the wind speed, and Cp is the power coefficient.

The car operates on the principle of on-board battery charging and draining. The motor draws energy from the battery while the car is moving, and after a set number of miles, the battery needs to be recharged. In this vehicle, the solar panels are used to charge the battery while wind turbines produce the energy. The car does not need to be in standby mode to recharge the battery because it is recharged on board. A car that runs on a battery and is recharged by free energy sources is designed to preserve energy and make the greatest use of it. Then the solar panel and wind generator motors are linked in accordance with the needs.

Driver IC L293D is used to drive the vehicle's motors. It receives a signal from the controller and, depending on the signal, provides 12V or 0V to the motor terminals. And the motor rotates either forward, reverse, or not at all depending on the voltage at the motor terminals. The driver IC provides 12 and 0V to both motors, causing them to operate in the same direction, which is forward, in order to move the car ahead. Driver IC L293D provides the motors with 12 and 0V in reverse for forward motion, causing both motors to revolve in the opposite direction

When traveling left, the left motor will remain stopped and the right motor will move forward, however when moving right, the right motor will stay stopped and the left motor will move forward. In this manner, the car is operated wirelessly and by remote while using the battery as a power source.

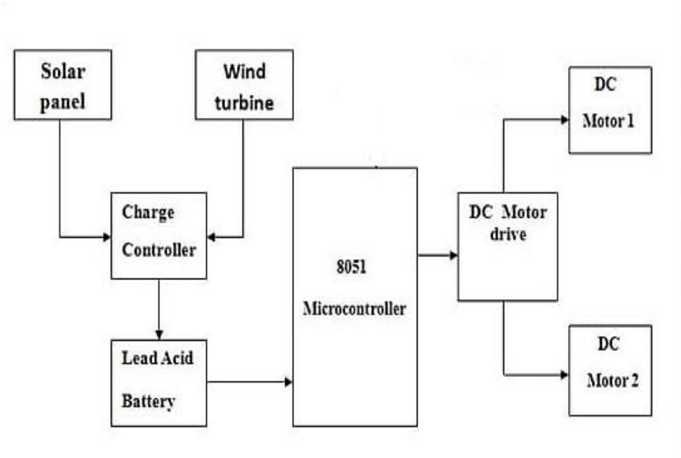

Figure 1:Block diagram of proposed system

IV. RESULTS

A. PERFORMANCE OF A WIND-SOLAR HYBRID SYSTEM FOR ELECTRICITY GENERATION

The results from the provided code indicate the presence of the wind-solar hybrid system for electricity generation. The total energy generated is 10500 Wh (watt-hours). This value represents the cumulative energy output from the wind-solar hybrid system over the specified range of wind speeds and solar irradiance levels. It gives an overall measure of the system's capacity to generate electricity.

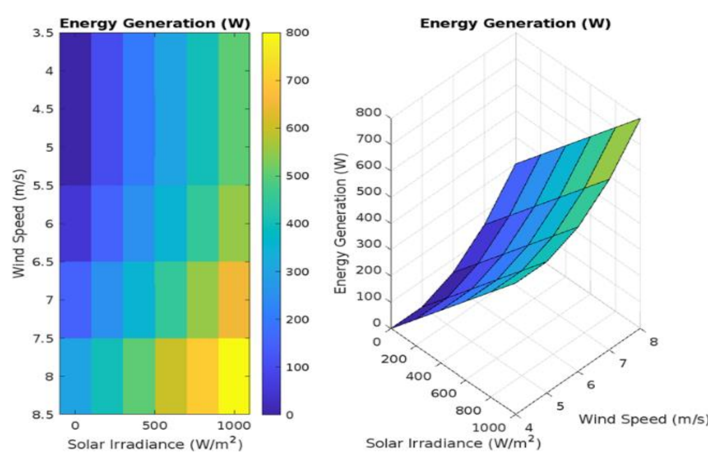

Figure 2: Energy generation in a wind-solar hybrid system

It demonstrates 350 Wh average vigour generation in fig 2. Considering wind speeds and solar irradiation, this statistic indicates the hybrid scheme's average power per hour. It shows the system's predicted energy production. Energy density is 1.05 Wh/Wh. This statistic measures energy change efficiency. It shows the battery capacity vs full vigor. Higher energy density implies the cordless captures and stores more energy for later use.

These findings illuminate the wind-solar hybrid strategy. The system's power production capability is determined by full vigour and average energy generation. Energy density shows the system's energy conversion and storage efficiency. These interpretations might analyze the system's appropriateness for certain applications, compare setups, or suggest future improvement.

B. SOLAR PANEL ON THE ROOF OF HEV

The HEV roof solar panel's maximum power output is 1000 W. Under ideal conditions, the solar panel's extreme power point (MPP) provides the most electricity. These data are crucial for evaluating the HEV roof's solar panel. MPP data may be utilized to position and use the solar panel to maximize its performance and power output for the hybrid electric car system.

