Design of Electric Motorbike Embedded with Perovskite Solar Cells

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***Abstract*—In the present day scenario the usage of fossil fuels in the automobile industry is very high, which is causing the degradation, and price hike of these fuels. From the beginning of automobile era, there have been several improvements in the design of fossil fuel based automobiles for achieving energy efficiency. At a point of time when the world needs to go-green and help in reducing the usage of fossil fuels, there is now a lot of concentration on usage of alternative fuels. One of the important initiatives in this direction is introduction of electric vehicles. The recent trends show that electric vehicles are given a lot of importance but the range (distance travelled per charge) is not high, as desired. Hence, the need of the hour is to work on effective utilization of natural resources to charge the battery by innovative methods. This paper describes the innovative design and analysis of a hybrid bike which can be charged both with the regular electric power supply as well as with solar cells. This design basically consists of the flexible solar panels placed on the both sides of electric motorcycle, unlike conventional solar panels. This makes the bike design not only innovative but also reduces space occupancy and improves style. It also helps in maintaining the aerodynamic design and helps in achieving greater range. With the addition of the solar panels having more area of exposure to the sun, it is possible to generate an additional power, thus increasing the range. The innovative design presented here makes an effective difference in using resources for the motorbikes, thus making them more eco-friendly. This paper also presents the analysis of the average power generated in each month of the year considering the number of average sunshine hours in each month.**

***Index Terms*—Electric vehicles, flexible solar panels, aerodynamic design, range, sunshine hours, innovation**

I. Introduction

The beginning of automobile era dates back to a century and beyond. The invention of IC engine vehicles might remain one of the greatest inventions in the history of mankind for sole reason of their consistent performance and long-term working. Since then there have been several updates and improvements done but nothing like introduction of electric vehicles into the world. Especially, at a point when the world needs to go green and help reducing the usage of fossil fuels. But slowly this technology is shifting towards hybrid electric vehicles and fully electric vehicles because of various aspects. These aspects include the need for better efficiency, less pollution and more renewable in nature. [1]

The trend of updating vehicles to electric is not only happening with four-wheelers but also with two-wheelers. The electric motorcycles are becoming part of the fast-growing world. An electric motorbike is a vehicle which runs on electric charge from battery. A typical electric vehicle works as per the following process. Firstly, the battery is charged using electricity which transmits the required power to the motor and in turn the motor provides torque to the wheel connected to it, generally the rear wheel [2]. There are many positive considerations to be taken into account in case of electric vehicles, one of them is that they do not emit any toxic gases which helps in reduction of the pollution. In addition to this the electric vehicles run at moderate speed which lowers the chances of accident rate especially in countries where this rate is very high.

The industry of electric vehicles is ever evolving, so the concept of using the electric vehicles must be improvised by integrating them with renewable resources of energy to charge the vehicle. Daily the sun releases immense amounts of heat and radiation in the form of solar energy. This solar energy is free of cost. Sunlight which is an abundant and accessible source would assist the electric power source so that the charging can be done in comparatively less time and also increase the range (distance travelled per charge) of the vehicle. The other advantage of sunlight is that the vehicle can be charged while in motion also.

Shruti Sharma et al. studied and discussed about how to choose solar cells based on aspects such as geography, working mechanism, materials, and technology used. They have reviewed about solar cells of different generations and also stressed on the importance of using solar cells, ways to improve them and proposed future applications in automobiles [3]. Solar cells are made up of semi-conductor materials like silicon and germanium. They mostly comprise of silicon boules. But in recent times many other elements are being introduced into solar cells for obtaining better efficiency. One such type of solar cells is perovskite. Shi D., et al. discussed on how perovskite solar cells became an assuring cell in recent times by having a peak cell efficiency of 30%. They also proposed that combination of perovskite/ C-Si tandem structure with inverted nanopyramid morphology which then increases the efficiency more than 31%. Their results have provided useful instructions for the fabrication of perovskite solar cells [4].

