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Prototype Development of Hybrid PV Wind System for Range Extension in EVs with BMS

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Abstract

In recent years there is an increase in the usage of electric vehicles. Compared to the conventional vehicle which use petrochemical to run, electric vehicles use the energy stored in the batteries to move forward. Due to this electric vehicle produce less pollution. Even though they are less polluting they do have their fair share of problems. The battery used in the EVs are made with rare earth metals not only costly but some of them are toxic. The battery in these EVs need a special care for their proper working. Generally, EVs use lithium-based batteries which has high energy density, less weight, compact, more charge cycles, no memory effect when compared to other types of batteries. In electric vehicles the Battery Management System takes care of the battery. BMS considers parameters like temperature, State of Charge, State of Health, Overvoltage and undervoltage protection, overcurrent and undercurrent protection. BMS also have a balancing system which do maintenance the proper SoC of all the cells in the Battery. This paper presents a new way to charge a EV using unconventional energy sources. Simulation and prototype of battery charging using wind and solar PV system is done. Active and passive balancing is simulated and the results are shown.

Keywords: *Solar Panels, MPPT, Alternator, Arduino UNO, Ni-mH Batteries.*

Introduction

When electricity was originally created in 1752, it quickly gained popularity as a source of energy. It is effective to transfer electrical energy into different forms of energy. The first primitive electric car was created in 1832. Later, a string of inventive breakthroughs increased the popularity and cost-effectiveness of electric vehicles. The battery supplies the energy needed to power an electric vehicle. The electric car's battery is made up of a sizable number of cells that are linked together in series and parallel to produce the necessary voltage and current to power the vehicle. Electric car batteries can vary in their chemical and structural design. Compared to other battery types, lithium ion batteries are more potent to other batteries.

To recharge a car battery a DC voltage source is required. Common power in our households and industrial is AC power. A special type of charger is required to convert the AC to DC to a particular voltage and current values. An electric car generally consist of two batteries, primary and secondary. The primary powers the electric vehicle where as the Secondary takes care of powering the Battery Management system. Secondary battery has

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low power rating compared to the primary battery. When charging a battery first the primary battery need to be charged, the secondary gets charge with the help of primary battery.

The following are disadvantages of charging batteries. Battery cells produce heat when they are being charged, which must be managed to prevent an explosion. When a cell reaches its cycle limit, the complete battery system must be changed because there is a limit to how many times it may be charged and discharged. The energy stored in the battery system, which is less than that of conventional transportation, is what determines how far an electric vehicle can travel. In order to travel over long distances, the battery must be charged as frequently as possible. The battery's charging speed is an additional issue. Typically, charging batteries takes longer than filling up a petrol tank.If we increase more cells in the battery there is also an increase in weight which will badly affect the range of the EVs. So there is need for proper balance between weight and range of the EVs[9].

Lack of fast charging and low energy to weight ratio of the system are two major drawbacks of EVs. However, the battery may be recharged with the help of renewable resources like the sun and wind. The range of an EV can be extended by utilising renewable energy sources that can generate the necessary power for the vehicle to drive. Additionally, this reduces the battery's capacity for charging cycles.

Solar panels can convert solar energy from the sun into electrical energy. There are various types of panels with varying degrees of efficiency. We require low mass panels for EVs. Consequently, the EV's weight doesn't much rise. A converter receives the electricity generated and changes it into the desired value. A Maximum Power Point Tracking (MPPT) system is required to draw most energy possible from the panels. It is possible to safely charge a variety of EVs using a current protection mechanism [2].

An automobile alternator is used by wind systems to produce power. A rectifier and a three-phase circuit make up an automobile alternator. To produce power, a wind turbine is connected to a car alternator. When the minimum speed is attained, the alternator generates the power that is used to supply the battery, drawing the current needed for the exciter from the battery. Only when the vehicle reaches a specific velocity does the wind system create enough power. Other cooling devices are not necessary because the wind cools the alternator[1].

These two sources are now connected in bus connection and are operated when the conditions are meet. The systems will charge the battery when the battery Soc value drops to a certain value.

