Chapter 14
Enhancement of Electric Hybrid Vehicle

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Introduction

An electric bicycle is a system of different components that improve the ride comfort with less effort, hence gives a smooth ride to the driver. Light electric vehicles are reducing urban vehicle overcrowding and local pollutant emissions [1]. Every electric vehicle has three goals: Increase the top speed of vehicle, increase the timespan of battery in a single charge and decrease the driver's effort. Solutions to the above problems are: Top speed is increased by the implementation of electric motor. The timespan of battery in a single charge is increased by using smart charging system in vehicle. By the use of electric motor, the pedaling time is decreased, so the driver's effort is also decreased. The bicycle has been an old-fashioned recreational product to a less polluting means of transportation and a compact, ultra-light personal mobility appliance [2].

For humans traveling has become essential. In order to stay with this fast-forward world, we need to travel from one place to another. It is very important that traveling time is very less with less efforts. Also it should be economical and easily available. With the fast-consuming resources of petrol and diesel, there is a need to find other different choice. Taking all this into account, a shift away from conventional-based fuels to using renewable sources of energy is necessary. Electric bike, which will

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be driven by battery thus provides the required voltage to the motor by using some motor controller [3].

With the advancement in the bicycle industry, significant challenges are posed on the bicycle electric system. It involves a complex recharging system, which is used to replace the regenerative braking system, which results in improvement of fuel economy. The regeneration is better for single, three-switch method and stopping time is better for two switch and plugging [4]. E-bike helps in smooth and safe drive at a cost-effective price and it is a user-friendly vehicle [5]. E-bikes has less pollution, low maintenance cost, reduces noise as compared to conventional IC engine bikes. These bikes use chemical energy stored in the rechargeable battery packs [6].

Modern world demands high technology that gives solutions to the current and future problems. Fossil fuel shortage is the main problem nowadays. Considering thr current ratio of usage of fossil fuels will let its life up to only next few decades. Undesirable climate changes are the red indication for not to use more fossil fuel any more. Best alternative for the automobile fuels to provide the mobility and transportation of peoples is by sustainable electrical bike. Future e-bike is the premier technical application as a visionary solution for the better world and the next generation. E-bike comprises the features like high mobility efficiency, compact in size, electrically powered, comfortable riding experience, lightweight vehicle [7]. An e-bike offers a cleaner travel, normally short to medium distance instead of fossil-fueled automotive. From conventional automobile for transportation, we experience problems like traffic congestion, parking difficulties, and pollution from fossil-fueled vehicles [8].

E-bike

An electric bicycle is also known as e-bike, e-motor bike. It is a bicycle with an electric motor and different arrangement used to run the bike. Power diagram of an e-bike is given in Fig. 14.1. Low-power e-bikes use small motor that is used to assist the rider's pedal-power. More powerful e-bikes are very closer to moped-style functionality: if the rider pedals during the ride then it is not an electric motorcycle.

E-bikes use rechargeable batteries, which provide electricity backup up to 25–35 km/h, depending on different laws, while more high-powered e-bike can run up to 45 km/h (28 mph).

E-bikes are the electric motor-powered version of motorcycle, which have been in use since the late nineteenth century.

E-bikes are the mechanical connection between the pedal and the wheel, as the power transmission is purely electric. This principle allows the cyclist to always pedal in optimal conditions and provides more freedom to the designer to effect the pedal feel and the cyclist's effort [1].

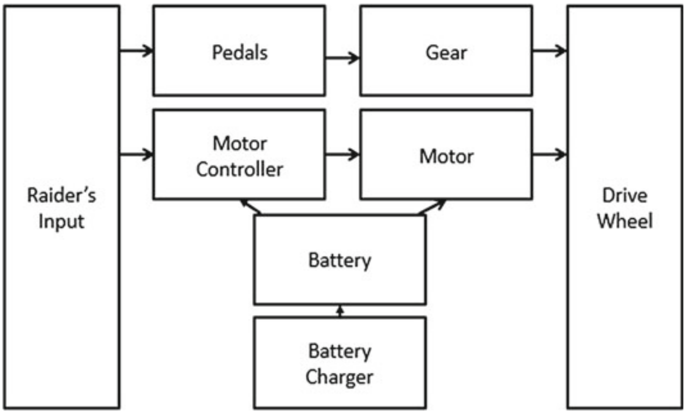

Fig. 14.1 Power diagram

Classes of E-bike

The classification of e-bikes is mainly decided on its power train. The motor of e-bike assists the rider using a pedal assist system or by a power on demand one. These can be defined as follows: In pedal assist system motor is regulated by pedaling. The pedal assist increases the effort of rider when he is pedaling. These e-bikes are known as pedelecs. These kinds of e-bikes have a sensor to detect the speed of pedalling, force of pedalling or both. If they sense the brake activation then they disable motor also.