Solar cells are classified into three types, First-generation (Mono crystalline), Second-generation (Polycrystalline), Third-generation (Thin film) based on the composition of material and usage. Askari et al. discussed about different types of solar cells such as Cadmium Telluride Solar Cell (CdTe), Copper Indium Gallium Solar cells (CIGS), Perovskite Solar cells, Hybrid Solar cells, Monocrystalline Solar cells (Mono-Si) and many other. They also discussed about various applications of solar cells ranging from households to automobiles [5]. The working of solar cells is based on the principle that when the light interacts with the silicon cells, it sets the electrons into motion, which initiates flow of electricity. This is known as Photovoltaic effect [6]. The major steps that occur in the process are, absorption of light to generate holes and electrons by the semiconductor followed by separation of these charge carriers and then reuniting these charge carriers on opposite sides of electrodes to generate a potential difference between the electrodes and there by producing current or electricity [3], [7]. Solar cells can be charged either with the natural light or with artificial light. Solar cells transform the photon energy from the sunlight into electricity which can be used for the charging the battery of the bike. This photovoltaic process of conversion of heat and light into electricity does not require any burning of fuel. The variable costs through the installation of solar cells will be less when compared to other forms of generation.

The solar panel is the accumulation of solar cells connected to each other by wires either in series or parallel connection depending upon their usage. These solar panels are available in both rigid and flexible forms. Mario Pagliaro et al. researched on thin-film flexible photovoltaics which are paving towards low-cost electricity production. They also discussed about organic, inorganic and organic–inorganic solar cells which are being deposited with flexible substrates by roll-to-roll printing technologies to achieve lightweight, economic solar modules that can be incorporated into any type of stringent surfaces. These types of photovoltaic cells are ready to provide cheap, clean electricity across the planet especially overcoming issues faced by the world such as increasing costs of electricity generated by burning of fossil fuel resources. They have also focused on recent achievements in the area of flexible solar cells, highlighted the principles behind the main technologies, and discussed future challenges in this area [8]. The Perovskite cells in flexible solar panel will be the best choice for automobile applications because of the efficiency they provide, which is up to 30% unlike any other cells and other reason being convenient manufacturing and assembly [4].

Mishra et al. discussed about the method of integration of the solar panels with an electric bicycle to increase the battery power. It was suggested that solar hybrid bicycles are becoming an alternative for the gasoline operated automobiles and thus making its manufacturing crucial [9]. In the similar manner, Shubham Rana et al. worked on integration of solar panels to a TVS make bike of 100 CC power. Solar energy is stored in four batteries of 12 V which act as a reserve power for the two-wheeler and the bike is eco-friendly in nature [10].

Sharada and Nataraj discussed about the combined effect of IC engine and electric motor in a motorbike supported with solar panel, where IC engine being the main active pickup and electric motor with solar cells being supportive propulsion unit for increasing the travel range of the two-wheeler [11]. Rajkumar et al. worked on similar setup as discussed in the above mentioned paper, in addition to that their setup is supported with regenerative braking power and solar energy to achieve the same goal of obtaining better range [12]. Fabian Fogelberg presented the method of sharing solar energy between numerous bikes by using a large solar panel for simultaneous charging of batteries in different weather conditions and positions of light incident on the panel and determined the range and efficiency of an individual bike [13].

As there will be no emission of gases from the electric vehicles, usage of renewable source such as solar energy to charge the vehicle lends a hand to the environment. Advantage with the solar cells is that their modules can be customized into required shapes and sizes of cells. Till date, research is carried out by placing the solar cells on the top of the bike as rectangular panels with which the frontal area (i.e., product of width of the bike and height of the bike including driver) of the bike has increased the frictional resistance on the bike. Keeping all the factors mentioned in above works, the present paper discusses a better way of arranging solar cells on the electric motorbike to achieve greater range.

II. Methodology

The present work discusses about the electric bike fitted with solar cells apart from a battery to supply the power, brushless DC (BLDC) motor to produce driving torque, and a belt drive for transmission of motion from motor to the wheels. The bike is set into motion when the power from the battery is utilized by the motor and produces torque to the motor shaft which connected to the rear wheel of the bike through a belt drive. This torque is varied accordingly by using an electric vehicle motor controller. A motor controller is used in altering the energy flow from battery to BLDC motor and hence helping in regulating the torque of the motor. The rotating motor shaft is connected to the rear wheel of the bike. This whole process involves numerous power losses due to which range of the bike reduces. So as to increase the range of the bike, the charging in the battery has to be enhanced. For this purpose solar cells are included onto the body of the bike, which will charge the battery continuously. A regulator is be used in order to convert the solar charge into DC power which is stored in the battery.

