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Development of a Pedal Operated Higher Power rating E-Rickshaw

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ABSTRACT

In this project a high power capacity rating pedal operated electric rickshaw has been designed and developed. The design is being carried out using the mostly standard component available in the market has been used for ease of maintenance. The uniqueness of this development is that it is pedal operated and motor driven which can help the rickshaw pullers to apply less manual effort while carrying passengers on gradient. The passenger's seat is designed such that four passengers can sit comfortably. The necessary calculations were carried out for required motor power and battery capacity. Accordingly the BLDC motor of 550 watt and rechargeable lead acid battery of 48V, 65 AH were selected for present purpose. The motion from pedal to rear axle has been transmitted through an intermediate axle. The strength analysis of chassis structure and stability of the vehicle has been checked through CAE software. The chassis and the body structures are assembled together using fasteners with a rubber pad to absorb the shocks. The batteries, controller and other electrical accessories are placed under the passenger seat and a charging point is mounted at the back. The speed of motor is being regulated by a throttle provided on the handle bar. The batteries may be charged from solar charging station or from by battery swapping method. The pay load capacity is 350 kgs (4 passengers + 1puller) and the max speed is 15-20 Km/hour. The 3 nos of prototypes have been developed with improved features. The laboratory level trails has also been carried out of the developed prototypes and a very satisfactorily results is obtained up-to a distance of 40 kms in a single charge.

Introduction

The world will face a huge problem in future for the scarcity of fossil fuel, as the number of automobiles are increasing day by day in a very fast rate also these automobiles using petrol or diesel are causing noise and air pollution. It is by known by everyone that the level of pollutions has been increased drastically too much and major portion of pollutions are being produced from the automobile sector which causes severe problems to human health and diseases. The recent reports indicate that the scientists have noted the evidence of global atmospheric changes due to the emission of pollutants from automobiles. The review of journals reveals that the estimated petroleum reserve in India is only about to 300 million tons. It is estimated that with increasing rate of consumption of petroleum products, the reserve may last for twelve more years only. Hence for the future requirements it may be necessary to India has to depend on import petroleum products from other countries. The air pollution on one side and the escalating prices of petroleum on the other side are giving threatening to the public transport, which is one, of the major consumers of petroleum products. Considering the above problem it is felt necessary for the development of a suitable transport system which is free from pollution and runs without using any fossil fuels. Thus a project has been formulated for the development of a pedal operated higher power rating capacity electric rickshaw for local transport of passengers. This paper mainly deals with the design and fabrication of a pedal operated cycle rickshaw which is suitable for suburban road conditions.

Pedal driven electric cycle rickshaw:

Mostly the standard parts available in the market have been used so that they can be easily replaced from the local market with minimum cost. The uniqueness of this development is that four passengers can sit comfortably, and rickshaw pullers can easily pull using less muscle power with a running speed of 10 to 14KM/hour (approx). A 550watt 12volt, BLDC motor has been used and is mounted at the bottom of the chassis structure and the drive is given through a sprocket and chain mechanism. The drive assembly unit consists of two axles shafts first one for transmitting motion from pedal to 1st shaft and 2nd or rear shaft will get drive from the BLDC motor through chain and sprocket mechanism. Three prototypes are being fabricated with research input and improvement. The different tests like design analysis & simulation is being carried out for the developed models, to check the design viability, stability and efficiency. The chassis and the frame structures were assembled together by using fasteners for ease of replacement. The e-Rickshaw is powered by 48Volts, 65AH lead acid battery and it will take 7-8 hours for fully charge the batteries. These controller and the batteries are placed under the passenger seat. The speed of motor is controlled by a throttle provided on the handle bar. The main supply line to the electrical circuit is routed to a junction box by on/off switch.

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Design and selection of the electric rickshaw.

The main problem in the design of electric vehicles arises due to the increase in gross vehicle weight of the vehicle. To resolve this problem, the design has been done accordingly by choosing the specific materials.The frame, body and chassis of the vehicle can be redesigned introducing hollow tubular structural members instead of solid sections. The conventional tyres are replaced with small diameter tyres to withstand additional loads and also to maintain the C.G as low as possible with reduction in wear and tear. Unnecessary peripheral members are eliminated to reduce the overall weight of the vehicle. The speed and range of the vehicle are also selected to suit the lighter structural frames and increased weight of the vehicle. The small size BLDC motor has been selected as per the rated wt and calculated power of the vehicle. The speed of BLDC motors is controlled by a throttle which is attached with the controller. With all these incorporations a suitable design has been evolved for a three wheeled rear axle driven 'battery powered cycle rickshaw'.