In power on demand: Throttle is used to active the motor and this throttle is placed on the handlebar like in motorcycles or mopeds or scooters.

Thus, e-bikes can be classified as: Pedelecs or S-Pedelecs.

Pedelecs: It has pedal assist or motorassist. This type of bike has maximum speed of 25 km/h and mainly its motor power is less than or equal to 250 W, so it is legally placed in bicycles.

S-Pedelecs: It has only pedal assist system. This kind of bikes uses more than 250 W motor power, so its maximum speed is also higher than pedelecs. Its maximum speed is around 45 km/h. So it is legally classed as a moped because of its speed.

Motors and Drive Train

There are many types or motor used in e-bikes, like hub motor, brushed or brushless motor, geared motor and so on. There are many arrangements available in different complexities as per different cost. The electric power assists system used with chain drive or belt drive. The power of motor is transmitted through the chain and sprocket arrangement. The power of motor is changed between 250 and 750 W to protect fast wear in drive train.

Battery

Normally e-bikes use rechargeable batteries. There are different types of battery available in the market. for example: lead-acid (SLA), nickel metal hydride (NiMH), nickel cadmium (NiCd) and lithium-ion (Li- ion). There are also different varieties of battery as per the voltage, weight, total charge capacity (Ah), ability to handle overcharging condition, number of cycles before losses in performance. The running cost of e-bike is very less but the battery replacement cost is high. The lifespan of battery depends on the type of use. Schematic charge/discharge cycles can help to increase the overall battery life. Transport vehicles are considered as one of the biggest contributors for global warming and air pollution. With the main focus on environment protection, many researches have been done to the development of electric vehicles (EVs). It has already been widely accepted that EV is a promising transportation alternative due to its high reduction in greenhouse gas emission and air pollution. Battery energy storage system is very important to energy storage and plays a major role in EVs. Among different kinds of batteries lithium-ion battery is the fastest developed and proved to be the most promising component for energy storage [9]. Battery is the most sensitive part in the powertrain of full e-bike or e-vehicle because of its cost and weight. The full electric vehicle range and price are mainly dependent on the battery performances [10]. Battery is the most sensitive element in hybrid powertrain, so a large recover current can cause damage to the battery and reduce its life. Nevertheless, the damage to be usually ignored in regenerative braking [11].

Battery Comparison

1. **LEAD-ACID BATTERY (SEALED)**
   Normally these kinds of batteries are simple to manufacture and cheap in cost. This technology is well-known and reliable. This battery has lowest self-discharge rate in all rechargeable batteries. But we are not able to store these batteries in discharged condition. Lead acid battery has low energy density.
2. **LITHIUM-ION BATTERY**
   This battery has the highest energy density to weight ratio and no memory effect. Li-ion-cobalt is the most developed Li-ion technology with flexible shape options. These batteries need periodic care for long life. However, these kinds of batteries can easily damage by discharge or over charge. All the lithium-ion technologies require a protection circuit to prohibit the overheating.

3. **NICKEL CADMIUM BATTERY**
   Mostly these kinds of batteries have long shelf life in any state of charge and are available in wide range of sizes and performance options. These batteries have high discharge capacity. We are able to do fast and simple charging even after prolonged storage. On the other hand these kinds of batteries have relatively low energy density when compared with newer system and also high self-discharge rate. These batteries are environmentally unfriendly because of some toxic contained in NICD batteries.

System Parts with Specification

We used a simple bicycle with V type brakes having a tire size of 26 in. and frame size around 19.7 mm (Fig. 14.2). Another main part is a PMDC type motor attached to the bicycle, which runs on a 24-V power and gives power output of 250 W. The RPM after reduction is 300 on full load current of 13.4 A and no load current 2.2 A (Fig. 14.3). We can achieve 8 Nm constant torque and stall torque up to 40 Nm. In order to control the motion of the motor a PMDC motor controller is used which runs on 13.2 mA current and 24 V. It runs upon 250 W power. The throttle required for the acceleration of bicycle is a twist-type throttle with inner diameter 23 mm, weight 210 g and a wire length around 1.56 m. We need a DC–DC booster to charge our battery. The XL6009 boost module costs less and delivers superior performance. The best working voltage range is 5–32 V with the super-wide boost output voltage of 5–35 V. It also has circuit protection, overheating protection and short-circuiting protection. The motor is run by two batteries of 12 V with ampere rating 26 Ah. The battery comes with sealed maintenance free up to 24 months warranty and weighs

Fig. 14.2 Pedal system

Fig. 14.3 Motor system

up to 9 kg and occupies 167 × 126 × 175 mm (l × b × h). For this work, we used lead acid battery just because of cost.