This process is advantageous because the battery gets topped up even during the movement of the bike. In addition, it

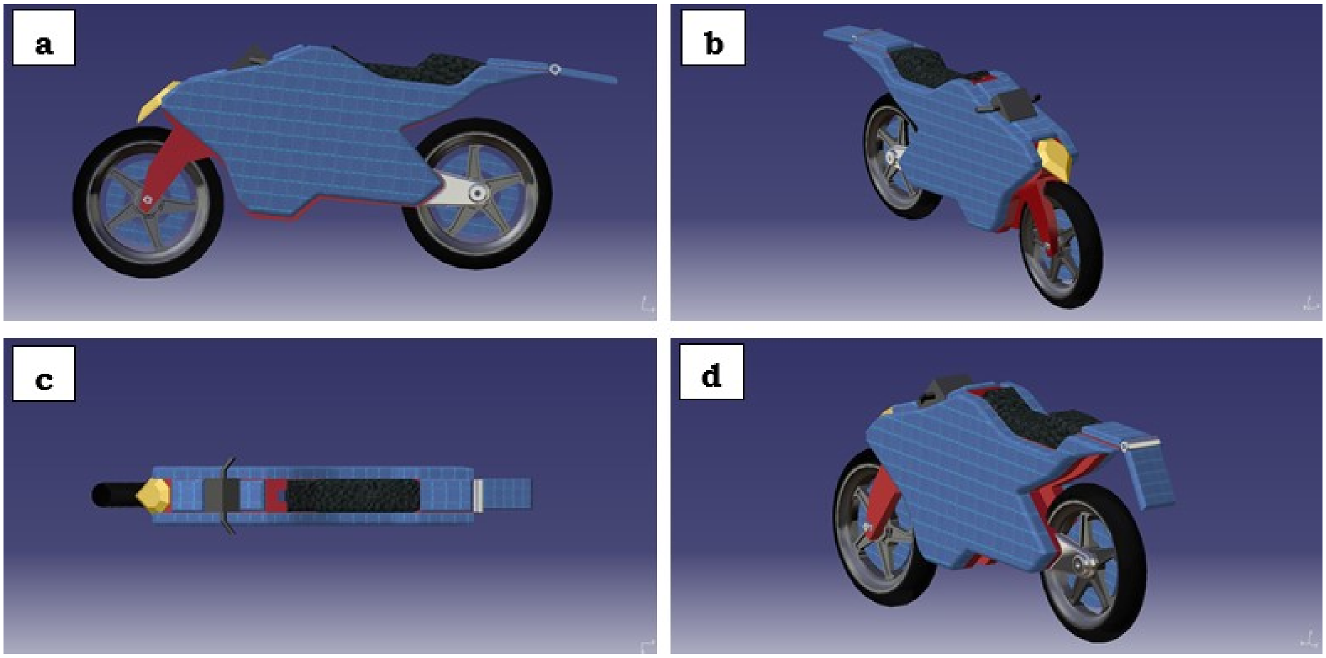

Fig. 1: CAD model of wheel

reduces the charging time required to power up the battery in idle position. This process increases the range of the bike by a significant margin.

III. Design Profile

In this work, design of two-wheeler electric motorbike with solar cells embedded on the body of motorbike as shown in the Fig. 1 is proposed. The entire body of the bike is supported by a Trellis Frame. This design basically consists of the flexible solar panels fitted on all the sides of motorbike as shown in Fig. 1. The solar panels are shown in blue colour are fitted on both sides (Fig. 1 (a) and (b)). Solar panels are also placed on the top as shown in Fig. 1(c) in the form of three distinctive panels with two in front of the seat and the other behind it. An extra solar panel is hinged to the rear end of the bike as can be seen in Fig. 1(d). This panel is adjustable according to the requirement i.e., when the motorbike is parked it can be completely unfolded and while in motion it can be folded beneath the pillion seat. Even the rims of two tyres are embedded with concentric flexible solar panels.

