Design and Implementation of Solar Panel on E- Rickshaw

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Abstract

In today's world, global warming is increasing at a tremendous level. There are several reasons like exhaust gases from vehicles, smoke from industries, deforestation and many more. Presently, most of the vehicles are running on internal combustion engines (ICEs) and producing exhaust gases. These exhaust gases are increasing the environmental pollution level and creating health problems. The best way to reduce the pollution from the automobile sector is to find an alternate way to fossil fuels. An alternate way can be the use of renewable energy in the automobile sector. These days electric vehicles (EVs) are in more demand and various research is also going on in this direction. Electric vehicles are the best substitute for fossil fuel-based vehicles. In recent days, EVs are very popular, and the main components of EVs are battery, DC motor, charge controllers, etc. Among these components, the battery is the most essential component of the EV because the battery helps to run the vehicle for a longer range. So, the use of the battery is an important parameter in EVs. With the help of solar energy in the EVs, the range of vehicles can be increased.

Keywords: Solar energy, Electric vehicles, Automobile: E- Rickshaw, Battery, DC motor

1. INTRODUCTION

Energy is one of the most important needs for the survival of human beings on earth and eventually on every planet of this universe. Humans are dependent on this type of energy to fulfil their all needs.[1] Humans are using fossil fuels for the smooth running of our vehicles for hundreds of years. Largely populated countries like India, China, U.S. are using a lot of fossil fuels for their transportation sector. But the main disadvantage of these fossil fuels is that they are not environment friendly and these are exhaustible. So, for the removal of such issues, we need to think of an alternate way, and the use of renewable energy is the option to tackle these problems.[2]

The solar electric vehicle is primarily powered by solar energy directly. Photovoltaic panels are used to collect solar energy, and this solar energy can easily be converted into electrical energy with the help of a photovoltaic cell. The PV cell collects a portion of the solar energy and stores it into the battery of the vehicle with help of the charge controller.[3] After storing the electrical energy in batteries, this energy is supplied to the DC motor to drive the vehicle continuously. The motor controller helps to control the amount of electrical energy to the motor corresponding to the throttle. The DC motor uses that controlled electrical energy to drive the vehicle.

1.1 Why we need Solar Electric Vehicles

When the combustion of fossil fuels takes place in automobiles, the engine produces a large amount of pollutants in their exhaust. These pollutants help to increase the rate of global warming and impact the environment. This is one of the biggest problems faced by the urban people throughout the world.

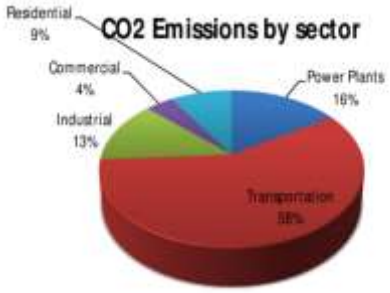

Figure 1. Different Sectors of CO2 Emissions [4]

The number of vehicles is increasing continuously with the increasing population and due to this, air pollution is also increasing. Figure 1 shows that the transportation sector is the main culprit for producing the CO_2 production. The earth has a limited amount of fossil fuels, and according to the consumption rate, fossil fuels are going to be eliminated in the near future. And these fossil fuels produce harmful gases during their combustion which impact the environment's health. Various actions and restrictions are taken to control the air pollution level but this is not sufficient. So, we have to shift towards the renewable energy side so that we can control the pollution level and can-do sustainable development.[5]

1.2 Working

A solar-powered electric vehicle is an electric vehicle that is powered by direct or indirect solar energy. The word "Solar Vehicle" directly shows that solar energy is used to perform all the functions of a vehicle. The solar-powered electric vehicle gets the energy from the solar energy it needs to move. The surface created by solar panels absorbs most of the light that falls on it with help of the photovoltaic effect.

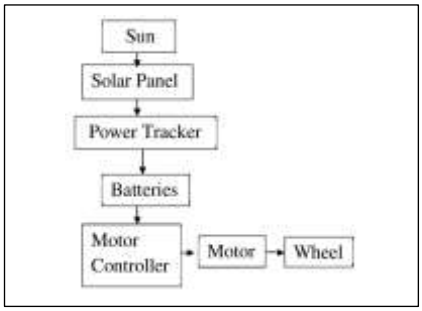

Figure 2. Energy flow diagram for solar-powered electric vehicle

The figure 2 gives an overview of the working of solar-powered electric vehicles. Sun is the main source of energy for the vehicle. Solar radiations are obtained on earth from the sun. Solar radiations are absorbed by the solar panel, and these solar radiations are converted into electricity by the photovoltaic effect in the solar panel. The electricity produced is being transferred to the batteries by the help of a power tracker which helps to charge the battery for future use. And then current flows from the battery to the motor via the motor controller for the movement of a vehicle. The motor controller helps to adjust the speed of a motor by its internal mechanism. The rest of the excess electricity is stored in the battery for future use during cloudy weather.[3] Solar panel helps to provide continuous current by photovoltaic effect to battery so that vehicle can cover a longer distance than its actual battery range.

