VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JnanaSangama, Belagavi – 590018

A Project Report
On

" Foldable E-bike "

Submitted in partial fulfillment of the requirements as a part of the curriculum,

Bachelors of Engineering in Mechanical Engineering

Submitted by

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2019-20

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CERTIFICATE

Certified that the project work entitled "**Foldable E-bike**" is a bonafide work carried out by **Mr.Vishnu M Nair, Mr.Vaishak SV,** bonafide students of **CMR Institute of Technology** in partial fulfillment for of the requirements as a part of the curriculum,

Bachelors of Engineering in Mechanical Engineering, of **Visvesvaraya Technological University, Belagavi** during the year **2019-20**. It is certified that all correction/suggestion indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the bachelor of engineering degree.

(Prof. Chidhananda.R.S)	**(Dr. Vijayanand Kaup)**	**(Dr. Sanjay Jain)**
Signature of the Guide	**Signature of the HOD**	**Signature of the Principal**

External Viva

Name of the examiners	**Signature with date**

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DECLARATION

We, students of Eighth Semester, B.E, Mechanical Engineering, CMR Institute of Technology, declare that the project work titled **"Foldable E-bike"** has been carried out by us and submitted in partial fulfillment of the course requirements for the award of degree in **Bachelor of Engineering in Mechanical Engineering** of **Visvesvaraya Technological University, Belagavi,** during the academic year 2017-2018.

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Place: Bengaluru

Date:

Project Report

On

Foldable E-bikes

BY

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ABSTRACT

In the concept of smart cities, quickness is something which everyone craves for. People prefer the fastest means while travelling from one place to another. Generally, while maintaining a trade-off between speed, comfort and cost public transit comes out to be the best solution. But since these vehicles have specific routes and stations, people face difficulty in going to the station from source location and then from the other station to destination. Use of fuel powered vehicles is not recommended due to the depletion of fossil fuels, also these vehicles pose a major threat to the safety to the lives of many. Apart from the noise and air pollution, fuel powered vehicles are quite powerful and thus unsafe if don't used with care. A foldable electric bike may be possible solution to these problems. While serving to the needs for ease and speed, it maintains safety. This bike has an upper limit for the power and speed which ensures safety of the rider. This bike can be folded to an extent that it can be stored in a backpack after use. This foldability makes it compatible for use with public transit, user can use it to travel to station and then fold & store it the backpack while travelling from the public vehicle. The weight of the bike is kept such that it may easily be carried on shoulders without the feeling of uneasiness. This bike is ideal to use for short distance (around 12 kilometers) trips. The major target of this foldable electric bike for commercialization are the people who travel by metros and public transport means for their daily routine work. This bike can be sold in cities where people needs a solution to travel shorter distance at low price.

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1. INTRODUCTION

A **folding bicycle** is a bicycle designed to fold into a compact form, facilitating transport and storage. When folded, the bikes can be more easily carried into buildings, on public transportation (facilitating mixed-mode commuting and bicycle commuting), and more easily stored in compact living quarters or aboard a car, boat or plane.

Folding mechanisms vary, with each offering a distinct combination of folding speed, folding ease, compactness, ride, weight, durability, and price. Distinguished by the complexities of their folding mechanism, more demanding structural requirements, greater number of parts, and more specialized market appeal, folding bikes may be more expensive than comparable non-folding models. The choice of model, apart from cost considerations, is a matter of resolving the various practical requirements: a quick, easy fold, a compact folded size, or a faster but less compact model.There are also bicycles that provide similar advantages by separating into pieces rather than folding.

Fig 1.1 :Unfolded bicycle

Fig 1.2 : Folded bicycle

1.1 HISTORY

Military interest in bicycles arose in the 1890s, and the French army and others deployed folding bikes for bicycle infantry use. In 1900, Mikael Pedersen developed for the British army a folding version of his Pedersen bicycle that weighed 15 pounds and had 24 inch wheels. It included a rifle rack and was used in the Second Boer War.

In 1941, during the Second World War, the British War Office called for a machine that weighed less than 23 lb (this was not achieved - the final weight was about 32 pounds) and would withstand being dropped by parachute. In response, the Birmingham Small Arms Company (BSA) developed a folding bicycle small enough to be taken in small gliders or on parachute jumps from aircraft.

This British WWII Airborne BSA folding bicycle was rigged so that, when parachuted, the handlebars and seat were the first parts to hit the ground (as bent wheels would disable the bike). BSA abandoned the traditional diamond bicycle design as too weak for the shock and instead made an elliptical frame of twin parallel tubes, one forming the top tube and seat stays, and the other the chainstay and down tube. The hinges were in front of the bottom bracket and in the corresponding position in front of the saddle, fastened by wing nuts. The peg pedals could be pushed in to avoid snagging and further reduce the space occupied during transit.

From 1942–1945, the British WWII Airborne BSA folding bicycle was used by British & Commonwealth airborne troops, Commandos, and some infantry regiments; some were also used as run-abouts on military bases. The bicycle was used by British paratroopers, Commandos, and second-wave infantry units on the D-Day landings and at the Battle of Arnhem.

The 1970s saw increased interest in the folding bike, and the popular Raleigh Twenty and Bickerton Portable have become the iconic folders of their decade. It was, however, the early 1980s that can be said to have marked the birth of the modern, compact folding bicycle, with competing tiny-footprint models from Brompton and Dahon. Founded in 1982, by inventor and physicist Dr. David Hon and his brother Henry Hon, Dahon has grown to become the world's largest manufacturer of folding bikes, with a two-thirds marketshare in 2006

1.2 FOLDING METHODS

Half- or mid-fold

Many folding frames follow the classic frame pattern of the safety bicycle's diamond frame, but feature a hinge point (with single or double hinges) allowing the bicycle to fold approximately in half. Quick-release clamps enable raising or lowering steering and seat columns. A similar swing hinge may be combined with a folding steering column. Fold designs may use larger wheels, even the same size as in non-folders, for users prioritizing ride over fold compactness. Bikes that use this kind of fold include, Dahon, and Montague, and Tern.

Vertical Fold

Instead of folding horizontally, this style of bike has one or two hinges along the main tube and/or chain and seat stays that allow the bike to fold vertically. The result leaves the two wheels side by side but is often more compact than a horizontally hinged design. The Brompton and Dahon Qix D8 both feature vertical folding.

Triangle hinge

A hinge in the frame may allow the rear triangle and wheel to be folded down and flipped forward, under the main frame tube, as in the Bike Friday, Brompton Mezzo Folder, and Swift Folder. Such a flip hinge may be combined with a folding front fork, as in the Birdy. Swing and flip hinges may be combined on the same frame, as in the Brompton Mezzo Folder and Dahon, which use a folding steering column. Folding mechanisms typically involve latches and quick releases, which affect the speed of the fold/unfold. Bike Friday offers a model, the Tikit, featuring a cable-activated folding mechanism requiring no quick releases or latches, for increased folding speed.