Chassis Fabrication

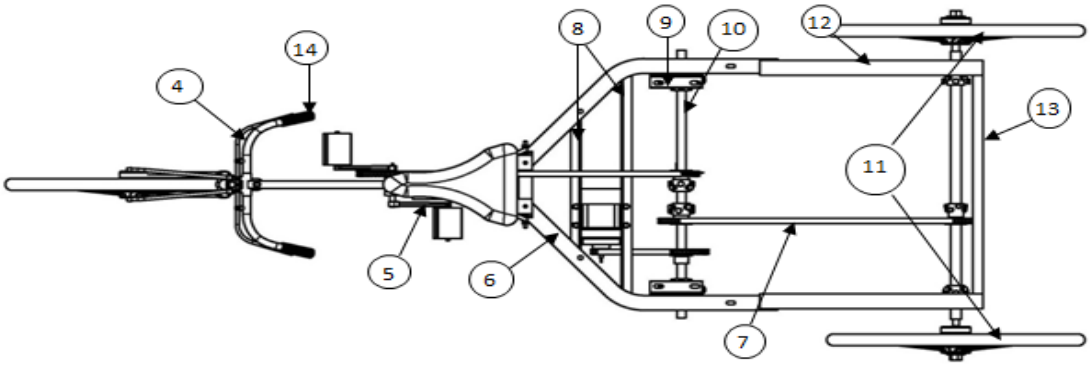


Fig.1

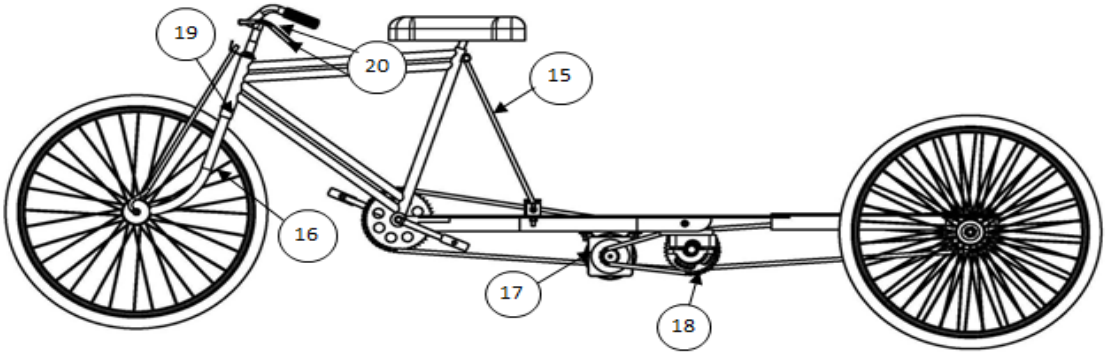


Fig.2

Figure .1 represents the 3D CAD Model of the e-rickshaw. The hood structure [1] is attached with the body [2]. The entire body is mounted on main Chassis [3] of the vehicle. The body has been designed for the seating of four passengers. The driver's seat, with adjustable height, is mounted on the main chassis.

Figure .2 represents the 2D drawing of main chassis of e-rickshaw. The chassis structure [6], on which main body mounted, is fabricated with structural angle. The front fork [16] and handle [4] is attached at the front side of vertical frame through thrust bearing [19]. The BLDC flange motor [17] is mounted by welded structural angles on the chassis structure. The motion of motor is transmitted through a chain & sprocket [18] to the first axle and the speed is controlled by throttle [14] through electronic controller, fixed on the handle bar [4].

The motor is mounted on the chassis structure by welding two structural angles [8].The disc braking system, is attached on both the rear wheel [11] and is operated by left & right lever [20]. The front axle [10] is mounted on the chassis structure by using plumber blocks [9].The power to the motor is supplied through 48V- 65AH lead acid battery, placed under the passenger seat. The drive to the front axle is transmitted through the pedal [5] and to rear axle is transmitted by the BLDC motor [17] through chain and sprocket mechanism [18] & [7].The chassis, body and frame structures were tightened by a tie rod [15]. The chassis is extended by using structural angle of the same size [12]. The chassis structure is being tightened by using structural angle [13].