2. CALCULATION

During the movement of a vehicle, there are certain resistant forces that act on a vehicle. These forces are rolling friction force, drag force, uphill resistance, and inertia force. With the increase in velocity, drag force increases rapidly.

The rolling resistance, aerodynamic drag, inertia force, and climbing force can be calculated using the below equations [2] –

$$Rolling\ force(Frolling) = mg \times \mu_{rolling} \times \cos\theta \quad (1)$$

$$Climbing\ resistance\ force(Fclimb) = mg \times \mathrm{Sin}\,\theta \quad (2)$$

$$Aerodynamic\ drag\ force(Fdrag) = (^{1}/_{2}) \times \rho \times C_D \times A \times V^2 \quad (3)$$

$$Acceleration\ force(Facc) = mass \times acceleration \quad (4)$$

$$Traction\ force(Ftrac) = Frolling + Fclimb + Fdrag + Facc \quad (5)$$

In these equations, ‘m’ is the Mass of the vehicle with load (Kg),

‘g’ is the Acceleration due to gravity (m/s^2),

‘C_D’ is Drag coefficient,

‘A’ is projected frontal area (m^2),

‘ρ’ is the air density (kg/m^3),

‘V’ represents the velocity of the solar-powered electric vehicle (m/s) and F_{trac} is the total force required to counterbalance the all forces which resist the motion of the vehicle.

The P_{trac} applied to the vehicle to move will be:

2.1 Estimation of DC Motor

The total power required by the vehicle to run on the road can be calculated using the equation number (6):

$$Traction\ power(Ptrac) = Ftrac \times V \quad (6)$$

where V represents the velocity of the solar-powered electric vehicle (m/s) and F_{trac} is the total force required to counterbalance the all forces which resist the motion of the vehicle [6],

where M is the total mass which includes the mass of the vehicle and mass of five passengers and mass of the battery and the mass of the solar panel.

Mass of vehicle = 200 kg

Mass of 1 passenger = 55 kg, (ICMR Report)

Mass of battery = 35 kg

Mass of solar panel = 25 kg

Total mass (M) = 200 + (55 x 5) + 35 + 25 =535 kg

Table 1. Specifications used during calculation

Total mass(M)	535 kg
Air Density(ρ) @ 27°	1.2 Kg/ m^3
Drag Coefficient (C_D)	0.44
Projected area(A)	1.8 m^2
Vehicle velocity (V)	25 km/h
Acceleration due to gravity(g)	9.81 m/s^2

Source: ARAI & Ministry of Road Transport and Highways

Vehicle is moving on a straight road with a velocity of 25km/h on a straight road. Here considering forces are rolling and drag forces only. Considering the data from Table 1 calculation of motor power is calculated as:

$$Rolling\ force(Frolling) = mg \times \mu_{rolling} \times \cos\theta = 535 \times 9.81 \times 0.011 = 57.73N$$

$$Aerodynamic\ drag\ force(Fdrag) = (1/2) \times \rho \times C_D \times A \times V^2$$

$$= (1/2) \times 1.2 \times 0.44 \times 1.8 \times (25 \times 5/18)^2$$

$$= 22.91\text{N}$$

$$Traction\ force(Ftrac) = Frolling + Fdrag$$

$$= 57.73 + 22.91 = 80.64\ N$$

The main aim is to determine the power of motor, so by multiplying the maximum velocity to our total traction force, we will get the total traction power. The power required to drive the vehicle will be calculated by using the equation number (2.6) as:

$$Traction\ power(Ptrac) = Ftrac \times Velocity$$
$$= 80.64 \times 25 \times \left(\frac{5}{18}\right) = 560\ W$$

Now, a DC Motor with a rating of 1000 W is sufficient and this used capacity is higher than the above calculated capacity. We decided to use a DC motor because of its long-life expectancy, low maintenance and operation cost .

2.2 Estimation of the Battery Capacity

Battery is the main component for continuous running of solar powered electric vehicle. Solar- powered electric vehicle can be used by the office staffs and college students. Consider the longest distance which will travel by our vehicle from Teachers colony to Yamuna gate, MNNIT, PRAYAGRAJ, UP, INDIA which is approximately equal to 1.5 km.

With 20 return trips in a day, the total distance will be:

Distance(D) = 20 (2 × 1.5) = 60 km.

The total distance to be travelled by solar- powered EV is 60 km then the total energy required by the DC motor during travel time is given by:

$$E_m = P \times \mathrm{T}$$

where T= (D/V)

$$E_m = 1\ KW \times (60/25)\ \mathrm{h} = 2.4\ \mathrm{kWh} = 2400\ \mathrm{Wh}$$

E_m is the capacity required by motor for smooth running of vehicle while E_b is the battery capacity required after considering the all loses.

