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Environment Friendly Electric Tandem Cycle With Regenerative Braking Arrangement & PV Charging System

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Abstract:- The issues of global warming and depletion of fossil fuels have created opportunities for electric vehicles(EV).Electric vehicles(EV) may reduce global green house gas emission(GHG)as the energy consumption in the world's transportation is high. This paper represents the working and construction arrangement of an electrically operated tandem cycle with regenerative braking arrangement. In regenerative braking, kinetic energy of the vehicle is stored in an energy storing device instead of being dissipated and the stored energy is used to drive the vehicle later on. This type of electric cycle results in reduced human muscle effort. Moreover the electric tandem cycle is environment friendly and does not emit toxic gases in the atmosphere. The electric tandem cycle does not produce sound pollution by creating noise. The electrically operated tandem cycle with solar charging system represents the utilization of renewable energy. The electrically driven tandem cycle is operated by a Permanent Magnet DC Motor (PMDC). The motor is powered by a battery pack of 24 V 10 Ah and it can be charged by a 24V 4 Ah Switched Mode Power Supply (SMPS) or a solar panel of 24 V. This environment friendly electrically driven tandem cycle reduces muscle power of a rider and it can be available at low cost. After completion of this experiment it has been recorded that the electrically driven tandem cycle can run more times after installing regenerative braking arrangement.

Keywords:- *EV-Electric Vehicle ,GHG-Green House Gas, PMDC-Permanent Magnet DC Motor, SMPS- Switched Mode Power Supply, ICE- Internal Combustion Engine, ECO- Ecology, HEV- Hybrid Electric Vehicle, ESC-Electronic Speed Controller, BLDC-Brushless DC Motor, PV- Photovoltaic, KE- Kinetic Energy.*

I. INTRODUCTION

Electric Vehicles(EV) play an important role from academia, industry and governments due to increasing concern over the serious problems world wide as there are shortages of non renewable fossil fuels, environmental pollution and global warming. Moreover the electric vehicle has resolved the problem regarding Green House Gas(GHG) emission. In the 20 th century the world energy crisis had placed a role in the automobile field due to continuous rising of global energy consciousness.Transportation sector plays a vital role in the green house gas (GHG) emission globally. The conventional vehicles utilize internal combustion engines(ICE)which depends on fossil fuels(e.g gasoline or diesel)for their operation and emit gases such as carbon dioxide, carbon monoxide, unburned hydrocarbons, nitrogen oxide etc to the atmosphere. The Fig. 1 represents the world total energy consumption in 2018. The Fig. 2 represnts transportation sector accounts for almost 14% of global Green House Gas emission(GHG). The electric vehicle is one of the solutions to reduce global Green House Gas(GHG) emission and in this way the electric vehicle(EV) has been launched in the market.As compared to fuel operated vehicles, the electricity operated tandem cycle provides not only cleaner and quieter ambiance but it is also avilable in low cost.Tandem cycle ia a cycle consisting of two seats and two pedals, made for two riders to ride together and it is made up of a lots of waste material but is an electrically operated cycle besides muscle power.The electrically driven tandem cycle is pollution free and eco friendly. The electric vehicles run by electric motor instead of internal combustion engines(ICE).This cycle is hybrid electric vehicle(HEV) which can be run by both human muscle power and electrical power.The electric power source is a battery pack of 24 V, 10Ah.This power has been utilized to operate a motor of rating 250 W, Permanent Magnet DC motor(PMDC) through an electronic speed controller(ESC)[1].The shaft of the motor is connected the cycle wheel through chain and gear set. The battery pack of 24 V, 10 Ah is charged by Switched Mode Power Supply(SMPS). The battery of the cycle can also be charged by photovolatic panel(PV) with in 4-5 hours.It has already been observed that the regenerative braking increases the running time.In regenerative braking the kinetic energy (KE) of the vehicle is stored inan energy storing device instead of being dissipated and stored energy is used to drive the tandem cycle later on. In hybrid electric vehicle(HEV) the energy recuperation occurs by mechanical energy to electrical energy via a generator[2].The electrical energy stored in a battery is used to operate the vehicle via a motor.