BMS uses these resources to assist in battery charging. Common BMS components include active cell balancing system, stable charging mechanism, and overvoltage undervoltage protection. There are primarily two types of cell balancing: one is active, and the other is passive. In terms of efficiency, active balancing is preferable to passive balancing.
The paper is organized as follows:

- **2nd Section** describes the System Model
- **3rd Section** describes Prototype Model
- **4th Section** describes the results
- **5th Section** describes the Conclusion

System Model

Block Diagram

Fig. 1 depicts the main flow of the paper's work. The MPPT technique is used to extract the greatest power from the DC power produced by the photovoltaic array. The gathered energy is converted into 12 V DC power and applied to the battery's recharge process. While the vehicle is travelling at higher speeds, the wind power system generates energy.

This power can be gathered using MPPT and transformed into DC power with rectifier circuits. These systems are modelled utilizing MATLAB software.

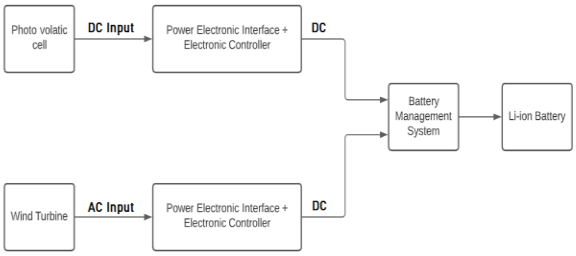

Figure 1: Block Diagram of Hybrid PV Wind system for EVs with Battery Management System

Car Specifications

Tesla MODEL 3 characteristics are used as a guide in this study. The following specifications are provided:

Table 1: Tesla Model3 specifications

Description	**Total**
Vehicle capacity weight	433kg
occupant weight(5x68kg)	340kg
Available Cargo	93kg (433kg – 340kg)

The overall weight of the Tesla Model 3 is displayed in Table 1 above. Model 3 has a 433Kg vehicle capacity that can be used for passengers or luggage. The remaining weight can be used for cargo or to install another energy source if the occupant weight is subtracted from the total capacity.

Prototype Model

Prototype Model of PV Array

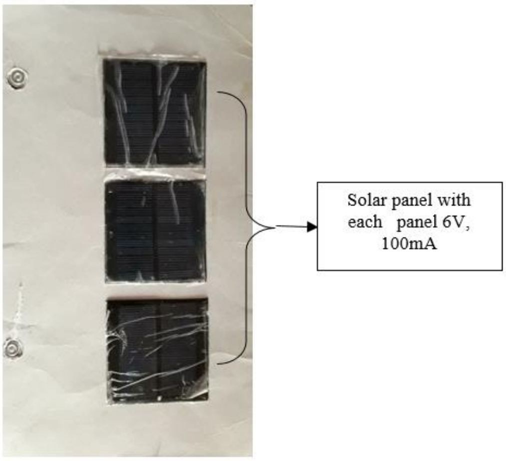

Figure 2: Solar Panels

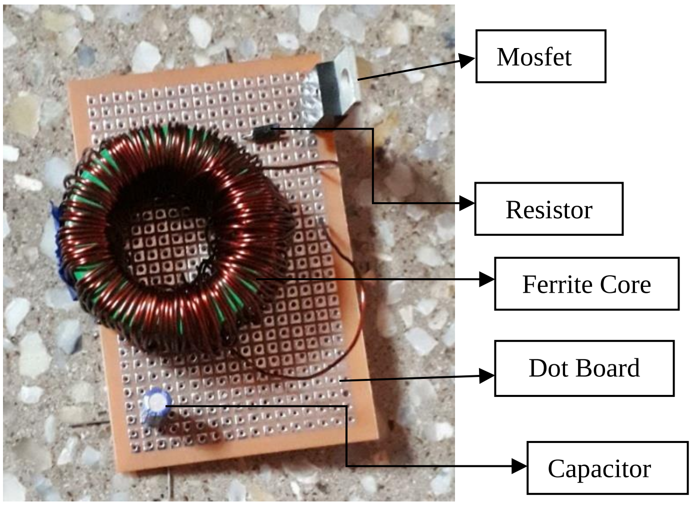

Figure 3: Prototype model of Buck Converter

The prototype device is depicted in Fig. 2 and is made up of three solar panels, each rated at 6V, 100mA. They are connected in series to produce an output of 18V at 100mA. Sensors that monitor voltage and current are used to measure the voltage and current. These inputs are given to the microcontroller (Arduino UNO), which tracks the Maximum power point using the MPPT algorithm. The microcontroller generates a PWM signal based on the inputs, which is then delivered to the Buck converter in Fig. 3. In order to extract the most power possible from the solar PV system, the Buck converter switches, lowering the output voltage to 6V.