Vehicle specification:

SL No	Specification	Dimension
1	L X W X H	2440 X 1218 X 1814
2	WHEEL BASE	1845 mm
3	TRACK WIDTH	1086 mm
4	GROUND CLEARANCE	135 mm
5	WEIGHT WITH LOAD (4+1)	503Kgs (Approx)
6	WEIGHT WITHOUT LOAD	153 kgs
7	WEIGHT OF CHASSIS	22.5 Kgs
8	WEIGHT OF FRAME	31 Kgs
9	WHEEL DIAMETER	525 mm
10	BATTERY WEIGHT	100 Kgs
11	HEIGHT OF C.G POINT	836 mm
12	Distance of CG from front wheel	1121 mm

BLDC Motor specifications:

Type	Series
Wattage	550 watt
Voltage	48 volts
Rated current	32 Amps
Duty	1 hour rating
Speed	1800 rpm
Insulation	Class F
Overload	60 Amp 48 Volts (Nominal) for 90 sec
Overall length	215
Overall height	205
Weight	18 Kgs

Power source:

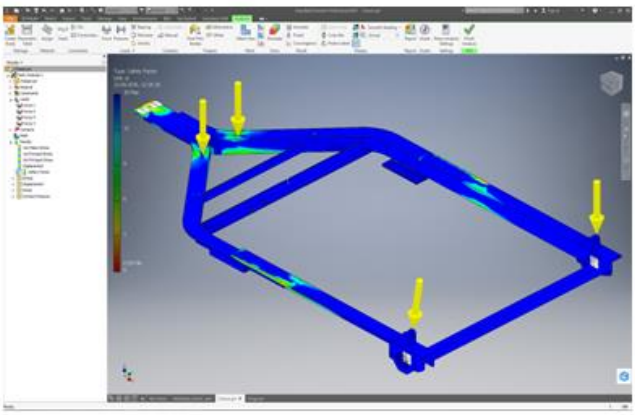
- Four numbers of lead-acid batteries, with specifications given are used.
- Battery type : Lead-acid battery system
- Rated voltage (V) : 12
- Rated capacity (Ah) : 70
- Battery configuration : 4 Nos. 12 V modules in series
- Battery dimensions (mm) : 510 x 220 x 240

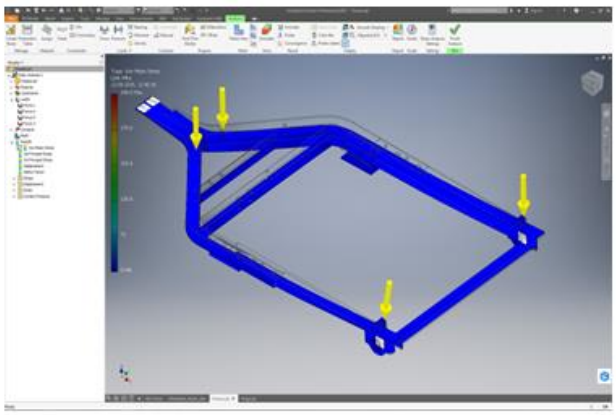
Comparative study of the available LEAD ACID BATTERY:

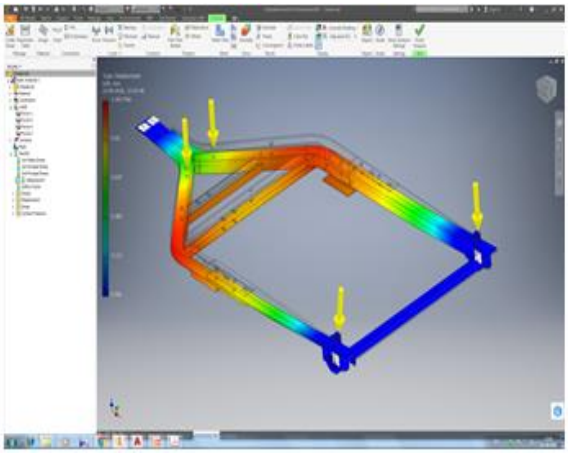
Battery weight (single unit): 20(kg)

