Design & Development of Multiple Alternative Energy Car

Drashtant Khandwala, Parthiv Pandya, Bhargav Ladani, Paumil Khatri, Jignesh Patel

Abstract*: *As a result of excessive air pollution caused from the vehicles the automobile industry is shifting its focus from traditional I.C. engine powered vehicle to electrically propelled vehicles. Although this shift is eco friendly when compared, it has its demerits too. Among these the range of an EV is preeminent. This research paper counters this downside of the EV by focusing on the depletion rate of the batteries, used to power the vehicle. Renewable energies like- Solar Energy & Wind Energy are used as the chief form of alternate energies by which power can be generated and connected with EV in order to help sustain and reduce the depletion rate of batteries. Along with these energies we can also use different technologies such as-Regenerative Braking, piezoelectric suspension system, etc. for reducing the depletion rate. These technologies can also be directly used for powering the secondary units such as headlights, horn, indicators, etc. This research paper revolves around this core idea and also to backhand this research we have fabricated a basic EV along with Solar & Wind module, namely the MAE-Car (Multiple Alternative Energy Car).

Keywords* : *Depletion rate, Electric vehicle, Horizontal axis wind turbine, Monocrystalline solar panels, Solar energy, Vertical Axis Wind Turbine, Wind energy,

I. INTRODUCTION

Automotive emissions have been aggravating the air index & tilling the earth's atmosphere with pollutants at a much higher rate. Apart from the harmful emissions of the conventional automobiles, studies also suggest that petroleum deposits are depleting at a much higher & faster rate[14]. Hence, it is necessary for the automobile industry to find an alternative technology for powering the vehicle & sustain the established automobile industry. Current transition that is observed in the automobile industry namely to the automotive emissions has resulted in the rise of the electric vehicles. Although having a more green & eco-friendly approach, the EV's have failed to gain popularity owing to their demerits. One of the prime barrier when it comes to an EV is the range & the recharging time of the batteries[11]. In this research paper, we have solely focused & gathered data regarding different types of energies that can be harnessed into an automobile & filtered out possible abiding energies that can readily generate power & lessen the discharge from the battery [8]. It is to be noted that certain concepts & energies are not included in the making of MAE-Car but it can be added at a later stage too. Along with this, different values of required torque & power outputs that are needed at a primary level for the propulsion of vehicle are calculated.

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II. METHODOLOGY

By the means of the alternative renewable energies available the objective is to:

"To develop an automobile vehicle running primarily on electrical energy as a form of working model which can be used for the experimentation to forfeit the main disadvantage of any EV, and provide a mechanical advantage by reducing the discharge rate of batteries used for propulsion of the vehicle when in motion by the means of – Solar & Wind Energy as primary source while research other form of energies & technologies that can be optimized for cultivating into useful work."

2.1. Block Diagram

Following is the block diagram based on the proposed method:

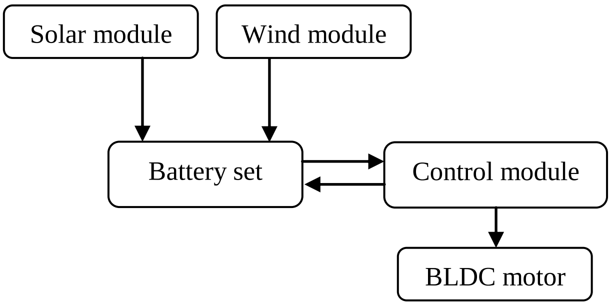


Figure 1.1. Block diagram for MAE-Car

2.2. Steps

1. Basic calculations of Power requirement for the MAE-Car.
2. Battery Specifications as per requirement.
3. Wind Energy module calculations.
4. Solar Energy module power output.
5. Comparison between theoretical & experimental outputs.

III. CALCULATIONS

We needed to decide how much power would be required of our electric motor to achieve our objectives. But before reaching to a conclusion first we need to assume certain parameters.

3.1. Assumptions

Following are the assumptions that will help us for simplifying the design and calculations [1], [2], [4]:

- Mass of vehicle(chassis): **120kg**
- Average mass of driver: **80kg**
- Mass of battery: 5kg×4= **20kg**
- Tentative mass of solar panel: **12-15kg**
- Tentative mass of wind turbine: **3.5-5kg**
- Miscellaneous masses: **2-5kg**
- Standard wheel diameter: **0.254m**
- Standard wheel radius: **0.127m**

3.2. Power requirement calculation [11]

1. Define velocity (v) and acceleration time (t) for the vehicle.
2. Find the acceleration required of the vehicle for different velocities.
3. Find out the Peak Torque (T).