Prototype Model of Wind Turbine

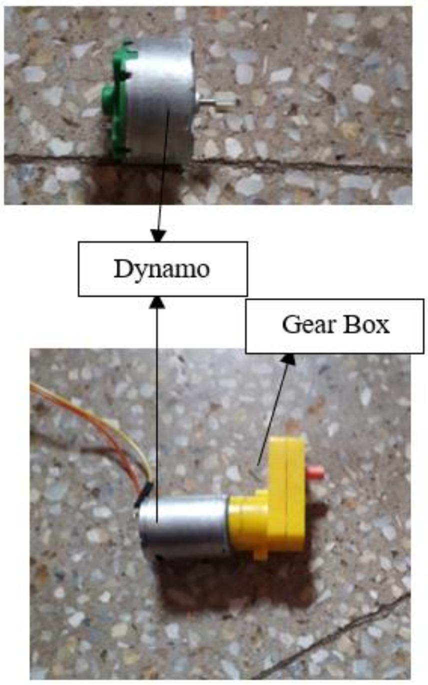

Figure 4: Dynamo with Gear box

When the wind blows, a dynamo in Fig. 4 produces DC voltage. A voltage sensor is used to measure the voltage, which the microcontroller then interprets. The batteries are charged using the system's energy output.

Prototype Model of Battery Management System

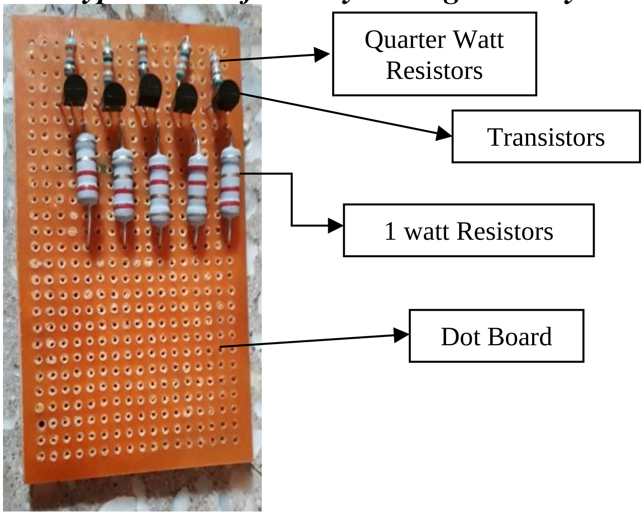

Figure 5: Prototype model of Passive Balancing

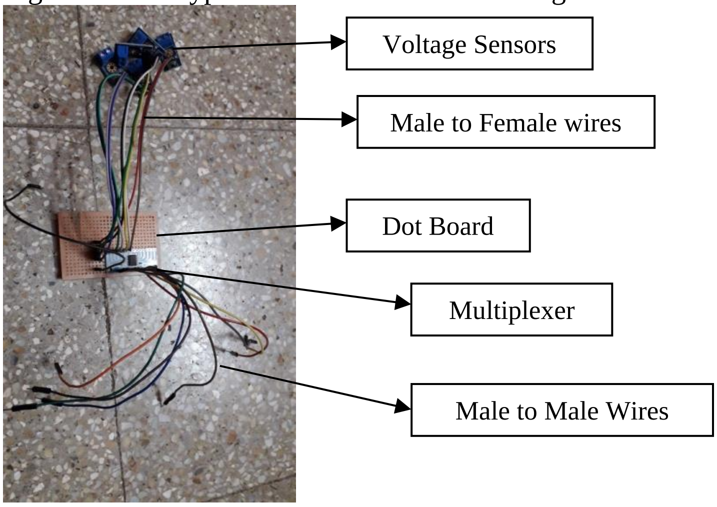

Figure 6: Prototype model of 16-bit Analog Multiplexer

All batteries are kept in top condition using a battery management system. State of charge (SOC), passive balancing, and voltage protection are all used in this prototype. SOC displays the battery's remaining capacity. Through voltage protection, the battery is protected from overvoltage and undervoltage. Passive balancing is used to lower each battery's SOC and maintain them all at the same level when the SOC of the batteries varies. Here, a multiplexer is used to sequentially connect each analogue input to the microcontroller (Fig. 6). The Arduino receives data from five different voltage sensors through the multiplexer.