S.NO.	MODEL NO. with Name	VOLT	Ampere Hours	Weight(Kg)	Price (In Rupees)	Remarks
1.	Exide EZ65L 65AH	12V	65AH	19.9	4433.00	18 months
2.	Exide little champ EXL65R	12V	65AH	17.5	4368.00	24 months
3.	Exide 2ER88L (FERO-12ER88L)	12V	88AH	26.7	4448.00	6 months
4.	Exide Dynex (DMX 65D26L-BH)	12V	65AH	17.6	4150.00	36 months
5.	SF SONIC FFSO F51080 65L	12V	65AH	21.8	4899.00	36 months
6.	AMRON Fresh FR650L	12V	65AH	20.5	4150.00	18 months
7.	BASE M80D26RL MF70AH	12V	70AH	22.5	4120.00	36 months
8.	SU-Kam SPB70	12V	70AH	23.0	4300.00	24 months
9.	Prestolite PR70FT RL	12V	65AH	21.0	5370.00	36 months

Analysis of the Chassis :

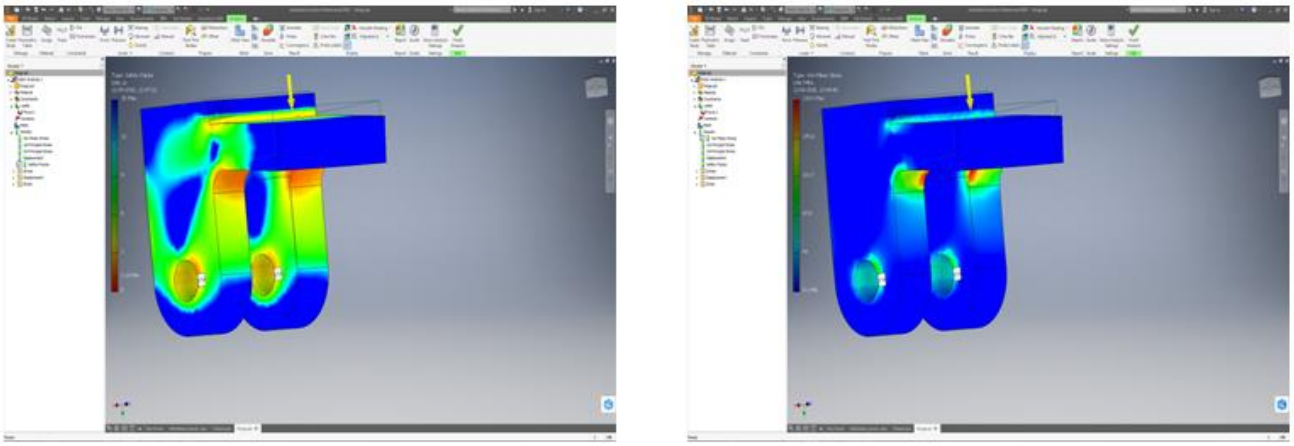






Stress and Von Mises analysis of the Chassis structures

Analysis of the Hinge bracket:



Stress and Von Mises analysis of the Hinge bracket

Analysis results of the vehicle:

The developed model has been analyzed to know the determine the strength of the cross section used, to know about the C.G of the vehicle and the load carrying capacity. The analysis report says that the chosen section were enough strong to carry the load and the C.G point has been much lowered by the selection of the small wheels. Hence it could be predict that the vehicle is balanced.

TEST RESULT OF THE BLDC MOTOR

Summary of this report:

Motor characteristic of BLDC motor is a straight line in a nature; but when controller is included for driving the motor then motor characteristic is not motor characteristic only; because it is governed by controller. Controller is also depends on switching of MOSFETs and Driver Ckt etc. In this report we are going to display the combined characteristic of motor and controller under different loading conditions. Based on these results we have to determine approximate rating of motor power (peak and rated power)

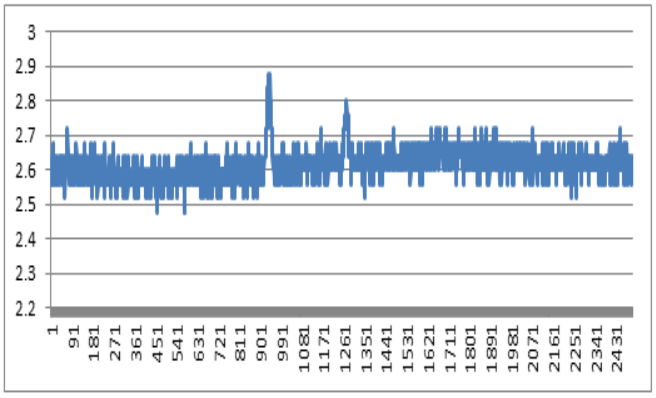
Final assumption of rating of motor power after analysis of performance of several test results