Methods of Producing Regenerative Energy

By Using Arduino and L293d

All Arduino circuits works on 5 V and our motor uses 9 or more than 9 V, so we cannot directly run the motor threw Arduino; hence we need a device that can run on both voltage and operate our system. In addition, L293D is one of the best suitable IC which can easily operate motor and Arduino (Fig. 14.4). In L293D V_{ss}: continuous 5 V input on V_{ss} is necessary to operate the circuit. Enable 1/2: here enable 1 and enable 2 both are in opposite direction. To operate any one side of this circuit we need to supply 5 V high pulse on that side enable pin. Output 1/2/3/4: Output 1 and 2 both are on the same side and output 3 and 4 are on the opposite side. All these output pins are designed to connect with motor. Vs: this pin is connected to our external power supply like battery but battery has two terminals so we need two pins to connect battery with circuit. This Vs pin is used to connect to positive terminal of battery. GND: GND 1 and GND 2 are on the same side of the circuit and GND 3 and 4 are on the opposite side of the circuit. Here, full form of GND is GROUND. We can directly connect negative terminal of the battery on any of this one. In addition, Arduino ground pin is connected to any of this one. Input 1/2/3/4: these are connected with motor so that we can easily operate the motor. For example: when we give high

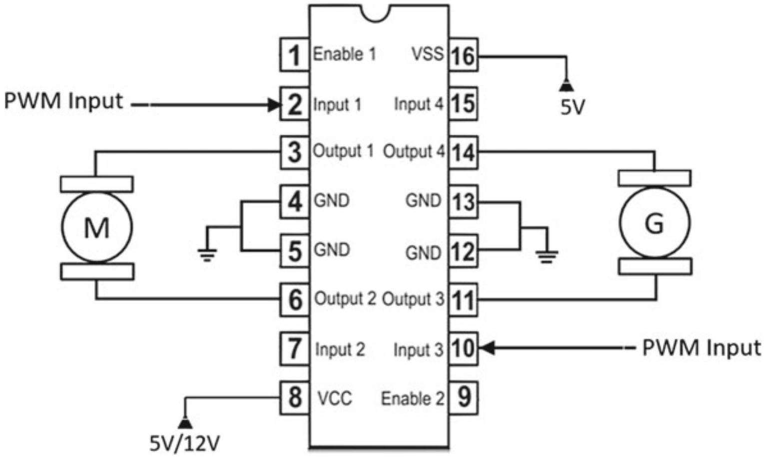

Fig. 14.4 L293D circuit diagram

pulse on input 1 and low pulse on input 2 at that time our left-hand side motor is run in forward direction and the same is applicable for vice versa (Fig. 14.5).

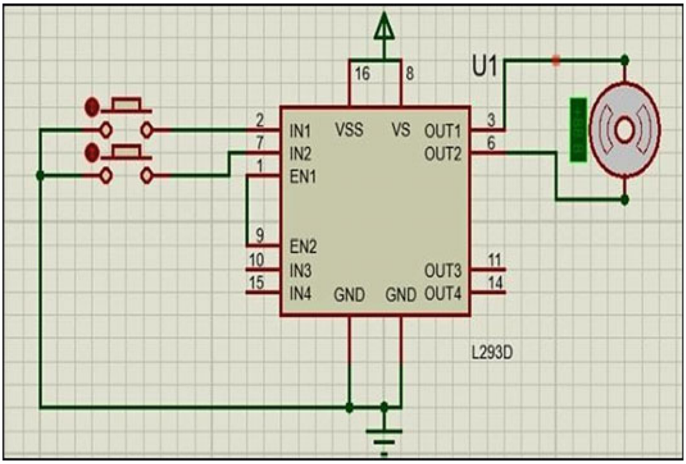

Fig. 14.5 Circuit diagram of L293d with switching

Arduino Coding

```
#define m1 2
#define m2 3
#define m3 4
#define m4 5
Void setup ()
{
pin Mode (m1, OUTPUT);
pin Mode (m2, OUTPUT);
pin Mode (m3, OUTPUT);
pin Mode (m4, OUTPUT);
}
Void loop ()
{
//forward
Digital write (m1, HIGH);
Digital write (m2, LOW);
//backward
Digital write (m3, LOW);
Digital write (m4, HIGH);
```