T=Force × Distance × Slope (1)

T= Mass × Acceleration × Distance × Slope

$T= (M_v+ M_b + M_s+ M_t) \times a \times R \times Slope$

Where, M_v= mass of vehicle

M_b= mass of battery

M_s= mass of solar panel

M_t = mass of wind turbine

R = Radius of wheel = 0.127m

a = Acceleration required

Here, considering peak torque (T) as,

Where, k=Constant at slope equal to 1

$= (M_v+ M_b + M_s+ M_t) \times R$

$= (120+20+15+15) \times 0.127$

= 21.59 kg-m

T= k × a = 21.59×a N-m

4. Find Angular velocity (ω) = v/R; (2)
5. Find Power (P) = T × ω; (3)

For the ease of calculation we have considered the values of velocity of the vehicle in a sequence with varying speed such as:

5km/hr; 15km/hr; 20km/h; 25km/hr; 30km/hr;

For different acceleration time as [11]:

5seconds; 10seconds; 15seconds;
20seconds; 25seconds; 30seconds;

Calculating different values for peak torque requirement at different values of accelerations. The following table shows the different values for **Peak Torque (T)**:

Table 3.1. Peak Torque table

Torque	*5s*	*10s*	*15s*	*20s*	*25s*
T_5	6	3	2	1.5	1.2
T_{15}	17.98	8.99	5.99	4.99	3.59
T_{20}	23.96	11.98	7.98	5.99	4.79
T_{25}	29.96	14.98	9.97	7.49	5.99
T_{30}	35.83	17.98	11.98	8.98	7.189

The above table gives a quite profound understanding and gives the value of Peak Torque that will be required to achieve different velocities when slope component is considered equal to one, at different acceleration time.

It can be observed that a diagonal patch highlights the value of peak torque (T_p) for different values of velocity at a particular acceleration time[3]. This is a general parameter assumed (highlighted) in the making of MAE-Car.

The values of angular velocities at different velocities are as follow:

Table 3.2. Angular velocity & Frequency

Linear velocity (v) (m/s)	*Angular velocity (ω) (m/s²)*	*Frequency (RPM)*
1.39	10.95	105
4.167	32.8	314
5.55	43.7	418
6.94	54.6	522
8.33	65.59	627

The power requirement at different velocities with respect to highlighted values of torque is as follow:

Table 3.3. Power required

Linear Velocity (km/hr)	*Angular Velocity (m/s²)*	*Acceleration Time (s)*	*Torque required (N-m)*	*Power required (Watt)*
5	10.95	5	6	66
15	32.8	10	8.99	294.87
20	43.7	15	7.98	348.72
25	54.6	20	7.49	408.95
30	65.59	25	7.19	471.52

The above table specifically gives the required amount of power that will be required to propel the MAE-Car at various presumed velocities under ideal conditions. It can be easily observed that the power requirement will increase when considering various resistances such as air resistance, rolling resistance, etc.[6]

Although the required velocity can easily be achieved by a motor of 500watts, a BLDC motor of 1800watts is used owing to the discussed resistances.

3.3. Battery Specification

For powering the MAE-Car we have utilized 4 VRLA (Valve Regulated Lead Acid) batteries connected in series to form a system of 48V 28Ah. The recharging time of the system, when using charger of 48V 2.5A will be as follows: Recharging Time of battery set when it is fully depleted [11]:

= 28/2.5 = 11.2 hrs

3.4. Wind energy calculation

It is to be noted that for the ease of calculations, we are considering the air medium as stationary [5]. This means that the velocity of the MAE-Car will solely be responsible for the movement of the turbine and also the velocity at which the wind will strike the blade will be equal to the velocity of the MAE-Car. The following are the parameters and generalized formula that will be useful for calculating the amount of power generated at different velocities of the air[5]:

Kinetic Energy (K.E.) = $1/2\ (m \times v^2)$ (4)

Mass flow Rate= (ρ x v x A) (5)

Where,

ρ: Density of the fluid (air) =1.225 kg/m^3

v: Velocity of the fluid;

A: Area or cross section;

$$\text{Kinetic Energy (K.E.)} = \tfrac{1}{2}(\rho \times A \times v^3) \quad (6)$$

Wind Power (P_w) = K.E.

$$P_w = \tfrac{1}{2}(\rho \times A \times v^3)$$

where,

A= D x H

D=Diameter of blade= 0.153m

H=Height of blade= 0.23m

A= 0.03519 m^2

$$P_w = \tfrac{1}{2}(1.225 \times 0.03519) \times v^3$$
$$=0.0431 \times v^3 \cong 0.043 \times v^3$$

From the above equation, we can easily find out the wind power that will be generated at different velocities of the MAE-Car. Also, it can be found out that at what speed the wind turbine will start to rotate in a manner to give useful positive work by which the system can be boosted with the mechanical advantage[9].