Magnet folding and suspension system

A magnet combined with a rear shock absorber forms the folding mechanism. The magnet connects and locks the back wheel section to the frame. To fold the bike in half, the magnet disconnects with one movement and in a second, and without having to use one's hands, the rear wheel rotates forward, and the bike folds vertically. This mechanism also enables one to roll the half-folded bike on its rear wheel.

Break away and other styles

Bikes may partly fold and partly disassemble for packing into a standard or custom sized suitcase for air travel. Other variations include: Bicycle Torque Coupling, a proprietary connector system that can be retrofitted to a standard frame; the Gekko, which folds from the seat tube like an upside down umbrella; the Giatex, which folds and retracts, adjusting to the size of the rider; the iXi, which literally breaks into two halves; and the Strida, which has a triangular frame and folds to resemble a unicycle.

Folding mechanisms may incur more cost and weight, allow folding smaller, and they tend to use smaller wheels. 24 inch wheels are the largest for which flip hinges are generally used, but smaller wheels, typically 16 or 20 inches, are more common.

Smaller size does not mean lighter weight, as most of these designs forgo the bracing benefits of the diamond frame and must compensate as a step-through frame does, with thicker metal. The step-through design is a boon to a wider range of rider size, age, and physical ability.

Another system found on folders, such as Montague Bikes, utilizes the seat tube as a pivot point for the frame to fold. This system uses a tube within a tube design to give the bike more torsional stiffness. It allows the user to fold the bike without "breaking" any vital tubes down, thus preserving the structural integrity of the diamond frame. This system is operated by a single quick release found along the top tube of the bike.

1.3 ELECTRIC BIKES IN INDIA

Bajaj Auto will be developing a new low-cost electric scooter for shared e-mobility service start-up Yulu that could be priced at around Rs 35,000. A report in Moneycontrol.com said that Bajaj has already started to develop the e-scooter to compete with Chinese players.

Currently, the Bangalore-based Yulu imports kits for electric scooters from China and assembles them in India. Yulu has an inventory of 4,000 e-scooters on the roads, which it intends to increase to 100,000 units by December 2020 and will be spending Rs 400 crore for the same. With the increase in production, Yulu will also be looking to expand its presence to 56 cities across India, reports Yourstory. The company currently offers its services in Bangalore, Bhubaneswar, Mumbai, Pune and Delhi.

Fig 1.3 : Yulu Miracle E-scooter

“We are spending about $600 per bike.We are getting them manufactured in China and assemble them in India.With Bajaj Auto coming on board,we can bring down the prices to $500 in the medium to long term. From over Rs 40,000 we can bring it down to Rs 30,000 to 35,000.A product is customized for shared mobility.”said Amit Gupta, Co-Founder & CEO, Yulu

Yulu's current e-scooters are powered by a 48V motor and come with a top speed of 25 km/h and a range of 60 km per charge.

In November 2019, Bajaj Auto invested $8 million in Yulu for it to expand its operations. Bajaj will also be considering assisting in vehicle finance to enable Yulu to achieve large scale deployment.
"At BAL,we believe that the two factors of congestion reduction and pollution control will drive the segment of shared micro-mobility in the future.That coupled with the expansion of Mass Rapid Transport System like Metro in large cities will further boost the demand for flexible last-mile connectivity.In Yulu we find an experienced and commited partner with the robust achievement of success matrix in a very short time.And this is why we decided to partner with them in their journey of bringing Yulu service to every neighbourhood of Urban India." said Rajiv Bajaj,MD of Bajaj Auto

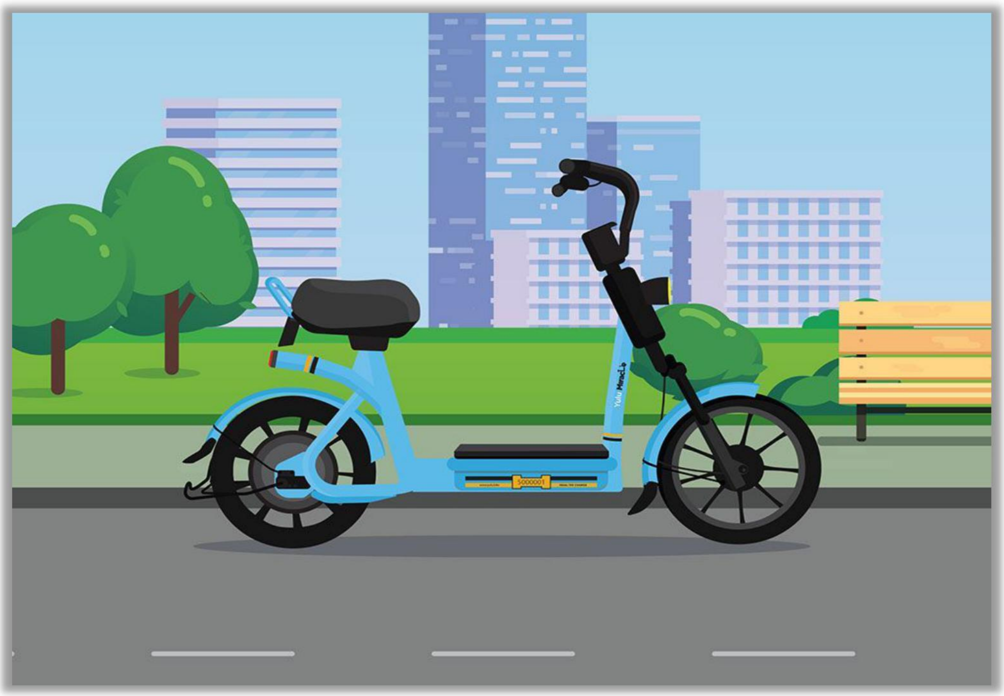


Fig 1.4 : Yulu Miracle

1.4 NEED FOR ELECTRIC BIKES

While many countries have included EVs as an element of transportation policy, their responses have varied according to their stage of economic development, energy resource endowments, technological capabilities, and political prioritization of responses to climate change. In India, a particular set of circumstances which are conducive to a sustainable mobility paradigm have created an opportunity for accelerated adoption of EV's over ICE vehicles.

These are:

1. A relative abundance of exploitable renewable energy resources.
2. High availability of skilled manpower and technology in manufacturing and IT software.
3. An infrastructure and consumer transition that affords opportunities to apply technologies to leapfrog stages of development.
4. A universal culture that accepts and promotes sharing of assets and resources for the overall common good. These circumstances position India to pursue an EV policy which systematically ensures that India's EV program keeps pace with the global scale since large economies seem to take significant steps towards electrification of vehicles. India's growth prospects create potential for developing leadership in EV in certain segments. In that sense, the policy will encourage a path which starts with India-specific characteristics and initiatives for its auto sector, building towards global relevance and applications.

The key objectives of the EV policy are:

1. Reduce primary oil consumption in transportation.
2. Facilitate customer adoption of electric and clean energy vehicles.
3. Encourage cutting edge technology in India through adoption, adaptation, and research and development.
4. Improve transportation used by the common man for personal and goods transportation.
5. Reduce pollution in cities.
6. Create EV manufacturing capacity that is of global scale and competitiveness.
7. Facilitate employment growth in a sun-rise sector. III.