The specification of Lithium ion battery ($LiFePO_4$) used is 48 V 72 Ah required for the motion of the bike, resulting in an total output of 3456 Wh. In general, the complete battery capacity cannot be used effectively. Hence, 80% of maximum discharge can only be utilized practically resulting in effective energy of 2764 Wh [14].The specifications of bike dimensions are assumed as follows. The length(l), width(w) and height(h) are considered as 1990 mm, 735 mm, and 1135 mm respectively. The mass (m) of the bike is considered as 130 kg and the average human weight is assumed to be 70 kg. The wheel radius (r) is considered as 0.216 m (8.5 inches) and the pressure in tyres as 3x10^5 Pa. Seat height from the ground according to the dimensions considered as 1015 mm and the driver height (h_d) from the seat as 400 mm. Hence the frontal area (A) of motorbike will be equal to product of height of motorbike with driver and width of the motorbike. However there are many parameters that reduce the area like, the area of the face will not be same as the body of the rider and so an adjustment is made to consider only 70 percent of the area from the total [15]. The average speed (v) the bike is considered as 45 kmph. The solar cells embedded are Perovskite Cells. Shi D., Zeng Y. and Shen W, stated the applications of Perovskite solar cells in automobile industry have an efficiency of 30%. In reference to this, 30 percent efficiency is considered for the calculations [4]. In general the solar output of these cells is considered to be around 1 kW/m^2 [15], [16].

IV. Calculations

A. Power requirement

The total tractive effort of the bike is effected by various parameters [17]–[19]. The rolling resistance and aerodynamic drag are considered with the coefficients as 0.015 and 0.6 respectively [20], [21]. The bike is assumed to be travelling on a levelled asphalt road.

Tractive effort = $(M * g * v * C_{rr}) + (1/2 * \rho * C_d * A * v^3)$

where M = mass of the bike with driver in kg
g = acceleration due to gravity = 9.81 m/s^2
v = average speed of bike in m/s
C_{rr} = coefficient of rolling resistance = 0.015

ρ = density of air in kg/m^3
C_d = coefficient of drag = 0.6
A = frontal area of the bike with driver = 0.72 m^2
By performing the calculations, the power required by the bike to overcome the tractive effort is 0.96 kW. Hence a motor with 3 kW peak power can be considered by taking into account the remaining losses.

B. Torque requirement

The RPM (N) required for the wheels of the bike to move at 45 kmph and a linear distance of 1.35 m is
N = Total distance covered per minute / 2 * π * r
Therefore N = 45000 / (1.35 * 60) = 555.55 rpm
Assuming the efficiency of the motor as 85 percent the torque required is 13 N-m [22].

C. Range

As it is considered that the bike runs at a speed of 45 kilometers in 1 hour. Therefore the power consumption of the bike will be 960/ 45 = 21.33 Wh/km. Hence the range (S) of the bike can be estimated as S = Battery capacity / power required for 1 km = 130 kilometers.

D. Solar Cells Area

Depending on the design characteristics, the areas of cells are calculated using the dimensions, obtained in 2D CAD model.