Now calculating the wind power that will be generated at different setup speeds of the vehicle we get the following values:

Table 3.4. Power generated by wind energy

Speed (km/h)	*Speed (m/s)*	*Wind Power*	*Actual wind power(85 % efficiency)*
5	1.39	0.0983	0.0785
10	2.78	0.7871	0.67
15	4.167	2.650	2.25
20	5.55	6.2628	5.324
25	6.95	12.3	10.46
30	8.33	21.18	18
35	9.72	33.64	28.59
40	11.11	50.24	42.7
45	12.5	84	71.4
50	13.89	115.23	97.95
55	15.28	153.4	130.4
60	16.67	199.19	169.31

It is quite understandable that with the increase in velocity of MAE-Car the power generated at the wind turbine also increases as they are dependent on each other. Here, approximately 12 watts are generated at a speed of 30km/hr. We have incorporated two such turbines and fused together in series to get optimum output of it. Hence total of 25 watts will be generated on an approximation basis can be noted.

3.5. Specification for Solar Panel

For obtaining the solar energy and converting it into electrical energy photovoltaic cells are used. It is to be noted that the power output of the panel is completely dependent on the technology and efficiency of the cells used. Hence, different power outputs can be achieved by varying the size, efficiency and arrangement of the solar panel [12].

For powering the MAE-Car we have utilized 4 solar panel of monocrystalline panel each 40 watts connected in series to form a system of 160 watts [10].

Power Output – 160 Watt
Open Circuit Voltage – 22.5 V
Short Circuit Current – 9.05 A
Dimensions - 660×435×35 Square mm

IV. MODELING

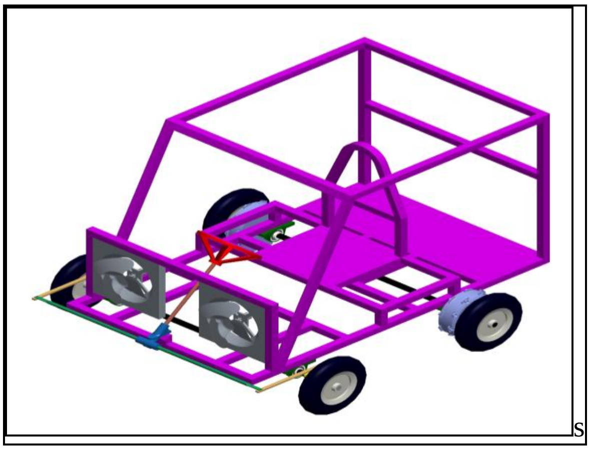


Figure 4.1. Main Assembly of MAE-Car

Figure 4.2. Actual MAE-Car

4.1. Improvised Wind Turbine design

After conducting trails it was observed that, particularly for HAWT (Horizontal Axis Wind Turbine) the starting speed required was quite high and also it is suitable for high altitudes [13].

So to overcome this problem in our MAE-Car we had to reconsider the turbine's type and redesign it.

We have considered VAWT (Vertical Axis Wind Turbine) as discussed earlier cause of the following reasons [7]:

1. Low starting speed
2. Stability at high speed
3. Power generation at low altitudes
4. Suitable for low power generation