2. LITERATURE SURVEY

2.1.1 **Title:** Fabrication of Electric Car

Author: Bjarni Freyr Gudmundson and Mr. Esben Larsen

Year: 2014

Bjarni Freyr Gudmundson and **Mr. Esben Larsen [1]** in their research paper have discussed various techniques in which the foldable electric motorbike can be developed. They made a conceptual design and did detailed analysis on specification, material selection, design and structural analysis, component selection, test drive. Their basic idea behind manufacturing this type of design was to give the comfort and compact ability to the driver, so that the driver can feel safe and comfortable to enjoy every ride of kart. For making a vehicle the following subsystems such as chassis subsystem handling subsystem, wheel and tire subsystem, brake subsystem and power train subsystem should be designed and fabricated. They worked on the power train for the vehicle and also initiated work on developing a powerful, lightweight motorbike. They thought about the cost and efficiency of vehicles. To minimize the cost of the vehicle, they used electric arc welding as it is a cheap and reliable option available. They also made a foldable electric bike, providing all details and procedures. They also discussed various future works that can be done on their project.

2.1.2 **Title:** Design and Fabrication Of Foldable Tri-Scooter

Author: Mr. Sachin Achari

Year: 2015

Mr. Sachin Achari [2] with his team has discussed the feasibility, use and design procedure of the foldable tri scooter. They made an effort in the experimental analysis as well as in the design part of the project. Their main aim was to design a portable automobile which should be very easy to carry as well as easy to handle by both the sexes with equal ease. The aim was also that it should be environmentally friendly and should be non-polluting. They used D.C motor as their main power source due to which there is no emission at all and also the problem of fuel consumption can be solved. Also keeping in mind the parking problems, they made a tri-scooter which can be folded easily, so after the use one can fold the tri-scooter and can carry it along with him/her. Their design allows users to easily transport the tri-scooter using less space when it is folded into a compact size. They were the first to offer foldable tri-scooter in the market. While designing they concentrated on power, economy, ease and comfort of riding and low maintenance cost. Also they concentrated on ergonomics factor to give the user a comfortable ride. Their objectives included folding ease, Portability, Reliability and retailer network. The Foldable Electric Bike Department of Mechanical Engineering, CMRIT 11 used mild steel as the frame material welded in suitcase shape which serves as the base to hold all the accessories such as motor, weight of the load to be conveyed and the weight of the person driving the unit. They also discussed the advantages of the foldable tri-scooter.

2.1.3 **Title:**Design and Development of Foldable Kart Chassis

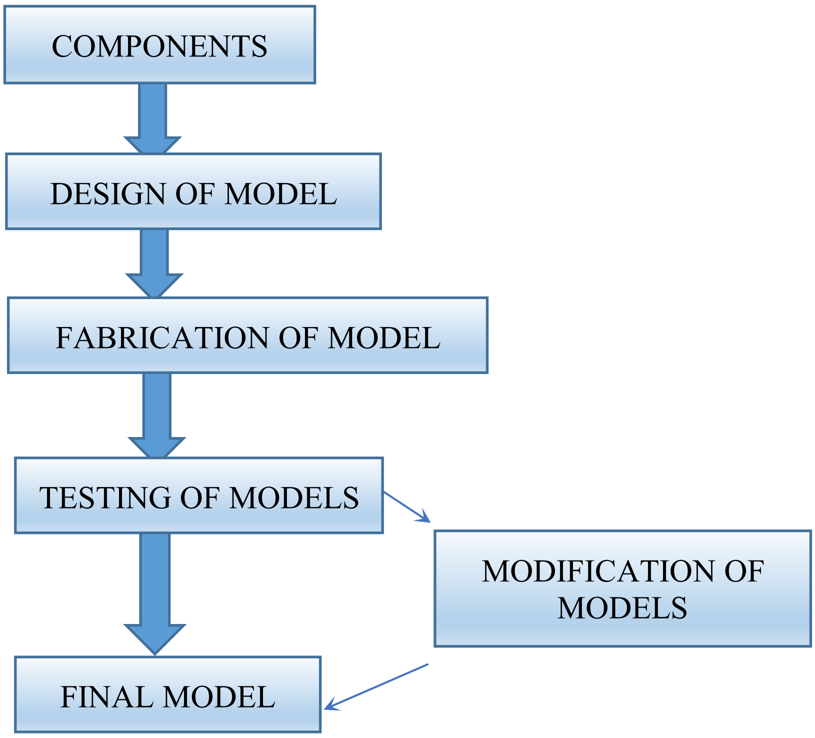
Autjor: Mr. Akash Chaudhary Raghuvanshi

Year: 2015

Mr. Akash Chaudhary Raghuvanshi [3] with his team had made an effort in developing foldable kart chassis. They understood the thing that the world is going towards compactness, where all things are going to compact and its time is to think about vehicles which can be folded easily and can be taken everywhere as luggage. By this innovative idea, he conducted the structural analysis on the frame of their kart vehicle and developed a GO KART named as ―ASHVA‖ which can be folded by its mid with the help of a joint that connected between its two chassis front chassis-rear chassis. They knew that Karts are used to just take the experience of racing cars. Mostly they are very entertaining vehicles in the markets. Taking this into consideration they manufactured an automobile that would be something really out of the box. As the speed of kart varies on the power of the engine and how much fuel it takes. The chassis of the kart was made up from mild steel and the joint of kart had been made up of mild steel. This joint gave more power and stability to their vehicle. They used a mechanical chain to transmit the power from the engine to the axle of kart. For a better karting experience, rack and pinion system was used by them. A fish body is a perfect aerodynamic natural structure, one can get inspired with hence the chassis of the kart was developed with an igniting idea of a fish body. Selection of material plays an important role in the strength and safety of the product that was the reason they chose AS-202 stainless steel round tubes as a chassis material. Also they chose the material for the shaft so that it can bear all the stresses.They discussed the material selection procedure. They made an effort in describing the joints that can be used in foldable vehicle chassis.

3.METHODOLOGY

The methodology of the project is as follows:



PROPOSED SYSTEM

This E-bike will use a semi-circular tube chassis which will follow the curvature of the wheel.With the help of a single sided swingarm it will allow the rear wheel travel to the inner portion of the chassis where it can be locked. The front forks can also be folded into the position beside the rear wheel in folded position. The bottom part of the chassis contains the battery and a contact patch for charging when docked.The folding chassis uses a telescopic mechanism for more efficient packing to reduce the size from 1.2m to 0.6m.