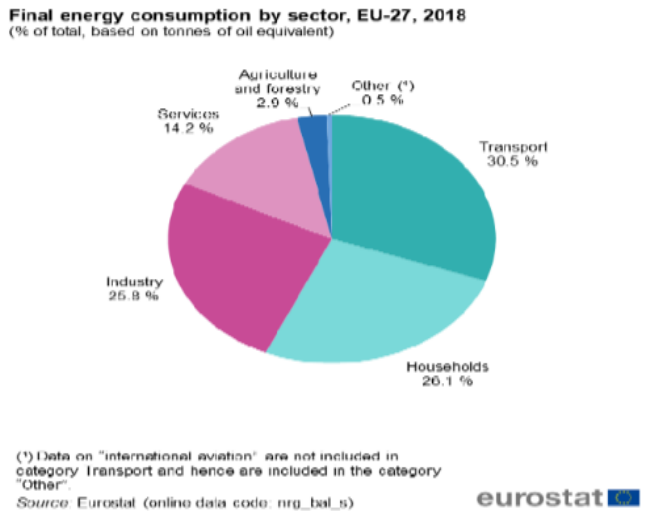

Fig. 1 World Total Energy Consumption in2018[dsource: Energy Consumption by energy source 1990-2040]

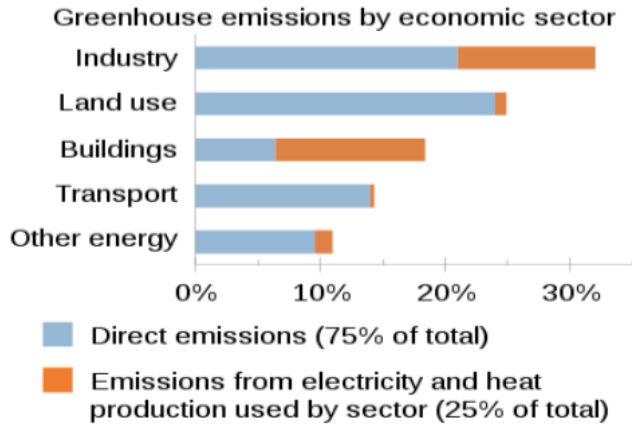

Fig. 2 Global Green house gas Emission [Greenhouse Gas Emissions by Economic Sector according to IPCC Fifth assessment]

Fig. 3 The growth of petrol price in 20 years has been plotted [Source:https://freefincal.com/india-petrol-diesel-historical-price-data]

A.Why Electric Vehicles are required?

In this age of civilization, the necessity of transportation is unplatable. Generally, the vehicles which depend on petroleum fuel are used almost everywhere. But for the new era of civilization, the electric vehicles(EV) are the new future of transportation. As the stock of fossil fuel is limited and moreover internal combustion engines(ICE) emit toxic gases in the environment which results in global warming, environment pollution etc.Moreover the price of petroleum is increasing rapidly in India so it will be beneficial for common public to adopt electric vehicles(EV) for their daily purposes.The growth of petrol price in last 20 years has been plotted in a diagram shown in Fig. 3, representing four major cities of India(Delhi, Mumbai, Chennai & Kolkata).The price of petroleum fuel has been increased rapidly all over India and it has been found that a major user of petroleum fuel is the vehicles which mostly includes daily travellers who travel on a daily basis at a distance from home to office or work place, market or other purposes. As a result big cities are mostly populated by the vehicles exhaust. For the betternent of environment and saving petroleum fuel, we are having electric vehicles(EV) as a great option.[3]

II. WORKING

The chassis of the cycle is made up of iron pipes which were collected from junkyard of two unused damaged cycles which were being reconstructed and assembled by welding and machining. Two paddles and two seats are placed in a tandem manner by which two riders can simultaneously paddle the cycle at the same time shown in Fg.4.The cycle is operated by a Permanent Magnet DC Motor (PMDC) also. The motor is powered by a battery pack of 24V, 10 Ah and the battery pack can be charged by a 24 V, 4 Ah Switched Mode Power Supply (SMPS) as well as solar panel of 24V. Fig. 5 represents the electrically driven tandem cycle after installation of motor and auxiliary electrical equipments. As the chassis is made up of iron pipes and the chassis is able to bear 120 Kg(kilograms) easily, equivalent of the weight of the two adult men. There is a pair of paddles which is connected to the rear wheel and this arrangement is used for transferring torque to the rear wheel while paddling. There is a Permanent Magnet DC Motor (PMDC) which is coupled with the rear wheel by chain and chain sprockets which are rigidly coupled to the wheel. So that whenever the motor will rotate, the wheel will also rotate and vice versa. As the Permanent Magnet DC Motor (PMDC) is coupled with the rear side wheel it will deliver torque to the rear side wheel as well as to provide traction stability to the cycle. The motor will be driven by a battery pack of 24 V and the battery is connected to an electronic speed controller (ESC), which is controlling the motor by varying the voltage and current input to the motor. As a result the motor will vary its speed as well as torque. The Electronic Speed Controller (ESC) has already been controlled by throttle controller which is placed on the front of the steering. The front steering has two brakes, among them one is mechanical brake and another one is electronic brake that means regenerative brake. But in terms of braking, the motor will work as a generator and energy generated during braking is restored in the battery storage. The Fig.6 represents charge percentage vs. distance. The graph