Consider the efficiency of motor as 90%, then the maximum energy that should be supplied by the battery to the DC motor is:

$$E_b = \frac{2.4\ Wh}{0.9} = 2.6\ kWh = 2600\ Wh$$

2600 Wh battery capacity is required for the smooth flow of 1000 Watt DC Motor and this battery capacity helps to cover this distance without any problem with all conditions imparted. [6]

To know the battery capacity in Ampere Hour (Ah):

Now, 48-volt batteries are generally used in E – rickshaw vehicles.

Voltage(V) x Ampere Hour (Ah) = Watt Hour (Wh)

48 V x (Required Ah) = 2600 Wh

Required Ah = $\frac{2600}{48}$ = 54.16 Ah

The battery Ah measured here as 54.16 Ah, which will be acquired by considering 48 Volt 20 Ampere-hour in parallel connection of three batteries.

2.3 Estimation of Solar- Panel Size

To provide the continuous supply of current to battery, solar panel is required. The solar panel size can be determined by total energy requirement for battery and losses occur during supply.

Now, assume the efficiency of battery, the efficiency of charging the battery and the efficiency of charge controller as ηb , ηch, and ηcc respectively .

The total energy required from the solar panel is :

$$E_p = \frac{E_b}{\eta b \times \eta ch \times \eta cc}$$

$$= \frac{2.6}{0.9 \text{ x } 0.9 \text{ x } 0.9}$$

$$= 3.566 \text{ kWh}$$

where Ep is the total power required from the solar panel for continuous functionality of the vehicle without a stoppage. [6]

To run the vehicle at 25 Km/h, we required a battery of 2.6 kWh with a motor capacity of 1 KW.

The total energy required from the panel is 3.566 kWh for the continuous functionality of the vehicle.

For Solar panel power output:

Solar energy (Wh) = Solar panel power output (W) x (Average hour of sunlight) x (75% because of 25 % loss due to dust, pollution, weather, etc.)

- During Summer:

3566 Wh = Solar panel power output x 10 hour x (0.75)

Then, Solar panel output requirement $= \frac{3566}{(10 \, x \, 0.75)} = 475.46 \sim 475$ W

- During Winter :

3566 Wh = Solar panel power output x 5 hour x (0.75)

Then, Solar panel output requirement = $\frac{3566}{(5 \, x \, 0.75)} = 950.93 \sim 950$ W

Now, solar panel capacity will be considered by using the average method-

Average for solar panel = $\frac{Summer \ \ required \ capacity + Winter \ required \ capacity}{2}$

$$= \frac{475+950}{2} = 712.5 \text{ W} \sim 720 \text{ W}$$

So, the 720 W capacity of the solar panel is sufficient for the continuous running of the vehicle.

3. ADVANTAGES

As solar vehicle is the need of the future because it has a lot of advantages.[4] Some of the major advantages are –

- There is no need to refuel the solar electric vehicle.
- Maintenance required for a solar electric vehicle is very low.
- Solar electric vehicles are noise-free because of the use of an electric motor.
- Solar electric vehicles are environmentally friendly because they do not produce any harmful gases.
- The efficient solar panels can be used to obtain a large amount of electrical energy.
- Solar EVs can be easily produced because of their easy mechanism.

4. CHALLENGES

Despite the wide range of advantages, solar electric vehicles come with some challenges too. These are some of the major challenges of the solar electric vehicle –

- Solar panels available on the market are less efficient for the conversion of solar energy into electrical energy, so we need a large surface area of solar panels on the roof of vehicles.[3]
- It is not easy to fix the solar panel on the top of the vehicle to get the low value of wind resistance during the motion of the vehicle.
- Solar electric vehicles cannot be used during winter and cloudy weather.
- Highly efficient solar panels are required in solar electric vehicles and these are too expensive and this can increase the initial cost of the vehicle.
- Solar electric vehicles are not able to run at high speeds as compared to IC engines

5. CONCLUSION

Solar electric vehicle's future is quite bright and it will bring advancement in the automobile industry as it can help to reduce pollution.[3] It also helps to reduce the dependency on a single source. Other conclusions are like as :

- To charge the 3.5kWh battery, solar panel requirement during summer will be of 475-Watt capacity and for winter, solar panel capacity will increase to 950 Watt.
- Solar panel capacity will increase during winter because of less solar radiation intensity availability.
- Solar electric vehicle is the best option for controlling the pollution level.
- With the implementation of solar panel, the range of distance covered by the vehicle will increase due to continuous charging from the PV solar panel.

Solar electric vehicles also have some disadvantages, but the advantages are more and because of this, solar electric vehicles are the future of the automobile industry. So, we can use solar electric vehicle in the upcoming future.

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