3.1COMPONENTS

3.1.1 HUB MOTOR

Comparison between different types of Hub Motor :

Type 1 : Stepper DC Motor

Advantages: Precision positioning stepper DC high holding torque

Disadvantages: Slow Speed , requires a controller

Application: positioning in printers and floppy drives

Typical Drive: Multi-phase DC

Type 2 : Brushless DC Electric Motor

Advantages: Long Life span, Low maintenance, High efficiency

Disadvantages: High Initial cost, requires a controller

Application: Hard Drives, CD or DVD Players, Electric Vehicles

Typical Drive: Multi-phase DC

Type 3: Brushed DC Electric Motor

Advantages: Low Initial cost, simple speed controller

Disadvantages: high maintenance(brushes), limited life span

Application: Thread mill exercisers, automotive starters, toys

Typical Drive: Direct(PWM)

Based on the above comparison, the brushless DC motor is selected,

BLDC Hub Motor: A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/ commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system. In hub motors, the axle is held firm so it can’t rotate and whole motor start to rotate.

Brushless motors offer several advantages over brushed DC motors, including more torque per weight, more torque per watt, increased efficiency, increased reliability, reduced noise, longer lifetime. With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter. The efficiency of BLDC motor is 84%. The BLDC motor can be configured in 1-phase, 2-phase, and 3-phase. Three-phase motors are the most popular among all the configurations and are widely used in e-bikes.

Fig 3.1 : Hub motor

The structure of a BLDC motor is divided into two parts:

• Moving part called the rotor, represented by permanent magnet

• Fixed part called the stator, represented by phase windings of magnetic circuit

Stator

The stator of a BLDC motor consists of stacked steel laminations with windings placed in the slots that are axially cut along the inner periphery.Traditionally, the stator resembles an induction motor; however, the windings are distributed in a different manner. Most BLDC motors have three stator windings connected in star fashion. Each winding is constructed with numerous coils that are interconnected to form a winding. One or more coils are placedin the slots and they are interconnected to make a winding. Each winding is distributed over the stator periphery to form an even number of poles.

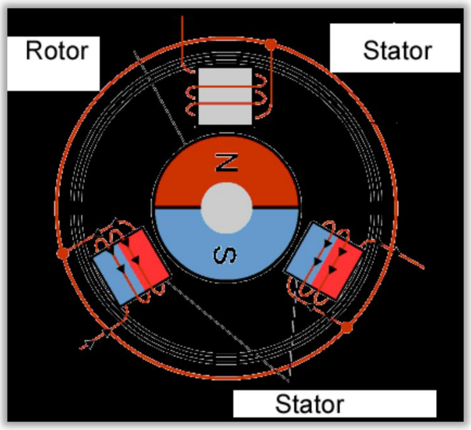


Fig 3.2 : C/S view of Motor

Rotor

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles.

BLDC Motor Mechanical Structure

Unlike a brushed DC motor, BLDC motor can be controlled electronically. To rotate the BLDC motor, the stator windings must energized in a special sequence. The rotor position must be known in order to understand which winding will be energized next. The rotor position is sensed using Hall Effect sensors that are embedded in the stator. Most BLDC motors have three Hall sensors embedded in the stator on the nondriving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they generate a high or low signal, which indicates that N or S pole is passing near the sensors. Based on the combination of these Hall Sensor signals, the exact sequence of commutation can be determined. Because of the increasing popularity of E-bikes, motors designed specifically for E-bike applications are now commercially available. These motors vary a great deal in how they are mounted to a bicycle and in how the power is applied to them.

The following power train and motor types have multiple examples in the market today:

Belt-drive transmission a specially designed motor is mounted low in the frame, and drives the rear wheel by use of a belt.

Direct drive (in-line chain drive) this method has the motor working with the primary bicycle chain the same chain that the rider uses when pedalling. Gearing for the motor varies with each manufacturer.

Frame-mounted motor with dedicated chain drive another common method is to mount a motor to the bicycle frame near the hub of the rear wheel, often on one side.
The motor has its own small chain that drives a planetary gear on the rear wheel. This specialized chain is separate from the primary bicycle chain that remains in use with the bicycle pedals. Gearing remains specific to the manufacturer or aftermarket motor conversion kit.
Wheel-mounted disk motor this is a pancake or dish plate motor, sometimes even called a Frisbee motor, installed on one or both wheels. These motors can be placed on both wheels, effectively doubling the power available to the rider. However, these motors increase weight and centrifugal force on wheels.

Hub motor ideally, the term hub motor refers to a motor that replaces the hub of a wheel. Sometimes this can be a flat disk motor, other times it is not a disk motor. In either case, the motor is the hub instead of being mounted beside it or near it.

Friction-based shaft: This type of electric drive installs the motor very close to one wheel. A shaft extends from the motor, and this rotating shaft drives the wheel by spinning in direct contact with it. The motor does not interact with the chain. Multiple gears for the motor are rarely supported.

Geared transmission-style shaft drive this type of electric drive is like a shaftdriven motorcycle. The cycle does not have a chain. The motor and the pedals apply power to a sealed and protected shaft that has bevel gears in front and back. Multiple gears (speeds) are supported.

Based on the information listed in Table, a 250-W rear hub motor is selected with the following performance details:

Rated Voltage : 24V
Rated Power : 250W
Wheel size : 12-18 inch
Rated Speed : 20km/hr
Weight : 3kgs

POWERTRAIN TYPE	ADVANTAGES	DISADVANTAGES
Belt-drive transmission	• Allows for a great deal of customization in design • Silent operation	Might reduce the performance of pedalling when motor is not used
Direct drive (conventional inline chain)	• No additional chain needed • Monocoque frames can hide the motor with great protection • The motor might inherit as many gears as are available to the rider • Low centre of gravity	• Perceived (Standard)drag upon the chain • Chain remains visible, perhaps vulnerable to dirt • Potential for noise
Frame mounted motor with dedicated motor	• A dedicated chaincan attain good power transfer without complications	• A second chain and planetary gear are required • Multiple gears for the motor may or may not be available
Wheel mounted disk motor (pancake motor)	• The most efficient approach so far • No planetary gears or spinning shafts are needed for power • Retain good protection from elements	• Places a great deal of weight in the wheels, with potential handling issues at higher speed. • Multiple gear for the motor may or may not be present
Hub motor (non-disk)	• No interaction with the primary bicycle chain required • No additional transmission required	• Adds weight to the wheels • Torque factors can enter operational consideration • Unsprung weight or mass
Friction based shaft drive	• Inexpensive • Easy to mount • By far the most mechanically simple concept	• Inefficient no gearing • Friction wear out tyres • Motor must sustain very high rpm's at higher cycle speeds
Geared transmission style shaft drive	• Multiple gears are common	• Changing tyres and reinstalling the wheel may become more demanding than other methods

Table 3.1 : Types of power transmission systems

3.1.2 Battery

Electric bicycles are often restricted to a speed of 30 km/h across level ground. A larger wattage increases the range and can increase the uphill torque, however, a larger wattage does not typically increase the maximum speed which is restricted.