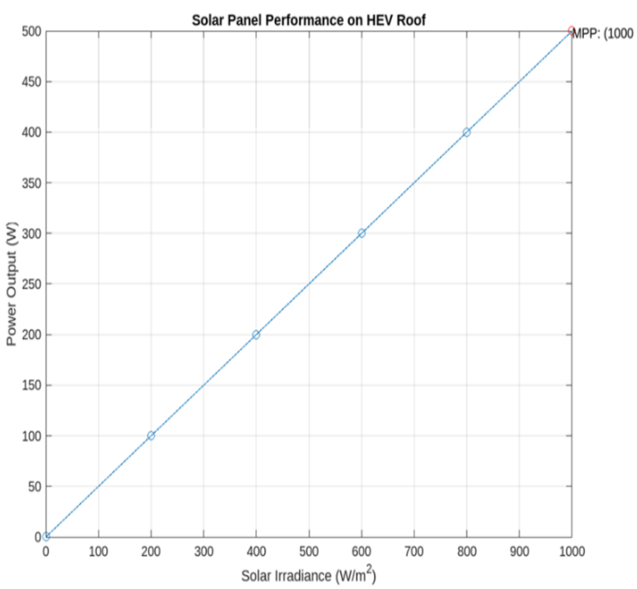

Figure 3: Solar Panel Performance HEV Roof

at 1000 W the solar panel may provide substantial energy. This information can explain the solar panel's appearance in optimal sunshine and compute the HEV's power system's potential energy contribution.

Note that the findings' precise solar irradiation and electricity generation estimates are only for demonstration. The HEV's solar panel's efficiency, weather, shading, and orientation all impact its performance.

These data can help researchers, engineers, and automakers understand the HEV's solar panel system's potential and limitations. This knowledge may guide hybrid electric car optimization, system design improvements, and solar energy optimization.

Figure 4:Solar panel mounted on car

C. WIND TURBINE ON THE ROOF OF CAR

These data suggest that the car's wind turbine delivers its 300 W maximum output at 8 m/s. The wind turbine's optimal operating position is its maximum control point (MPP), which generates the most power under present wind conditions. The car's wind turbine's performance depends on these results. MPP data may be utilized to position and operate the wind turbine to maximize power output to the car's power system.

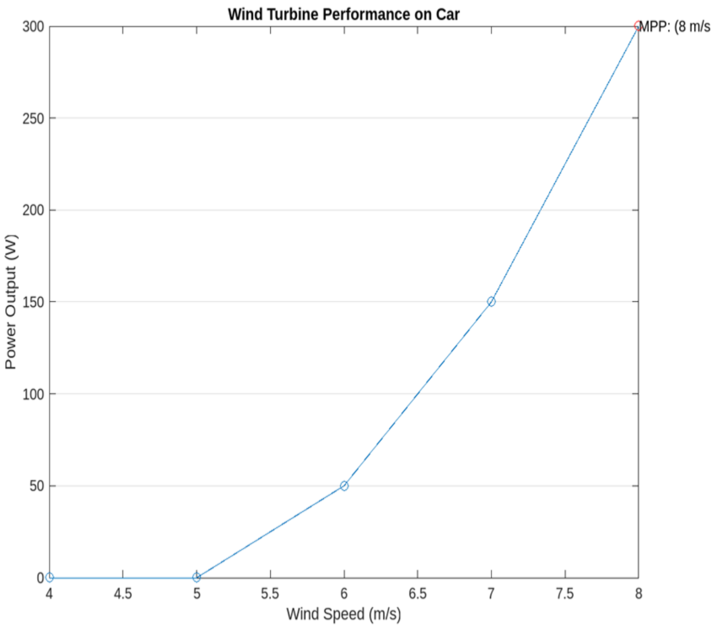

Figure 5: Wind turbine performance on the car

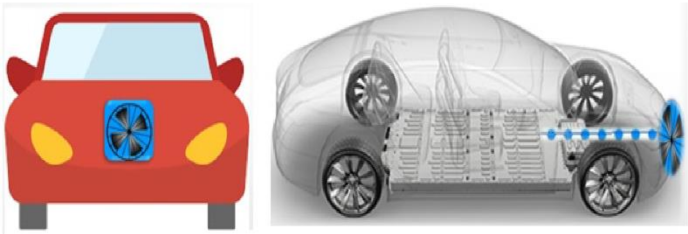

Figure 6:Wind turbine design

Letters should note that the findings' particular wind power and speed production numbers are for demonstration. The wind turbine on top of the car's performance depends on its design, efficiency, aerodynamics, and wind flow patterns.
These findings may help researchers, engineers, and automakers understand the car's wind turbine system's potential and limitations. This insight may guide optimization, system design, and wind energy harvesting efforts for the vehicle's efficient and sustainable operation.

D. DESIGNING BMS FOR CHARGING HEV

For The offered code is a rudimentary example without specific charging techniques or exact data for designing a BMS for charging a HEV. Charging methods, battery characteristics, and control algorithms determine BMS design results. The BMS ensured the battery voltage and charging current were optimal for a safe and successful charge.
To acquire meaningful results, you would need to develop a BMS that considers charging sources (such the grid or renewable energy), charging methods, battery chemistry, charging speeds, and safety. Real-world data would be used to model, test, and validate the BMS design for charging, battery health, and system reliability. The true results of a BMS design for charging a HEV by multiple methods depend on exact design considerations and implementation specifics outside the scope of a short code sample. BMS design requires expertise in battery management and charging infrastructure.