By Using Switching Method

Rider with the help of pedals runs conventional bicycles (Fig. 14.6) and the power-train of electric bicycle is simpler than the bicycle with energy regenerative system (Fig. 14.7). As shown in Fig. 14.8 energy regenerative system can be operating by some steps which are shown as below (Fig. 14.8) Start the e-Bike. When we press the accelerator pedal at that time current flows from battery to motor through controller, then wheel is rotated and bike is propelled. When we need to decelerate the vehicle without braking at that time press the switch so that current from the battery is cutoff and the motor works as a generator. At that same time our generator generates nearly about 3–15 V so that we are not able to charge 24 V battery system. We can use

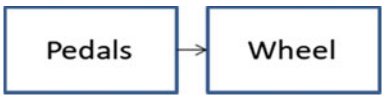

Fig. 14.6 Power train of a Bicycle

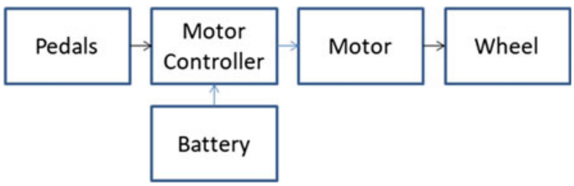

Fig. 14.7 Power train of e-bike

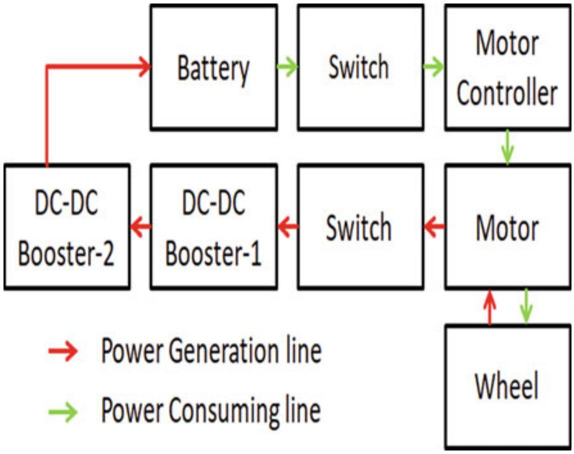

Fig. 14.8 Power train of e-bike with energy regenerative

DC–DC booster to boost the voltage so that we can charge the battery. When we use only one booster at that time, the booster is not able to boost the voltage and current levels to charge the battery sufficiently; hence we can use two booster circuits. To charge the battery with 6 A and 30 V, this current and voltage level is able to charge the battery rapidly. All the above conditions are applicable for braking application, but in braking, the charging of the system is very less. Therefore braking charging time is not much more efficient. When this energy regenerative system is on then at that time we are not able to accelerate the vehicle. Switch off the energy regenerative system to again accelerate or run the vehicle.

Calculation

Vehicle Speed Calculation

$$T2/T1 = N1/N2$$
$$18/14 = 300/N2$$
$$N2 = 256.66 \text{ R.P.M.} \tag{14.1}$$

where,

T2 = Driven Gear Teeth
T1 = Driving Gear Teeth
N2 = Driven Gear Speed
N1 = Driving Gear Speed

$$\begin{aligned} \mathrm{V1} &= r * \omega \\ &= 0.33 * 2\ \mathrm{N2}/60 \\ &= 0.33 * 2200/60 \\ &= 8.8652\ \mathrm{m/s} \\ &= 31.91496\ \mathrm{km/h} \end{aligned} \tag{14.2}$$

where,

$V1$ = Minimum Speed (km/h)

Charging Time Calculation

$$\begin{aligned} &\text{Battery : 24 v 35 Ah Charger : 24 v 7 Ah} \\ &\text{For Battery : Current(I)} = 35\ \text{Ah} \\ &\text{For Charger : Current(I)} = 7\ \text{A} \end{aligned}$$

$$\begin{aligned} \text{Charging Time} &= \text{battery current rating} \div \text{charger current rating} \\ &= 35/7 \\ &= 5:00\ \text{h} \end{aligned} \tag{14.3}$$