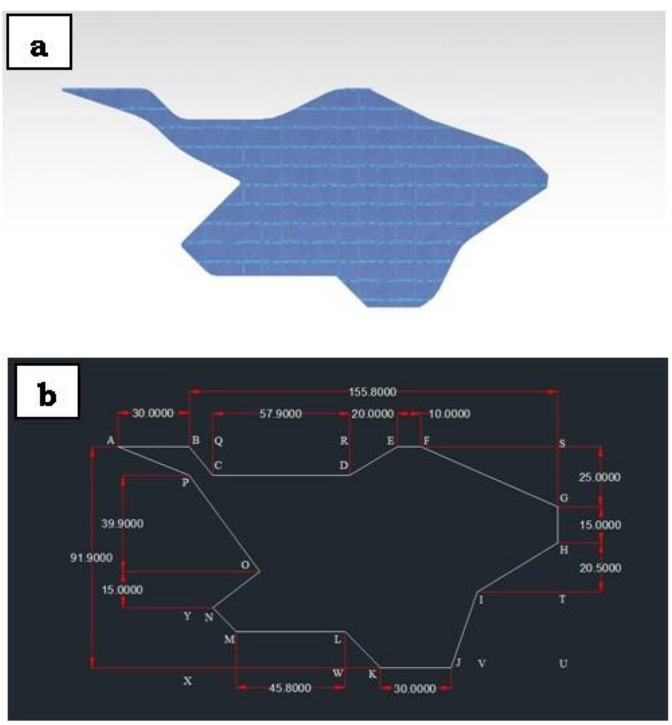

Fig. 2: Side view of the body

1) Side Cells Area: From 3D model of the solar panel, a 2D model is drafted with the dimensions as shown in the Fig.2 (a). The total area of the panel from Fig. 2(b) is considered as sum of areas of rectangle(BSUX) and triangle (ABP). From this, areas of rectangles QCRD, IVUT, YLWX and triangles BCQ, DRE, FSG, HIT, IJV, LWK,POY are subtracted resulting in a surface area of 0.93 m^2.
Solar side surface area = BSUX + ABP - (BQC + QCRD + RED + FSG + HIT + ITUV + IJV + LWK + LYXW + POY) = 0.93 m^2.

2) Area of cells in wheel: The solar cells on the wheel are placed as a disc as shown in the Fig. 3. The area of this disc is approximated as 0.1 m^2 for each wheel.

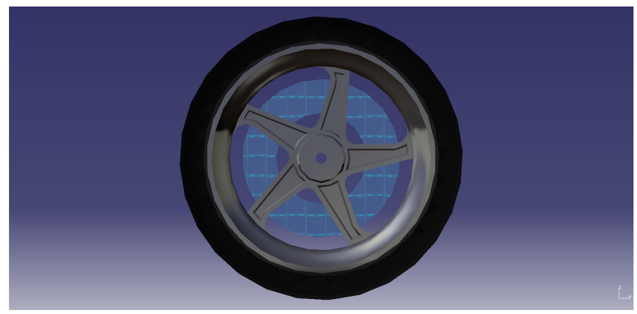

Fig. 3: CAD model of wheel

3) Top Cells Area: By considering the design of the top view, all the cells are approximated as rectangular panels as shown in Fig. 4(a) . Hence the total area of the cells on the top will be equal to sum of areas of rectangles RIHQ, PGFO, NEDM, LCBK, ASTG, PVJU as shown in Fig. 4(b). After the calculations being done, the area of solar cells on the top is 0.52 m^2

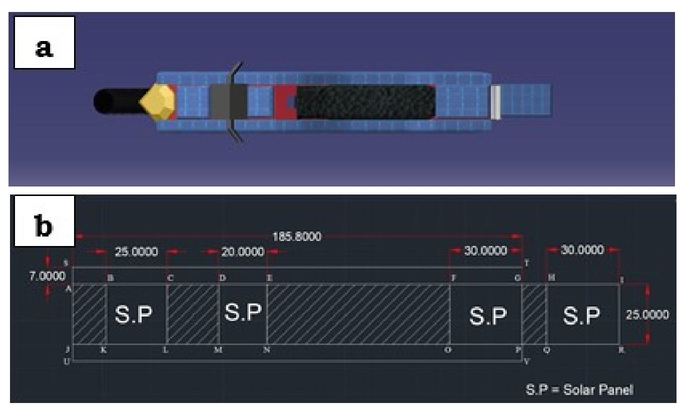

Fig. 4: Top view of the body

E. Solar Power Output

Considering on a hot sunny day, the sunlight starts at Seven o'clock in the morning and ends at Six o'clock in the evening. So the bike receives the light for 11 hours approximately on the given day. But the same amount of light will not be incident on all the cells of the bike.

Hence, the day is divided into three different time periods and accordingly the power output from the solar cells is calculated.

1) From 7 AM to 11 AM and 3 PM to 7 Pm: Assuming that the area of solar cells on one side of the bike and wheels (0.93+0.2) of the bike and 50% of the top (0.52) are exposed to the sunlight in the mentioned time, the power generated from this area of cells in this period is 1.39 * 300 * 8 = 3336 Wh.