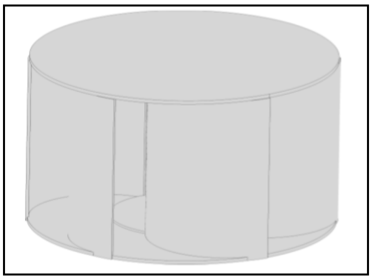


Figure 4.3. Vertical Axis Wind Turbine

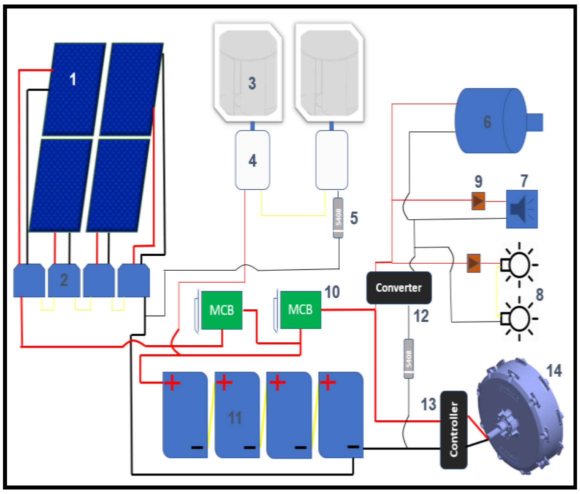


Figure 4.4. Circuit Diagram

Table 4.1. Circuit Block Diagram Description

Sr No.	Name	Sr No.	Name
1	Solar Panel	8	LED Light
2	Solar Controller	9	Switch ON/OFF
3	Wind Turbine	10	MCB Switch
4	Epson motor	11	Battery
5	Diode	12	Converter
6	Dynamo	13	Battery controller
7	Horn	14	BLDC Motor

V. RESULTS

Considering each energy

1. Solar Power Output: 40 x 4 = 160 watt
2. Wind Power output: 30watt at 40km/hr (by both wind turbine)
3. Dynamo Power Output: 9V x 2A = 18 watt (Considering dynamo at RH rear)
4. Total power generated by the system: 208 watt
5. Total Power used by Motor: 500 watt

Total mechanical advantage [11]:
= **(**Total power generated by the system/ Total Power used by Motor**)** x 100;
= **(**208/500**)** x 100;
= 41.6%;

Hence, even after considering various barriers and using it at optimal point by the help of our technology we can achieve an advantage of approximately 41.6% in the current electric vehicle.

Hence, the MAE- Car will be having an extended range of 1.4 times that of the conventional EV. Also, the battery depletion rate will reduce which will result in the prolonged battery life cycle[8].

5.2 Experimental data

Once the making of different components was done they were assembled together and it collectively shaped the EV into our project MAE-Car.
After this practical data was needed to collect and verify with respect to the theoretical one.
The flow for experimentation is as follows[11]:

1. Trials for top speed and acceleration time
2. Trials for range of the EV
3. Trials for range of the MAE-Car

5.2.1. Speed Analysis of MAE-Car

In this analysis, time in seconds was obtained for achieving desired speed in kmph experimentally. This was necessary as to compare this values with the acceleration time assumed above. The values of time in seconds with respect to speed is tabulated as follow:

Table 5.1. Speed analysis of MAE-Car

Sr No.	*0-5 kmph*	*0-10 kmph*	*0-15 kmph*	*0-30 kmph*	*0-40 kmph*
1.	2	3.5	5	11	18
2.	1.5	3	5	10	14
3.	2	4	6	12	19
4.	2	4.5	7	12	21
5.	1.5	4	7	14	23