Power Train type	Advantages	Disadvantages
Lead-Acid	• Inexpensive and simple to manufacture • Mature , reliable and well known technology • Low self-discharge	• Not to be stored in a discharged condition • Not Environmentally Friendly
Lithium - ion	• Highest energy density to weight ratio • Eliminates need for periodic care for a long life • Has no memory effect • Achieves a better cost performance ratio	• All lithium ion technology requires a protection circuit to prevent over heating • Can damage easily by overcharge or discharge
NiCd	• Fast and simple charge even after prolonged storage • High number of charge and discharge cycles , if properly maintained • Good load performance , the NiCd allows recharging at low temperatures	• Relatively low energy density when compared with newer systems • Memory effect • Environmentally unfriendly , the NiCd contains toxic metals • Some countries are limiting the use of NiCd battery
NiMH	• Less prone to memory than the NiCd periodic exercise cycles are required less often • Environmentally friendly ,	• Limited service life • Repeated discharges with high load currents reduce the battery cycle life • Performance degrades if stored at elevated temperatures

Table 3.2 : Comparison of the different battery types available

Based on the information listed in Table, 2 Lead Acid batteries are selected. The 12-V, 7.2AH battery is selected with the following performance specification:

• Maximum discharge current: 108A

• Charging cycles: 1000 times

Lead acid batteries

The storage battery or secondary battery is such a battery where electrical energy can be stored as chemical energy and this chemical energy is then converted to electrical energy as and when required. The conversion of electrical energy into chemical energy by applying external electrical source is known as charging of battery. Whereas conversion of chemical energy into electrical energy for supplying the external load is known as discharging of secondary battery.

During charging of battery, current is passed through it which causes some chemical changes inside the battery. This chemical changes absorb energy during their formation. When the battery is connected to the external load, the chemical changes take place in reverse direction, during which the absorbed energy is released as electrical energy and supplied to the load. These batteries come with a light-weight (1 kg each) secure connector.

A universal charger with the following specifications is available off the shelf.

• AC input: 240 V

• Charger output: 30 V at 2 A

Fig 3.3 : Battery

3.1.3 Controller

For precise speed control of servo system, closed-loop control is normally used The speed, which is sensed by analog sensing devices (e.g., tachometer) is compared with the reference speed to generate the error signal and to vary the armature voltage of the motor.

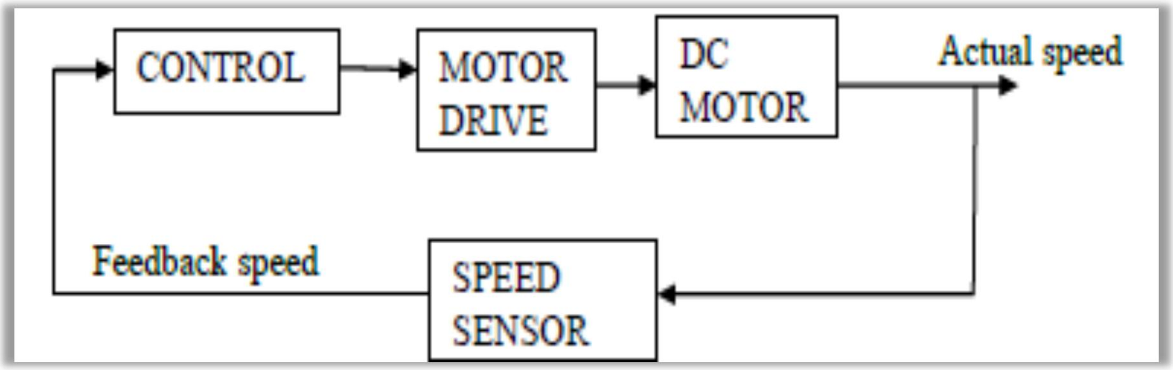


Fig 3.4 : Basic block diagram for DC Motor speed control

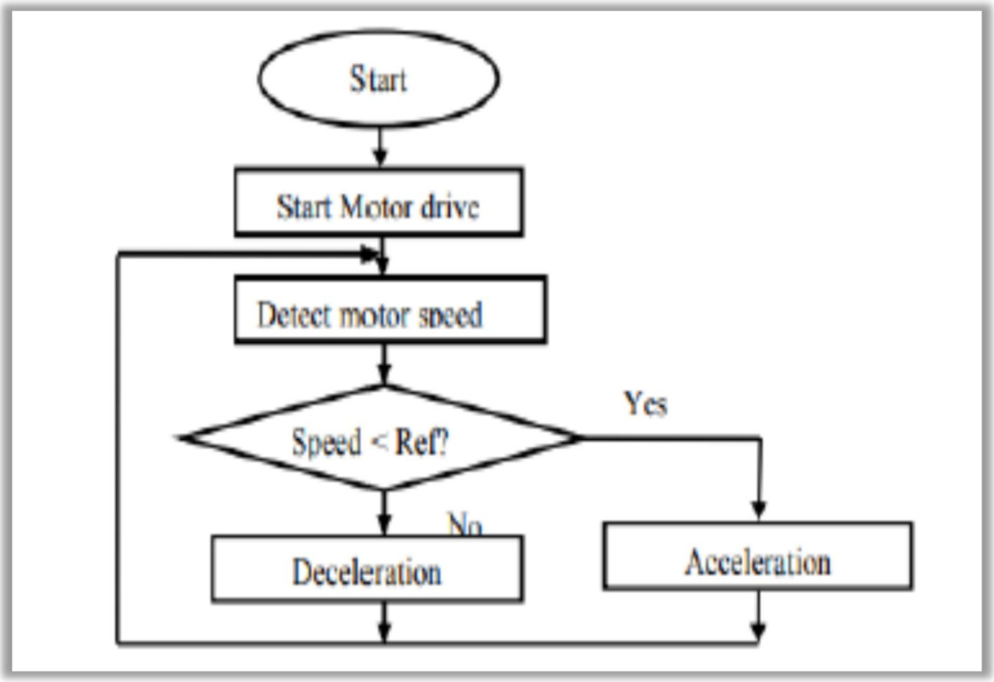


Fig3.5 : Basic flow chart of DC motor speed control

E-bike Controller Specifications:

Voltage: DC 24V

Minimum Voltage : DC 20 V

Maximum Current: 17 Amps

Wattage: 250W

Throttle : 1-4V

Level Brake: low

Under Voltage Protection: 20.5 Volts

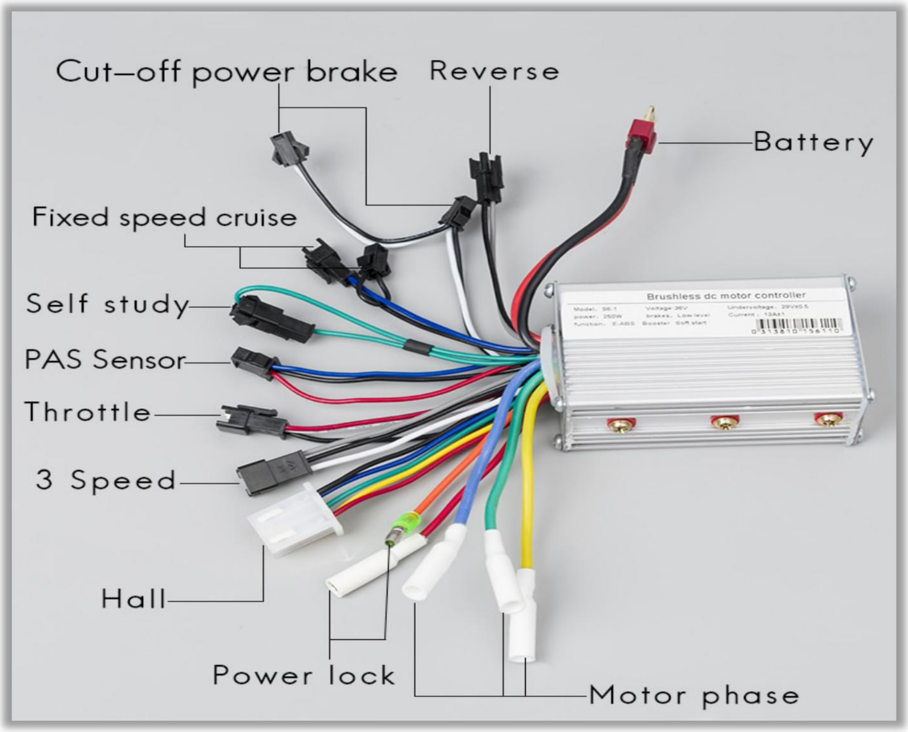


Fig 3.6 : Controller attachment layout

E-bikes require high initial torque and therefore models that use brushless motors typically have Hall sensor commutation for speed and angle measurement. An electronic controller provides assistance as a function of the sensor inputs, the vehicle speed and the required force. The controllers generally allow input by means of potentiometer or Hall Effect twist grip (or thumb-operated lever throttle), closed-loop speed control for precise speed regulation, protection logic for over-voltage, over-current and thermal protection. Bikes with a pedal assist function typically have a disc on the crank shaft featuring a ring of magnets coupled with a Hall sensor giving rise to a series of pulses, the frequency of which is proportional to pedaling speed. The controller uses pulse width modulation to regulate the power to the motor. Sometimes support is provided for regenerative braking but infrequent braking and the low mass of bicycles limits recovered energy.

3.1.4 Brakes

E-brake cut off levers are an integral part of many E-bike systems either to trigger regenerative braking or act as a motor safety shutoff when the rider engages the and brakes. On conversion bikes this typically requires replacing your entire brake levers with a lower quality 3rd party lever that has an integrated switch, and on systems with hydraulic brakes options are both limited and expensive.

Fig 3.7 : E-brake lever

An E-brake cut off switch is designed for reliable attachment to your existing hydraulic or mechanical brake levers, so that you do not need to replace or modify your entire brake assembly just to have E-brake functionality. Unlike other common approaches using a separate magnet and sensor assemblies which need to be carefully positioned and are prone to misalignment over time. The e-brake operates through a small cable secured to the moving part of your lever arm. There is no need to bleed your lines on hydraulic systems or feed a new brake cable with mechanical brakes, your physical braking system stays exactly the same. There are two versions of the e-brakes available depending on the mechanical construction of your brake lever.

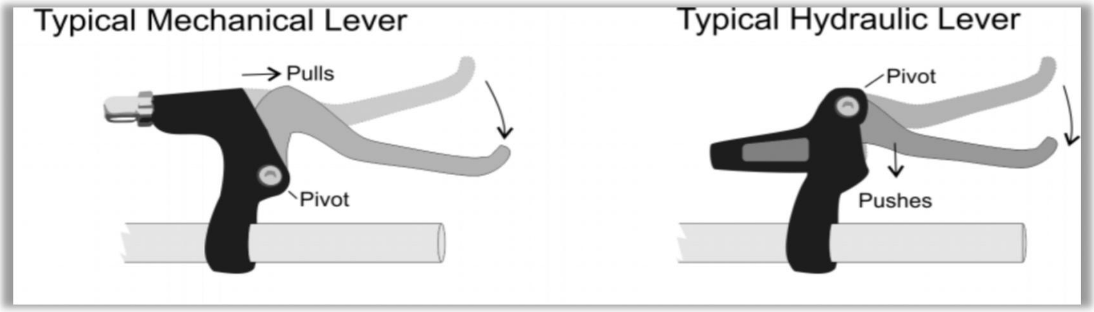


Fig 3.8 : Types of levers

A **disc brake** is a type of brake that uses the calipers to squeeze pairs of pads against a disc or "rotor" to create friction. This action slows the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed.

Fig 3.9 : Disc brake in a cycle

Mountain bike disc brakes may range from simple, mechanical (cable) systems, to expensive and powerful, multi-piston hydraulic disc systems, commonly used on downhill racing bikes. Improved technology has seen the creation of vented discs for use on mountain bikes, similar to those on cars, introduced to help avoid heat fade on fast alpine descents. Although less common, discs are also used on road bicycles for all-weather cycling with predictable braking, although drums are sometimes preferred as harder to damage in crowded parking, where discs are sometimes bent. Most bicycle brake discs are made of steel. Stainless steel is preferred due to its anti-rust properties.Discs are thin, often about 2 mm. Some use a two-piece floating disc style, others use a floating caliper, others use pads that float in the caliper, and some use one moving pad that makes the caliper slide on its mounts, pulling the other pad into contact with the disc. Because energy efficiency is so important in bicycles, an uncommon feature of bicycle brakes is that the pads retract to eliminate residual drag when the brake is released. In contrast, most other brakes drag the pads lightly when released so as to minimise initial operational travel.

3.1.5 Throttle

Electric bicycle's throttle is the physical connection between you and your Ebike. There are three main types of throttles: thumb throttles, half twist throttles and full twist throttles. Of course, each type of E-bike throttle has its own advantages and disadvantages, and each have their own effect on your riding experience.

Fig 3.10 : Types of throttle

Full twist throttles are sort of the antithesis of thumb throttles as they are the largest type of E-bike throttle and require the whole hand to operate. The full twist throttle takes up the entire end of the handlebar, completely replacing whatever grip would originally be on the end of handlebar.

Fig 3.11 : Full throttle

To operate it, the rider simply grabs a handful of throttle and twists it back towards himself. Anyone who has ridden a motorcycle or moped will find the full twist throttle familiar. It operates just like the throttle on most motorcycles. Many people prefer full twist throttles because they are operated by the full hand – all five fingers grip that sucker. That allows you to hold on tight, handle well and use your wrist instead of your thumb to apply the twisting motion. For that same reason though, many people complain that full twist throttles lead to a sore wrist. Just like riding full speed with a thumb throttle can

exhaust the thumb, Twist throttles tend to tire out the rider's wrist over long periods .Another disadvantage of full twist throttles is that they are most likely to be accidentally engaged. Because the throttle continues all the way to the end of the handlebar, bumping into walls, doorways and even handlebars of other bikes in close proximity can send the bike accidentally accelerating off into the distance with the unprepared rider trying to hang on. These LED battery meters are notoriously inaccurate. They work not by measuring the actual capacity of the battery but rather by measuring the voltage level. Basically, if all your lights are on you know your battery is mostly charged and if the lights are a near the end (red LED) then you know your battery is about to die. Many E-bike throttles also come with buttons that can be used to control different functions. The most common is an on/off button to start your E-bike. These buttons can also be used for things like lights and cruise control, assuming your Ebike supports these features. Some throttles have momentary contact buttons that only work when the button is held down. These types of buttons are better for features like horns or regenerative braking, something you'd want temporarily and only for as long as the button is pressed.