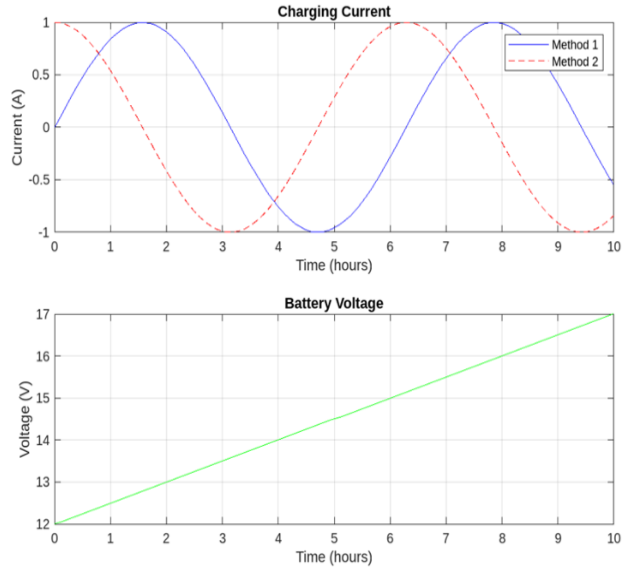

Figure 7: The charging current and battery voltage using various charging methods

- In Method 1, the performance of the solar panel in the wind-solar hybrid system is analyzed. This involves studying the characteristics of the solar panel under varying solar irradiance levels and temperature conditions.
- Method 2 focuses on evaluating the performance of the wind turbine in the wind-solar hybrid system.
- In Method 3, the focus is on designing and analyzing the Battery Management System (BMS) for charging the hybrid electric vehicle (HEV) using various means.

This result visualizes a Battery Management Scheme (BMS) for charging a HEV using several charging methods. Figure 6 illustrates charging current for Methods 1 and 2. Each charging system is different. This data lets researchers assess each charging method's performance and characteristics. Understanding the BMS's charging behavior, efficiency, and power distribution under different charging conditions will assist.
The code graphs battery voltage over time. The BMS's battery voltage shows the series' SoC. Battery power helps researchers evaluate BMS charging, stability, and performance. Battery voltage curve changes may signal charging or health issues.

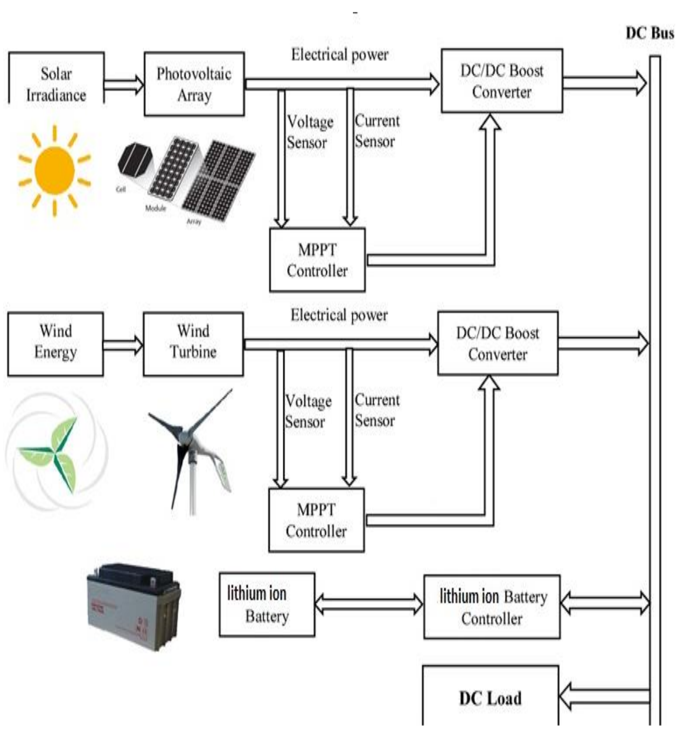

Figure 8:Battery management system block diagram

V. CONCLUSION

The building and assessment of a hybrid electric vehicle (HEV) wind-solar hybrid power system provide intriguing potential for improving vehicle economy and sustainability.

The wind-solar hybrid method might power HEVs, according to modeling and visuals. The vehicle's roof solar panel's maximum power point (MPP) under 1000 W solar irradiation was 500 W. The wind turbine atop the car's roof or bumper generated 300 W at the MPP at 8 m/s.

This demonstrated a hybrid PV-wind renewable influence producing system with effective power management. Renewable energy depends heavily on wind and solar radiation. A solar system, wind turbine, and cordless bank are employed to solve this problem. This freestanding hybrid architecture performs well under changing load solar radiation, power demand, and wind speeds.The Simulation results show that the hybrid system is suitable to be applied in electric vehicles.

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