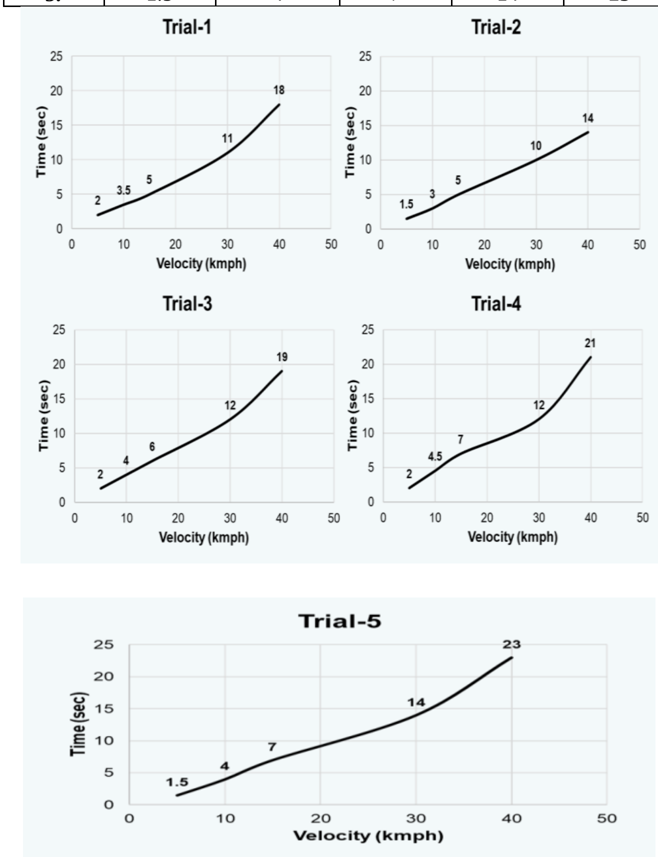


Figure 5.1. Graphs of speed analysis

5.2.2. Depletion rate of EV

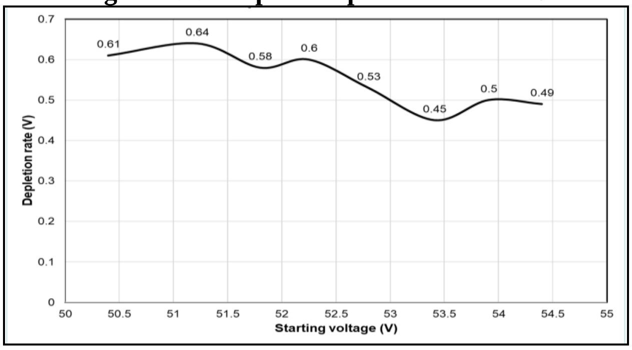
Following are the observations regarding the depletion rate of EV:

Table 5.2. Depletion rate of EV

Sr no.	*Distance Travelled*	*Voltage before starting*	*Voltage after starting*	*Total Depletion*
1.	0.6	54.3	53.91	0.39
2.	0.6	53.91	53.53	0.38
3.	0.6	53.33	53.09	0.44
4.	0.6	53.09	52.66	0.43
5.	0.6	52.66	51.18	0.48
6.	0.6	52.18	51.6	0.58
7.	0.6	51.6	51.09	0.51
8.	0.6	51.09	50.47	0.62

The Graph for depletion rate of EV is as follow:

Figure 5.2. Graph of depletion rate of EV



5.3 Observation

5.3.1 For EV

Average depletion rate = 0.4788 V for 0.6km

Total range of EV = [(48 x 0.6)/0.4788]= **60.15 km;**

It should be duly noted that the depletion rate when the battery is fully charged is less than the depletion rate once it is not at 100%. Hence, the above value for 60.15km is purely ideal considering battery runs in the same manner with the same depletion rate. When actual trials were done, it was found that the range of the EV is **42 to 45km** on average.

5.3.2 For MAE-Car

Following are the observation table and readings for the MAE-Car

Table 5.3. Depletion of MAE-Car

Sr No.	*Distance Travelled*	*Voltage before starting*	*Voltage after travelling*	*Total Depletion*
1.	0.6	54.7	54.35	0.35
2.	0.6	54.35	54.04	0.31
3.	0.6	54.04	53.75	0.29
4.	0.6	53.75	53.43	0.32
5.	0.6	53.43	53.08	0.35
6.	0.6	53.08	52.69	0.39
7.	0.6	52.69	52.31	0.38
8.	0.6	52.31	51.9	0.41

Average depletion rate = 0.35V for 0.6km

Total range = [(48 x 0.6)/0.35] = **82.29 km**

It can be inferred that this value is suited for the MAE-Car when the battery is in full charge state.

Comparing this ideal value of MAE-Car with the ideal value of the EV we get,

$$\text{Total increase in range} = \frac{\text{Difference between the two values}}{\text{Actual value which is to be compared}}$$

Therefore, increase in range = (82.29-60.15)/60.15

= 0.368 = **36.8 %**

VI. CONCLUSION

The feasibility of the proposed methodology was the primary concern in the research and development of the MAE-Car. A basic standard EV was required to compare the proposed methodology. Owing to this requirement a basic car propelling with the help of electric energy was developed. The values of power requirement with respect to the speed assumed for this basic car are tabulated in the table 3.3. After this various power outputs from the modules suggested in the methodology were calculated. For the final verdict, the theoretical & experimental range in both the cases i.e. basic EV & MAE-Car, was calculated based on the depletion rate. On comparison, an increase in the range upto 36.8% was noted. This value is less compared to the theoretical value discussed above, owing to the various losses such as mechanical losses, heat losses, Degradation of component's efficiency, etc. From the above values and the observations it can be profoundly said that for sure by introducing the discussed technology we can increase the range of any EV.
It should be noted that our project is merely a starting point in the entire journey for the optimisation of the range of EV.

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He has guided more than 12 projects at UG level and 8 students at PG level. He has also published 8 international research papers in various international journals. He has also been awarded by Indus University as a form of appreciation in "Enhancing the Quality of Academic Output".