Fig 3.12 : LCD display

3.1.6 Material for Chassis

Steel and aluminum are the two most popular materials used in both metal spinning and metal stamping. Each material has a defined and distinct set of characteristics that make it the right – or the wrong – material for the job. When selecting material for your spun part it's important to consider the following: cost, the shape of the spinning, and most importantly the end application.

Aluminum vs Steel Cost

Cost and price are always an essential factor to consider when making any product. The price of steel and aluminum is continually fluctuating based on global supply and demand, fuel costs and the price and availability of iron and bauxite ore; however steel is generally cheaper (per pound) than aluminum (see galvanized vs stainless for more info on steel). The cost of raw materials has a direct impact on the price of the finished spinning. There are exceptions, but two identical spinning (one in aluminum and one in steel) the aluminum part will almost always cost more because of the increase in the raw material price.

Strength & Malleability of Steel vs Aluminum

Aluminum is a very desirable metal because it is more malleable and elastic than steel. Aluminum can go places and create shapes that steel cannot, often forming deeper or more intricate spinning. Especially for parts with deep and straight walls, aluminum is the material of choice. Steel is a very tough and resilient metal but cannot generally be pushed to the same extreme dimensional limits as aluminum without cracking or ripping during the spinning process.

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Corrosion Resistance of Steel and Aluminum

While malleability is very important for manufacturing, aluminum's greatest attribute is that it is corrosion resistant without any further treatment after it is spun. Aluminum doesn't rust. With aluminum there is no paint or coating to wear or scratch off. Steel or ―carbon steel‖ in the metals world (as opposed to stainless steel) usually needs painted or treated after spinning to protect it from rust and corrosion, especially if the steel part will be at work in a moist, damp or abrasive environment.

Weight Differences in Steel and Aluminum

Even with the possibility of corrosion, steel is harder than aluminum. Most spinnable tempers and alloys of aluminum dent, ding or scratch more easily as compared to steel. Steel is strong and less likely to warp, deform or bend under weight, force or heat. Nevertheless the strength of steel's tradeoff is that steel is much heavier /much denser than aluminum. Steel is typically 2.5 times denser than aluminum.

From the above comparison, Mild steel has been selected for the following reasons:

Mild Steel Specifications :

Grade : IS 2062 E250 (Fe 410WA)

Chemical Composition (%):

Carbon	Silicon	Manganese	Nitrogen	Phosphorous	Sulphur
Max 0.23	Max 0.40	1.50	Max 0.012	Max 0.045	Max 0.045

Table 3.3 : Chemical composition of mild steel

Recyclable

No different than most metals, scrapped mild steel is vital in the production of more of the same. Most steels can be recycled indefinitely without losing their quality, and due to its magnetic properties mild steel is particularly easy to recover from unsorted waste.

Can be Carburized

The major downside to mild steel is that it has a relatively low tensile strength, meaning it'll break more easily under tension than other steels. Luckily, there is a solution. Carburizing is a heat treatment process in which either iron or steel is heated, with carbon liberated as it decomposes. When cooled via 'quenching', the surface is now hard, whilst the core remains soft and tough.

Ductile

Ductility is the measure of how much a material can be plastically deformed by elongation, without fracture. Materials that are strong in this regard can go more than 15% before they are permanently deformed and unable to go back to its original shape. Mild steel shares good company in this regard with copper and thermoplastics, able to bend, stretch and have relatively large forces applied to it, making it easier to form, shape and weld.

Weldable

Unlike high-carbon steel, mild steel can be coalesced with far greater ease. Due to the specific properties of the metal, electric currents travel through it without distorting the 'make-up' of the material.

Cost-Effective

The least expensive of all steel types, many everyday objects are created using mild steel, including auto-mobile chassis, motorcycle frames and a great deal of cookware.

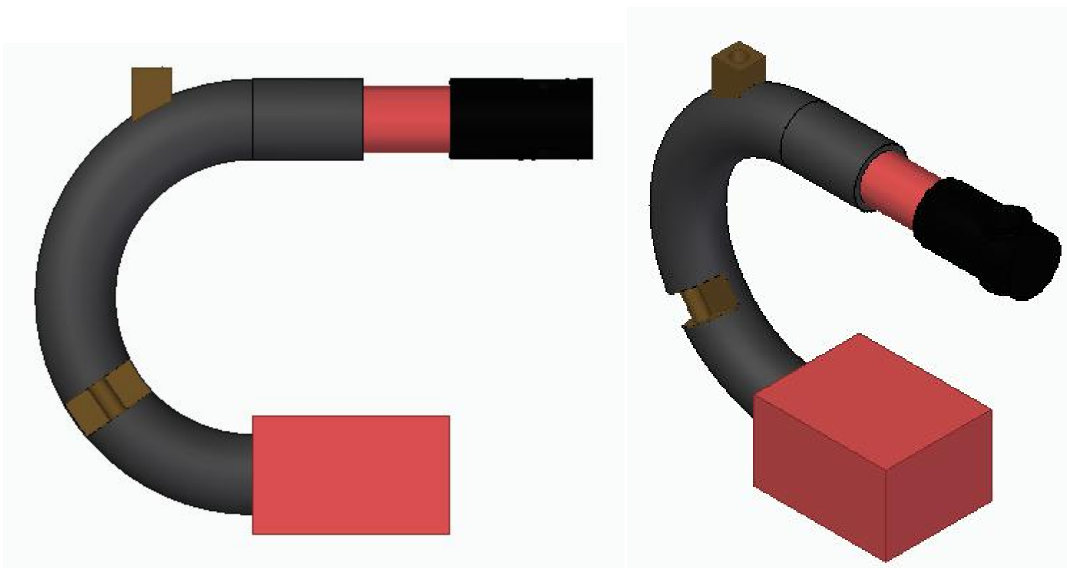

Fig 3.13 : Chassis design in front and iso view

3.1.7 Swingarm

A **swingarm**, or "swinging arm" (UK), originally known as a swing fork or pivoted fork, is the main component of the rear suspension of most modern motorcycles and ATVs. It is used to hold the rear axle firmly, while pivoting vertically, to allow the suspension to absorb bumps in the road.

Originally motorcycles had no rear suspension, as their frames were little more than stronger versions of the classic diamond frame of a bicycle. Many types of suspension were tried, including Indian's leaf spring suspended swingarm, and Matchless's cantilevered coiled-spring swingarm. Immediately before and after World War II, the plunger suspension, in which the axle moved up and down two vertical posts, became commonplace. In the latter, the movement in each direction was against coiled springs.