Prototype Model of Hybrid System

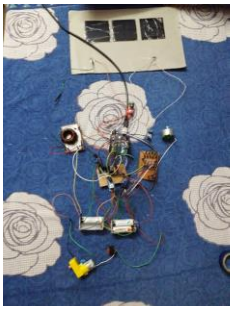

Figure 7: Prototype model of Hybrid System

Fig.7 shows the prototype model of the hybrid system which consists of solar and wind as the renewable energy sources arduino micro controller is used to run the incremental conductance algorithm, thereby extracting maximum power out of the solar. The output of the dynamo is regulated using zener diode. The BMS takes care of the Ni-mH batteries by keeping them within their tolerance values.

Simulation Model

Simulation Model of Passive Balancing

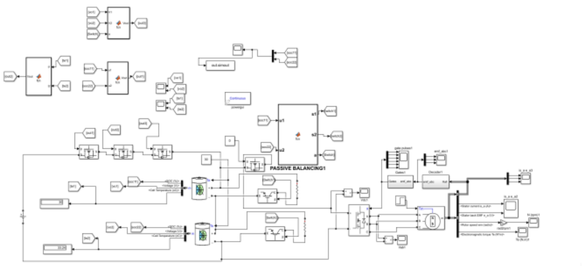

Figure 8: Simulation model of passive cell balancing using BLDC motor

Figure 8 depicts a simulation model for balancing passive cells using a BLDC motor. In this case, two Li-ion batteries power the BLDC motor. In passive balancing, each cell in the stack seems to have the same capacity as the weakest cell. During the charging cycle, a small amount of energy is extracted from high SoC cells using a relatively low current to ensure that all cells charge to their maximum SoC.

Simulation Model of Active Balancing

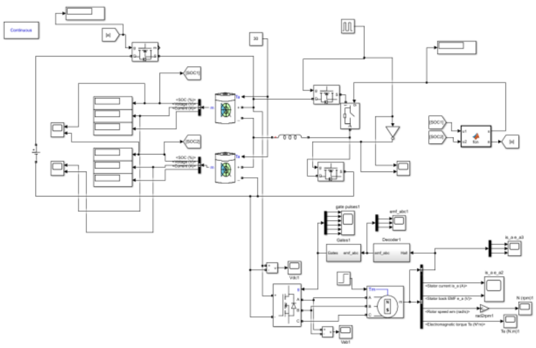

Figure 9: Simulation model of active cell balancing using BLDC motor

Fig.9 depicts a simulation model for active cell balancing using a BLDC motor. In this case, two batteries are also used to power the BLDC motor. Active cell balancing, a more advanced method of balancing, increases the total usable charge in the battery stack to prolong system run time by spreading charge between battery cells during charge and discharge cycles.

Result Analysis

Solar PV Array, Wind System and Hybrid System Prototype Results

Figure 10: Output Voltages of Solar Panels – 1,2,3 at 5:00 PM

From the Fig.10, the multimeter reading shows Vo_1=3.9312V, Vo_2=4.3965V, Vo_3=4.4402V respectively from 3 different solar panels.

Table. 2: Solar Panel Outputs at different timings

S.no	Timings	Voltage in Panel-1	Voltage in Panel-2	Voltage in Panel-3	Total
1	9.00 AM	5.5	5.4	5.4	16.3
2	10.00 AM	5.5	5.6	5.6	16.7
3	11.00 AM	5.2	5.2	5.3	15.7
4	12.00 AM	5.5	5.6	5.6	16.7
5	1.00 PM	5.6	5.4	5.4	16.4
6	2.00 PM	5.6V	5.2V	5.64V	16.44V
7	3.00 PM	4.5V	4.2V	5.2V	13.9V
8	4.00 PM	6.4V	6.3V	6.1V	18.8V
9	5.00 PM	3.9V	4.4V	4.44V	12.74V

From the above Table 2, the individual solar output values are taken at a particular time and tabulated the values. At 2pm the total output voltage is 16.44V.