represents that the battery discharging time has been raised during running after adopting the regenerative braking arrangement. The graph also represents that it has been tried to plot 1.5-2 Km more distance by using regenerative braking arrangement than the previous experiment without using regenerative braking arrangement. In terms of efficiency, a result can be drawn by collecting the data obtained from the experimental work and it can be determined by simple calculations considering the running time. It has been concluded that the efficiency of electrically driven tandem cycle has been increased by 14% shown in Fig. 7 after utilizing regenerative braking arrangement.

Fig. 4 Before installing the motor and auxilary electrical parts.

Fig. 5 The electrically driven tandem cycle after installation of motor and auxiliary electrical equipments.

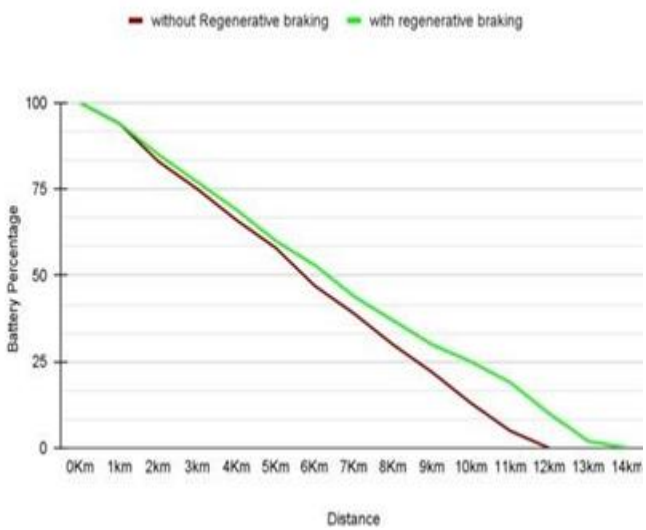

Fig. 6 Graphical representation of charge percentage Vs. distance.

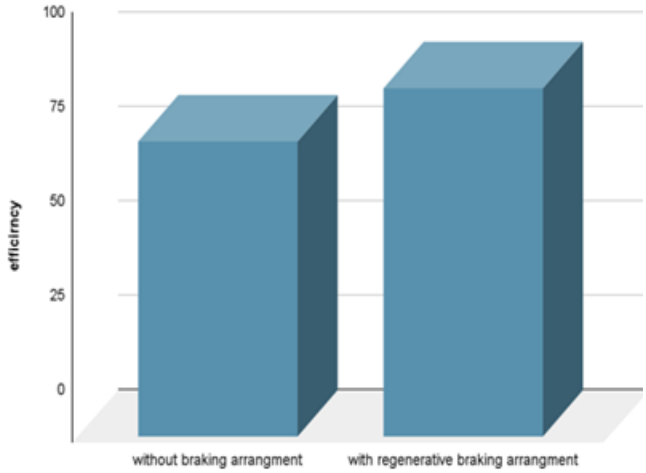

Fig. 7 The efficiency of the Tandem cycle has been increased by 14% after adopting regenerative braking.

III. CONSTRUCTION

A. Chassis

The chassis of the tandem cycle has been made by recovering two old bicycles and few aluminum pipes which have been welded and machined with electric arc welding, gas welding etc. to form a chassis in a shape of tandem cycle as well as the motor has been mounted and bottom sprockets have been arranged. Fig. 8 represents the chassis of a tandem cycle.