Experimental Result

In the current time there are number of e-vehicles available in the market. They do not have regenerative system. So we developed this regenerative system. In the traditional electric cycles BLDC motors are used but in our system we used PMDC motor because it has no input power consumed for excitation, which improves the efficiency of DC motor. No field coil hence space for field coil is saved which reduces the overall size of the motor. Cheaper and economical for fractional kW rated applications as compared with BLDC motor. In our system, we have innovated two methods which are cheaper, simple in construction, less maintenance and easy to operate. In the operation, we have achieved the highest speed up to 35 km/h by changing the gear ratio of motor driving gear and wheel sprocket gear. We need this change because this only enables the motor to give max. speed of 15 km/h with the available traditional gear set. Under the condition that the motor and wheel gear ratio is 1:1. When we apply the 1:1.28 gear ratio (in other words motor has 14-teeth gear and wheel sprocket has 18-teeth gear set) (Eq. 14.1) we get nearly about 27 km/h speed with around 110 kg weight, which is better than the currently available gear set in the market (Eq. 14.2). The changes made are in our favor as our main goal is to regenerate the electricity when vehicle is in deceleration mode. When we attach the motor at the wheel gear set in 1:1 ratio and if vehicle starts to decelerate, then at that time huge amount of load is transmitted to motor through wheel, so the problem of slipping of chain arises. Electricity regeneration can be done by many conventional methods, like by using different conventional ICs but we did the same thing in a different way for reduction in cost. Therefore, we need to fix clearance between both gears. We have used regenerative braking system using electrical switches and connected the electrical wires so that it is easy to operate and control. After the testing of recharging system, the charging voltage obtained is of the range 25–32 V and the current rating is 1.5–4.7 A, which is sufficient to charge the 24 V battery. Using this method, we can easily reduce the cost of the system largely and increase the efficiency because of a smaller number of components used in this system. If we use 24 V, 35 Ah battery and 24 V 7 A charger, then it take around 5 h to charge the full battery (Eq. 14.3).

Conclusion

From the above theoretical calculation and practical experimentation, we conclude that by changing the gear ratio the speed of vehicle is increased. By using the regenerative system we are able to generate the energy and with this energy we are able to charge the battery up to 30%.

If one vehicle can save about an average of 30% of energy, then an average of about 30–40% of charging electricity is conserved by using this type of vehicle. In addition, electric bill can also be reduced, as the battery can last long per charge.

The durability and convenience to consumer can be improved by using this type of vehicle. Charging of lead acid batteries can be done when vehicle is in motion and accelerator in rest condition. Thus, a number of different aspects with the use of e-bike in different situations emerge. These include lower energy cost per distance traveled for a single rider, savings in other costs such as insurance, license, registration, parking, and improvement of traffic flow, environmental friendliness, and the health benefits of the rider.

We can conclude that this e-bike is efficient and can reduce energy losses. It is economical for human being. E-bike has zero-pollution emission. Therefore, less pollution reduces the traffic visibility problem in city. E-bikes do not affect the environment and does not contribute to global warming effect. By using this kind of electric vehicle we can save our environment. In future, we can reduce the undesirable climate change by less use of conventional IC engines and more use of e-vehicles.

References

1. Guanetti J, Formentin S, Corno M, Savaresi SM (2017) Optimal energy management in series hybrid electric bicycles. Automatica 81:96–106
2. Salmeron-Manzano E, Manzano-Agugliaro F (2018) The electric bicycle: Worldwide research trends. Energies 11:1–16
3. Shinde Kung D (2017) Literature Review on Electric Bike. IJRMET Int J Res Mech Eng Technol 7:2249–5762
4. Joseph Godfrey A, Sankaranarayanan V (2018) A new electric braking system with energy regeneration for a BLDC motor driven electric vehicle. Eng Sci Technol Int J 21:704–713
5. Pothirasan N, Rajasekaran MP, Muneeswaran V (2018) Real time reactive power compensation for battery/photovoltaic hybrid power source for internet of hybrid electric vehicle system. Cogn Syst Res 52:473–488
6. Katoch S, Rahul Bindal R K (2019) Design and implementation of smart electric bike eco-friendly. Int J Innov Technol Explor Eng 8:965–967
7. Trivedi MM, Budhvani MK, Sapovadiya KM, Pansuriya DH, Chirag D (2017) Design & development of E-bike—a review. Des Dev of E-Bike—A Rev 1:36–43
8. Sharma Y, Banker P, Raikwar Y, Chauhan Y, Sharma M (2018) R&D on Electric Bike, 610–614
9. Liu D, Song Y, Li L, Liao H, Peng Y (2018) On-line life cycle health assessment for lithium-ion battery in electric vehicles. J Clean Prod 199:1050–1065
10. Redondo-Iglesias E, Venet P, Pelissier S (2018) Calendar and cycling ageing combination of batteries in electric vehicles. Microelectron Reliab 88–90:1212–1215
11. Wu J, Wang X, Li L, Qin C, Du Y (2018) Hierarchical control strategy with battery aging consideration for hybrid electric vehicle regenerative braking control. Energy 145:301–312