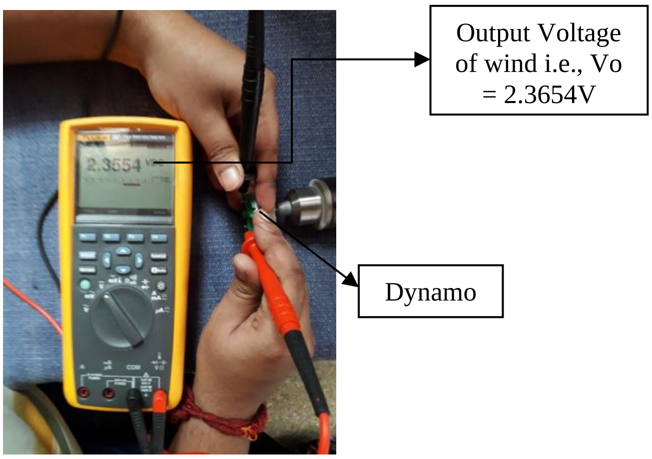

Figure 11: Output Voltage of Wind System

From Fig.11, the output voltage of the dynamo is 2.63V running at a particular speed. This solar and wind output voltage is connected to battery for charging it.

Figure 12: Discharging of batteries at a time gap of 1 hour

Fig.12, illustrates the results of a simulation of passive cell balancing for two cells, where one cell's SoC is assumed to be 70% and the second cell's SoC to be 50%. The higher SoC cell is discharged to the value of the lower SoC cell. After balancing the cells, both cells eventually achieve the SoC at 50%.

Passive Cell Balancing, Active Cell Balancing Simulation Results

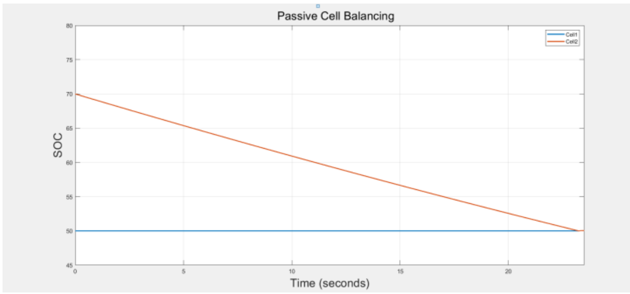

Figure 13: Simulation result of passive balancing using BLDC motor

The results of a simulation of passive cell balancing for two cells, with one cell's SoC assumed to be 70% and the other cell's assumed to be 50%, are shown in Fig. 13. The value of the cell with the lower SoC receives a discharge from the higher SoC cell. The SoC for both cells ultimately reaches 50% after balancing the cells.

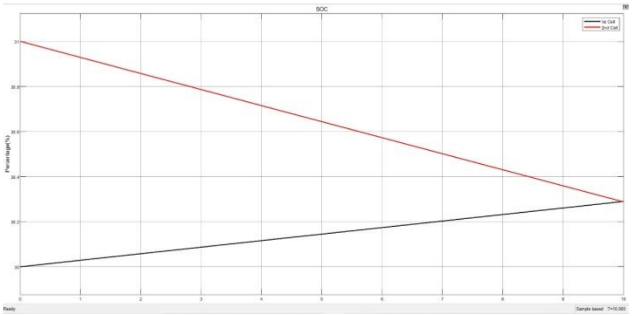

Figure 14: Simulation result of active cell balancing using BLDC motor

The outcomes of a simulation of active cell balancing for two cells, where one cell's charge is 30% and the other is 31%, are shown in Fig. 14. The higher-charged cell sends energy to the lower-charged cell in order to bring the two cells into equilibrium. After balancing, as seen in Fig. 14 above, both cell charges are converging at the same location.

Comparative Analysis

Table. 3: Comparison

S.no	Active	Passive
1.	Use active devices like switches	Mainly use passive elements like resistors
2.	Energy is transferred to other cells.	Energy is dissipated in resistors.
3.	Complex	Simple
4.	Less heat generation.	More heat generation.

The comparison of active and passive cell balancing is provided in Table 3.

Conclusion

According to this study, solar and wind energy may be used to power electric automobiles. Solar panels with higher efficiencies could generate more electricity. By charging the EVs with other sources, the car's range can be extended and the number of times it needs to be recharged at a charging station reduced. Because batteries are the most expensive component of electric vehicles, it is possible to generate more power from renewable energy sources if the right precautions are taken. BMS monitors each and every cell. Consequently, this system helps to both safeguard and enhance battery efficiency. As opposed to passive balancing, active balancing sends the energy to a cell with low energy, passive balancing, which dissipates surplus energy in the cell via a resistor.

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