Fig. 8 The chassis of the tandem cycle.

B. Permanent Magnet DC Motor

There is a 24V, 250W Permanent Magnet DC Motor (PMDC) producing around 8 N-m torque at 300 r.p.m (revolution per minute) connected to the wheel of the cycle via a chain and a chain driven pulley (not freewheeling) which is tightened to the rear wheel capable to pull more than 125 Kgs at a speed of 10-15km/hr. Fig.9 represents the motor which has been installed in the cycle is Permanent Magnet DC Motor(PMDC).

Fig. 9 Permanent Magnet Dc Motor has been installed in the cycle.

C. Battery

There is a battery pack of 24 V, 10 Ah which can be charged by three different ways.

This battery pack can be charged by 24 V charger directly from 220 V AC supply of house hold power socket. This battery can be charged by solar panel also. The motor itself which is capable to generate the electricity from the inertia of the cycle. Fig. 10 represents the battery pack of 24 V has been installed in the cycle.

Fig. 10 The 24 V battery pack has been installed in the cycle.

D. Electronic Speed Controller (ESC)

The device is used to control the speed of the motor. During the time of braking, it disconnects the circuit, from the motor. This controller has been installed in the cycle, between the connection of motor and batteries. This electronic speed controller (ESC) is controlled by a sensor that is placed on the throttle. The Fig. 11 represents the Electronic speed controller(ESC) and connections.

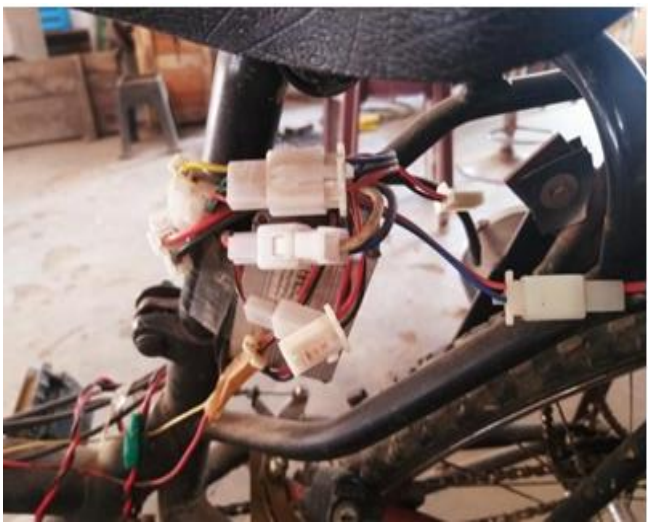

Fig. 11The Electronic Speed Controller(ESC) and connector sockets.

E. Regenerative Braking System

Regenerative braking is an energy recovery mechanism that slows down a moving vehicle or object by converting its kinetic energy into a form that can be either used immediately or stored until needed. In this mechanism, the electric tandem cycle uses the vehicle's momentum to recover energy that would otherwise be lost to the brake discs as heat. This contrasts with conventional braking systems, where the excess kinetic energy is converted to unwanted and wasted heat due to friction in the brakes, or with dynamic brakes, where the energy is recovered by using electric motors as generators but is immediately dissipated as heat in resistors.

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In addition to improve the overall efficiency of the vehicle, regeneration can significantly extend the life of the braking system as the mechanical parts will not wear out very quickly.

It has been obtained from the experimental work that after installation of regenerative braking arrangement the efficiency of the vehicle has been increased by 5%-20%. The electric vehicles (EV) and hybrid electric vehicles (HEV) can only be equipped with this facility. This process is generally established by using external generator brakes. In this cycle, the motor itself works as a brake and it converts the inertia of the cycle into electrical power to charge the battery of the cycle. For this purpose a power converter is being used. It works by redirecting the terminals of motor/generator, while applying braking. The Fig. 12 shows the regenerative braking arrangement.