Motor Performance parameter:

Sl No	Parameter	Determined Value
1	Rated output power	315 watt
2	Rated Battery voltage	48 volt
3	Peak motor power	600 watt
4	No load speed	2850 Rpm
5	Full load current	9 amp
6	No load battery current	2.65 Amp
7	Full load battery current	25 Amp
7	Peak torque	5 NM
8	Efficiency	72%
9	Gear ratio	1:3

No load characteristics:-

- No load motor speed: 2850 RPM
- No load battery current: 2.65 Amp
- X axis: no of samples
- Y axis: Current (Amp)



Load characteristic Graph:

To determine the load characteristics motor is connected with a DC Generator and torque sensor.

Experimental Setup as shown in figure 3 &4.

Figure 3. Set up for motor test bench.

Figure 4. Coupling of dc generator for electric loading.

Test Results:

Performance of the motor with different electrical loading was taken in a sequential manner and all of the results and calculations are given in table 1. & 2.

Table 1: overall drive efficiency connected with motor, reduction gear, torque sensor, dc generator and electric bulbs are connected in a cascaded manner.

Battery voltage	Battery current	Load voltage	Load current	Input Power	Out Put Power	Over all drive efficiency%
47.83	4.7	28.16	3.21	224.801	90.3936	40.21049728
47.76	6.24	32.4	3.08	298.0224	99.792	33.48473135
47.63	8.15	45.02	3.7	388.1845	166.574	42.91103844
47.47	9.7	54.5	4.12	460.459	224.54	48.7643851
47.3	11.1	62.4	4.3	525.03	268.32	51.10565111
47.25	12	66.1	4.46	567	294.806	51.99400353
47.14	13.3	51.4	6.54	626.962	336.156	53.61664662
47.02	15.3	49.44	8.16	719.406	403.4304	56.07826457
46.87	17	54	8.56	796.79	462.24	58.01277626
46.76	18.8	58.57	8.91	879.088	521.8587	59.36364733
46.58	21.2	46.3	7.77	987.496	359.751	36.43062858
46.34	25	51.92	8.16	1158.5	423.6672	36.57032369

Table 2. Motor efficiency calculated from input battery power and results obtained from torque sensor.

Torque sensor OUTPUT In mV	Shaft Torque	Gear Ratio	Motor Torque before Gear	motor speed	shaft SPEED	motor output Power (W) = Torque (N.m) x Speed (RPM) / 9.5488	Motor efficiency%
40	1.668335	3	0.5561117	1230	410	71.63385459	
60	2.5025025	3	0.8341675	1254	418	109.5473825	91.0948283
80	3.33667	3	1.1122233	1410	470	164.2337154	
110	4.5879213	3	1.5293071	1395	465	223.4190038	
133	5.5472139	3	1.8490713	1368	456	264.9054886	
142	5.9225893	3	1.9741964	1404	468	290.2743561	
166	6.9235903	3	2.3078634	1347	449	325.5583974	
180	7.5075075	3	2.5025025	1320	440	345.9391026	
208	8.675342	3	2.8917807	1308	436	396.1177442	
238	9.9265933	3	3.3088644	1275	425	441.8149019	
275	11.469803	3	3.8232677	1245	415	498.4886375	72.16834506
352	14.681348	3	4.8937827	1170	390	599.6277779	70.65503227

The Signature of the battery current and output load current from dc generator is in figure 5 & 6.

Battery Current profile:

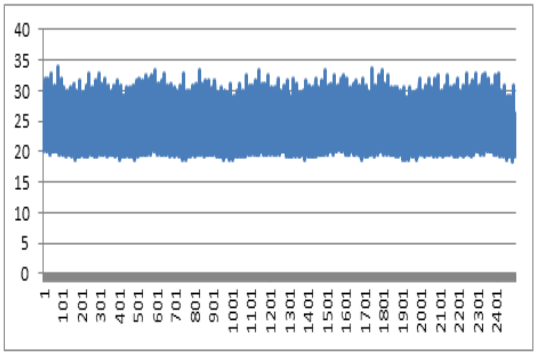


Figure 5. Battery Current (Amp) with no of samples.