2) From 11 AM and 3 PM: In this period of time (i.e., from 11AM to 3PM), the sunlight will be incident mostly on the top(0.52) along with 50% of the side(0.93+0.2). The power generated from this area in this time period will be = 1.085 * 300 * 4 = 1302 Wh

3) Total power: The total solar power generated in the assumed conditions is 4638 Wh. As previously derived, the power required for the bike to travel 1 kilometer is 21.33 Wh/km. The distance that the bike can travel using the power generated by the solar cells is 4638/21.33 = 217 kilometers

4) Average power in a year: From the above calculations, as the time periods are equally divided, the weighted mean of the area will be equal to the average of the area in three time periods. Hence the weighted mean of the area is 1.28 m^2. The data of average sunshine and the power output in different months is calculated and represented in the graph as shown in Fig. 5 [23].

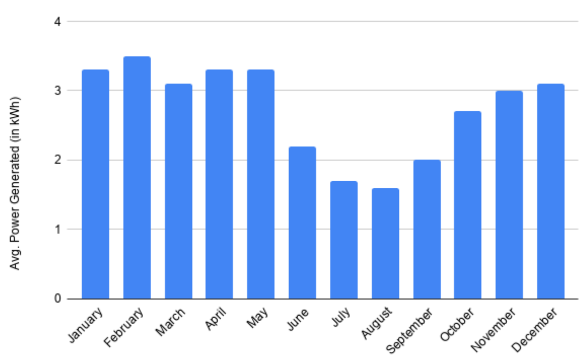

Fig. 5: Average Power Output

V. Results and Discussion

A better environment is created when electric vehicles are used on large scale rather than an automobile running on IC engines. The present work discusses about an electric motorbike which is modified into a solar hybrid bike by fixing flexible solar panels onto the body. The design proposed provides a better efficiency and range for electric bike theoretically, making it convenient for daily commute. The proposed model has demonstrated that the range of normal electric bike can be increased through the method of including solar panels. As mentioned, the vehicle is required to have the design suggested, to get the optimum solution. So, the range obtained for the electric motorbike from battery is 130 kilometers with fixed parameters like constant speed of 45 kmph, coefficient of drag of 0.6 and having a motor with peak power of 3 kWs. Now, with the addition of these solar panels on to body of bike which have a mean area of exposure to sun of approximately 1.29 m^2, it is able to generate an additional power of 4.6 kW per day which increases the range by 217 kilometers, summing up to total of 347 kilometers. The present work also shows a bar chart analysis of this motorbike with proposed design, on how much average power is generated (kWh) in each month of the year from January to December considering the number of average sunshine hours in each month of the year in Hyderabad, India.. From the analysis (Fig.5) maximum power, range and efficiency is in the month of February and the minimum in the month of August. This change in the power generation may be attributed to the amount of sun light available. As per the availability of sunlight, during summer the motorbike is expected to have high efficiency and while in the rainy season it is expected to be low. Nevertheless, this is a new method in the ever-trending automotive field and all the work related to similar concepts and automobiles must take this route for greater development and advancements to achieve a clean and green world.

The design which is showcased here makes effective difference in countries located close to equator which have more sunshine hours. As the cells used here are durable, these last long for a considerable amount of cycles. Apart from this, less weight, easy handling, stress free daily commute will add to its pros. The only disadvantage is that it is not at all efficient during rainy and cloudy weathers. Compared to IC engine motorbikes this solar-electric motorbike is more efficient and economic because of its unique profile. On a long- range graph, it has a very negligible decline in the performance as the power is generated by an abundant source. Furthermore, solar energy adds almost one and half times of range to the total range, making it require a lot less charging time. This motorbike will be a new innovation in automotive era, it is more eco-friendly.

VI. Conclusion

The present work is on a proposed design of electric powered hybrid bike with solar panels. An attempt is made in this work to design an electric bike fitted with flexible solar panels on all sides of the bike. The theoretical calculations carried suggest the following:
(i) An additional power of 4638 Wh can be generated by the solar panels fitted on the bike.
(ii) The additional power generated can increase the range (distance travelled per charge) by 217 km.
(iii) The solar panels fitted will help in enhancing the efficiency of the bike during summer.
(iv) The solar electric hybrid bike is a better solution as a replacement of fossil fuel driven bikes.
(v) It is a performance enhanced eco-friendly system.

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