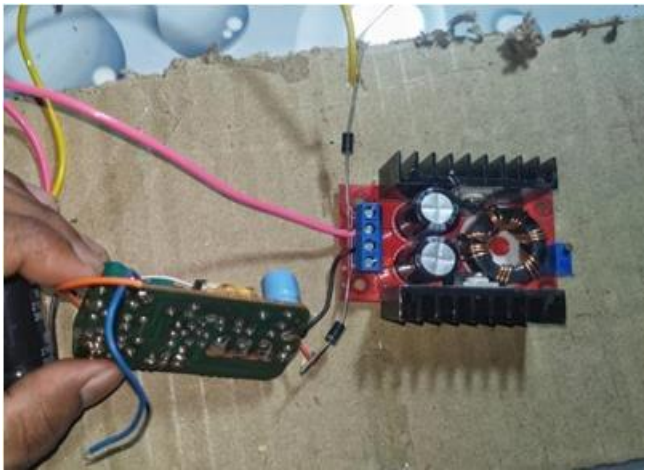

Fig. 12 Relay & power converter arrangement for regenerative braking.

F. Solar Panel

The solar panel converts sunlight into DC electricity to charge the battery. This DC electricity is fed to the battery via a solar regulator which ensures the battery is charged properly and not damaged. DC appliances can be powered directly from the battery, but AC appliances require an inverter to convert the DC electricity into 240 Volt AC power.

Fig. 13 Solar panel used to charge the battery pack of 24 V, 10 Ah

Though the solar panels are not directly implemented to the electrically driven tandem cycle. An experiment was performed with the solar panels, a battery pack of similar specifications of 24V, 10 Ah and a charge controller. It can be concluded from the experimental work that the battery pack of 24V ,10 Ah was fully charged with in 4.5 hrs by using solar panel. The Fig. 13 represents the solar panel which has been used to charge the battery pack of 24 V, 10 Ah.

G. Battery Charger

The battery pack of 24 V, 10 Ah has been charged by a 24 V, 4 Ah Switched Mode Power Supply (SMPS) charger. The Fig.14 represents the battery charger of 24 V, 4 Ah.

Fig.14 The Battery Charger of 24 V, 4Ah.

H. Battery Indicator

This is the charge level indicator which shows how much power has been left in the battery. It represents how much the cycle can go more and when it should be needed to put the cycle in charging.

I. Tandem paddling arrangement

This cycle is a Hybrid Electric Vehicle (HEV) so it has an arrangement for paddles connected to the wheels via a chain and a freewheeling pulley. So that riders can run this cycle by paddling along with the motor. There are two paddles arranged in such a manner where the main rider and the pillion rider can paddle the cycle.

J. Power Converter

During the process to recover the kinetic energy (KE), the motor works as a generator. It has been observed that the current from the motor is in the opposite direction while braking. So to utilize the opposite current, the system power converter is used in this cycle. The power converter has been installed to recover the kinetic energy of the cycle in the form of electrical energy which has been stored in the battery pack of 24 V, 10 Ah which has been installed in the electrically driven tandem cycle and this process is also known as regenerative braking.

The power converter which has been used in the electrically driven tandem cycle is nothing but an electrical circuit for changing the electrical energy from one form into the desired form optimized for the specified load. In this project the power converter is a device which may do one or more functions and give an output that differs from the input. It is used to increase or decrease the magnitude of the input voltage, invert polarity [4].

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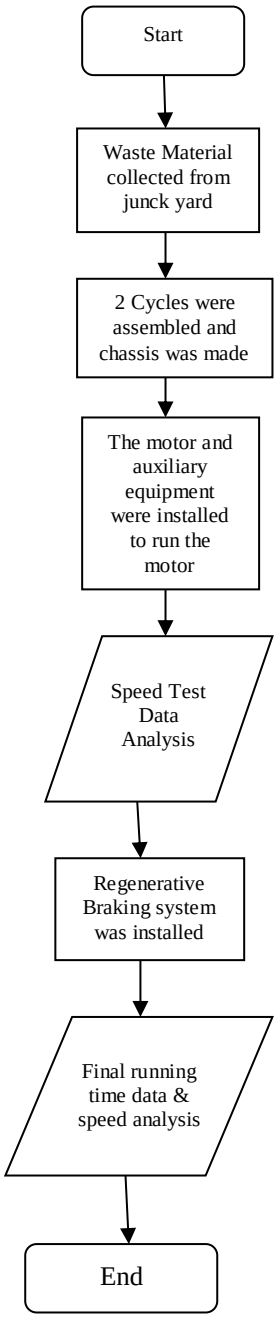
IV. COMPONENTS REQUIRED