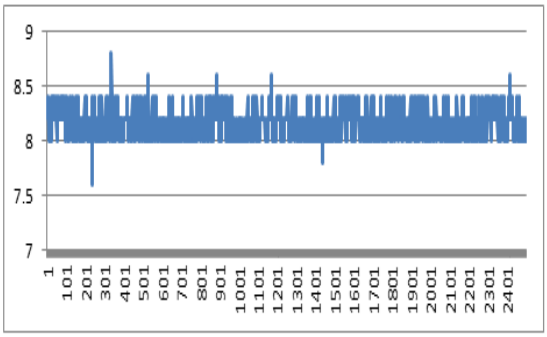


Figure 6. Load current (Amp) with no of samples.

Analysis of the Load current profile:

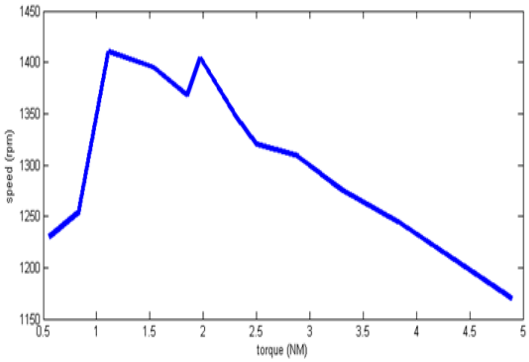


Figure 7. Characteristics of Speed & Torque Curve for BLDC Motor with Controller.

Technical Specifications:

Power source	: Motor and Manual
Type of drive	: Motor assisted pedal driven
Electric motor	: BLDC flanged type Motor (550W, 48V)
Charging	: Batteries may be charged from solar charging station or by swapping method
Battery	: Deep discharge type leads acid batteries
Transmission	: Chain & sprocket mechanism
Brakes	: Front wheel drum & disc brake on rear wheel
Axle & Motor	: The motor is mounted on the fabricated axle structure on the chassis.
Pay load	: 350 Kg (driver and four passengers)
Drive sprocket	: 40 teeth, mounted on the pedal crank
Driven sprocket	: 32 teeth
Chain tension	: Provided manual

Benefit:

- Remove drudgery & hardship of the rickshaw pullers
- Gives assistance to rickshaw pullers during riding on the gradient
- Gives greater mileage and load carrying capacity
- Batteries can be easily charged from solar or by battery swapping method
- The earning of the rickshaw pullers will be increased
- The rickshaw pullers can lead a better life

Laboratory level trial:

The developed prototype has been tested along with four passengers with full charge of the battery, the result obtained shows that it can covers a distance of 40 Kms and found that battery is still having still 50% charge.

Conclusion:

The feasibility study and research carried out by CMERI on making e-Rickshaw revealed that e-Rickshaw is a feasible mode of transport for first and last mile connectivity in semi-urban areas. As e-Rickshaws are already in use for covering short distances, so we decided to make it more efficient and eco-friendly. This is more environments friendly and is considered to be an alternative fuel vehicle. Our economic feasibility states that the optimum development cost of a single unit of e-Rickshaw is found to be Rs. 80,000 and Calculation reveals that the payback period of this system is around 1.3 years & the cost of production of a single unit of electricity for a span of 20 years comes out to be Rs. 1.3(One Rupee & Thirty Paisa). It is found that with the invent of e-rickshaw the average revenue earned by owned drivers is Rs. 15,000 where as the average revenue earned by rented drivers is Rs. 9,000 per month. The overall study reveals that the earlier income earned by drivers with manual operated rickshaw is found to be Rs. 4,800/- only as specified by Govt. of India. The e-Rickshaw is found to be technically feasible than many other polluted vehicles on the road, it is noise free, cheaper and most efficient of all another type. This e-rickshaw is considered to be an alternate replacement of other fossil fuelled driven vehicle. This developed e-rickshaw can be charged by battery swapping mechanism or by a rooftop Solar PVs charging units (Plug-in Electric vehicle). The developed e-Rickshaw helps in employment generation. The basic primary feature of cheap transport cost & noise-free rides motivate users to use these rickshaws for their short distances.