TABLE-I

SL No	Equipments used in this project	Specifications	Quantity
1	Chassis	Old damaged Cycle	2
2	PMDC Motor	250 W,240 V	1
3	Battery Pack	24V	1
4	Battery Charger	24 V	1
5	ESC/Motor Controller	300 W	1
6	Power Converter(DC)		1

V. FLOW CHART



VI. MATHEMATICAL EXPRESSION

Equations

Power rating of the battery pack (P) = VI (1)

P= (24×10) =240 W

Where,

Voltage rating of the battery pack (V) =24 V

Current rating of the Battery (I) = 10 Ah

Running time of the motor in minutes, theoretically calculated

$$\frac{\text{Power Raing of the Battery}}{\text{MaximumPower of the Motor}} \times 60 \quad (2)$$

$$\frac{240}{250} \times 60 = 57.60 \text{ minutes}$$

[If it has been assumed that the electrically driven tandem cycle running with 100 % efficiency- Theoretical calculation]

Now efficiency in minutes with respect to time of operation of the electrically driven tandem cycle with regenerative braking arrangement,

$$\text{Efficiency} = \frac{53}{57.60} \times 100$$

$$= 92.01\%$$

Where, Total running time of the tandem cycle in minutes with 100 % efficiency (assumed), theoretically = 57.60 minutes.

Total running time of the electrically driven tandem cycle in minutes with regenerative braking arrangement = 53 minutes.[data obtained from experiment].

Total running time of the electrically driven tandem cycle in minutes without regenerative braking arrangement = 45 minutes.[data obtained from experiment].

Now efficiency in minutes with respect to time of operation of electrically driven tandem cycle without regenerative braking arrangement,

$$\text{Efficiency} = \frac{45}{57.60} \times 100$$

$$= 78.12\%$$

Improvement in efficiency = 92.01% - 78.12%

= 13.89%

Torque of the motor with gear

$$= 9.55 \times \frac{P_{output\ of\ the\ PMDC\ Motor}}{\frac{2\pi \times 3000}{60}} \quad (3)$$

$$= 9.55 \times \frac{250}{\frac{2\pi \times 3000}{60}}$$

$$= 7.60 \text{ N-m}$$

Where, Output power (P_{output})of the Permanent Magnet DC Motor (PMDC)= 250 W

Speed of the Permanent Magnet DC (PMDC) Motor in r.p.m(N) = 3000 r.p.m.

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VII. RESULT & DISCUSSION

Table-2 This table is representing about the data obtained from the experimental work regarding the electrically driven tandem cycle with regenerative braking arrangement and without adopting regenerative braking arrangement in terms of running time and speed.

	Without Regenerative Braking arrangement	**With Regenerative Braking arrangement**
Speed	12 km/h – 16 km/h with the load of two adult male riders of 51 kg. & 70 Kg.	12 km/h -16 km/h with the load of two adult male riders of 51 Kg. & 70 Kg.
Running Time	Before installing the regenerative braking arrangement the cycle was able to run up to 35-40 minutes using a single charge.	After installing the regenerative braking arrangement the cycle is able to run more than 45-50 minutes using a single charge.

VIII. CONCLUSION

It has been concluded that before installing the regenerative braking arrangement the electrically driven tandem cycle was running with a speed of 12-15 Km/h at load condition. It has already been recorded that the electrically driven tandem cycle can run at the same speed at the same load condition after installing regenerative braking arrangement but it has been observed after finishing the experiment that the proposed two wheeler electrically driven vehicle is able to run around 6-8 minutes more time after installation of regenerative braking arrangement as compared to without installing regenerative braking arrangement. As the conventional internal combustion engines (ICE) emit toxic gases from their exhaust to the environment which is very harmful for the environment and the stock of fossil fuel is limited and is going to run out soon [5]. Then the transportation system will remain dead in future. To avoid that nightmare there is a necessity of an alternative source to run the vehicles. So for a new generation of vehicles, electricity represents a great opportunity in transportation system. Moreover the electric vehicles (EV) have high efficiency, low maintenance cost, low running cost and pollution free. On its next version a brushless DC motor (BLDC) will be used which is more efficient than a Permanent Magnet DC Motor (PMDC). On the next up gradation of the proposed work, it will be tried to increase its torque and speed. So that people can easily use this type of vehicle as a substitute for low displacement fuel based motorcycles available in the market for their daily purpose.

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