Some manufacturers, such as Greeves, used swingarm designs for the front forks, which were more robust than telescopic forks. In particular, sidecar motocross outfits frequently use swing arm front forks. The swingarm has also been used for the front suspension of scooters. In this case it aids in simplifying maintenance. In motorcycles with shaft drive, such as the Yamaha XJ650 Maxim, the shaft housing forms the left side swingarm.

A **single-sided swingarm** is a type of swingarm which lies along only one side of the rear wheel, allowing the rear wheel to be mounted like a car wheel (unlike the conventional motorcycle double-sided swingarm). Single-sided swingarms are traditionally found on small motorcycles or scooters, where a robust chain case doubles as the swingarm linking the engine and rear wheel. Single-sided swingarms need to be much stiffer than the double-sided versions, to accommodate the extra torsional forces, and as a result, they are usually heavier than double-sided arms. Having a single mounting point guarantees proper wheel alignment

Fig 3.14 : Single sided swingarm

The main advantage of the single-sided version is ease of maintenance. A single-sided swingarm makes it much easier to remove the rear wheel, provided the bike has a centrestand or you have a paddock stand to hand. This is a huge advantage in competition, especially in endurance events, but it also comes in very handy for the rest of us. If you have to replace your tyre, it's much easier to whip off the wheel and take it to the fitter yourself, saving yourself a few quid.

Another advantage is cosmetic – the bike looks cleaner in design on one side. Some would argue that it also looks less symmetrical. It's not just the design that looks clean, either. A single-sided arm has fewer nooks and crannies and inaccessible bits, so it's easier to scrub chain oil off it. Less of the bike is hidden, so that grimy area around the rear wheel is less of a problem to get to.

The disadvantages are that single-sided swingarms have to be larger and more heavily engineered to enable them to cope with the stresses imposed upon them, increasing unsprung weight. Bearings also have to be larger and stronger to cope and an unusually large socket is needed to remove the wheel retaining nut.

Wheel alignment becomes a greater problem, too – it's much easier to make adjustments to a wheel attached on both sides.

Fig 3.15 : Swingarm

3.2 DESIGN AND CALCULATIONS

3.2.1 Design calculation

Here we have used permanent magnet self-generating motor with 250-watt power and 2100rpm. The motor runs on 24volts and 7.2amps power source. This motor can reach a peak current during starting equal to 15 amps.

$$P = \frac{2*3.14*N*T}{60}$$

$$250 = \frac{2*3.14*2100*T}{60}$$

T = 1.136 N-m = 1136 N-mm

Torque at wheel shaft = T*R_{chain} = 1136*6 = 6820 N mm

Speed of wheel shaft = $\frac{2100}{6}$= 350 rpm

3.2.2 Brakes

For effective braking of vehicle, the braking torque of wheels should be greater than motor torque at wheels. The designing of brake system is based on this factor.

Generally, lever ratio lies between 4 to 6. We have assumed it to be 5.

The force applied on the piston= 100 N

Net force on lever end = lever ratio *force on the Pedal

= 5*100=500 N

Force produced by caliper = Force produced at lever end = 500 N

Force on rotor =Force produced by caliper =500 N

Total frictional force =

Force on rotor *coefficient of friction between pads & disc * No. of caliper

F =500*0.4*2 =400 N

Deceleration = $\frac{Force}{Mass} = \frac{400}{100}$ = 4m/s^2

$$\text{Stopping Distance} = \frac{\text{Velocity}^2}{2*\text{deceleration}}$$

$$= \frac{(4.167)^2}{(2*4)} = 2.17m$$

$$\text{Stopping Time} = \frac{\text{Velocity}}{\text{Deceleration}} = \frac{4.167}{2.17} = 1.92 \text{ s}$$

Total stopping time = Stopping Time + Driver Reaction

= 1.92 + 1.5 = 3.42 s

Effective Radius of rotor = $\frac{2(R^3 - r^3)}{3(R^2 - r^2)}$ =73.3

Braking torque = Braking Force *effective radius = 400*0.0733 = 29.32 N-m

Torque at wheel =8.76Nm

Torque at wheel < braking torque

3.2.3 Motor Requirement Calculations

The power required by a motor to carry a load of 100kg is calculated as follows:

Power = I * V

= 7.2 * 24 = 172.8W

Now, if we compare it with 250W motor.

The efficiency is **69.12%**

To select the power of the motor for particular power output from input power

Power = $\frac{(1.732*I*E*p.f)}{1000} = \frac{(1.732*7.2*24*69.12)}{1000}$

= 0.20686KW = **206.86W**

Hence, we select a 250-wattmotor, which is sufficient for electric bikes.

3.2.4 BLDC MOTOR CALCULATIONS

In order to choose the required DC motor that can do the job, we conducted a theoretical study that aims to help us choose the optimal type and size of DC motors.

R = Reaction of incline

F_x =Friction force.

W = cycle weight.

Maximum mass of cycle with person = 100 Kg

This mass accounts for both the mass of the cycle approximated to be equal to 20 Kg, and the mass of a standard user, which is about 80 Kg.

g = 9.81 m/s^2

Maximum angle of inclination: α_{max}= 37°. According to the international laws for transportation the maximum slope angle should not exceed 37°.

Coefficient of friction: $\mu = 0.5 - 0.7$, we will assume the value $\mu_{max} = 0.7$, to account for the worst possible conditions.

Wheel Radius: r = 15.24cm = 0.1524

Wheel perimeter: $P_{wheel} = \pi d = 0.9575$ m

The average velocity of the cycle is $V_{avg} = 15$ km/h = 4.167 m/s

Weight of the Cycle W= M × g = (80+20) × 9.81 = 981 N

Reaction of the incline R = W cos (37°) = 783.461 N

Friction force $F_x = \mu_{max} \times R = 0.7 \times 783.46 = 548.42$ N

Weight in the direction of the movement $W_x = W \sin(\alpha) = 981 \sin(37°) = 590.38$ N

At equilibrium, $\Sigma F(X) = F - f_x - W_x = 0$

$F = f_x + W_x = 548.42 + 590.38 = 1138.8$ N

Propulsion force (initial force), Propulsion force F = 1138.8 N

Torque at the wheel, $T = F \times R = 1138.8 \times \frac{152.4}{2} = 867.76$ N-mm

3.2.5 CALCULATION OF SPEED

V = 15km/hr. = 4.167m/sec

$V = \frac{\pi d N}{60}$ or $N = \frac{60V}{\pi d}$ N= 260 rpm T = 867.76 N-mm

Available dc motor in market 250W &2500 rpm, so we have to design transmission to achieve torque of 867.67 N-m at 260 rpm.

To find new torque T_1

$T_1 = \frac{60P}{2\pi N} = \frac{250*60}{2\pi*2500}$, $T_1 = 0.95$ N-m or T = 950 N-mm

Hence final speed $V = \frac{\pi*0.21*260}{60}$,V=4.19 m/sec = 15.084≈ 15 km/hr.

As generated torque and speed is more than required value so design of motor is safe.

4. CAD model of E-bike

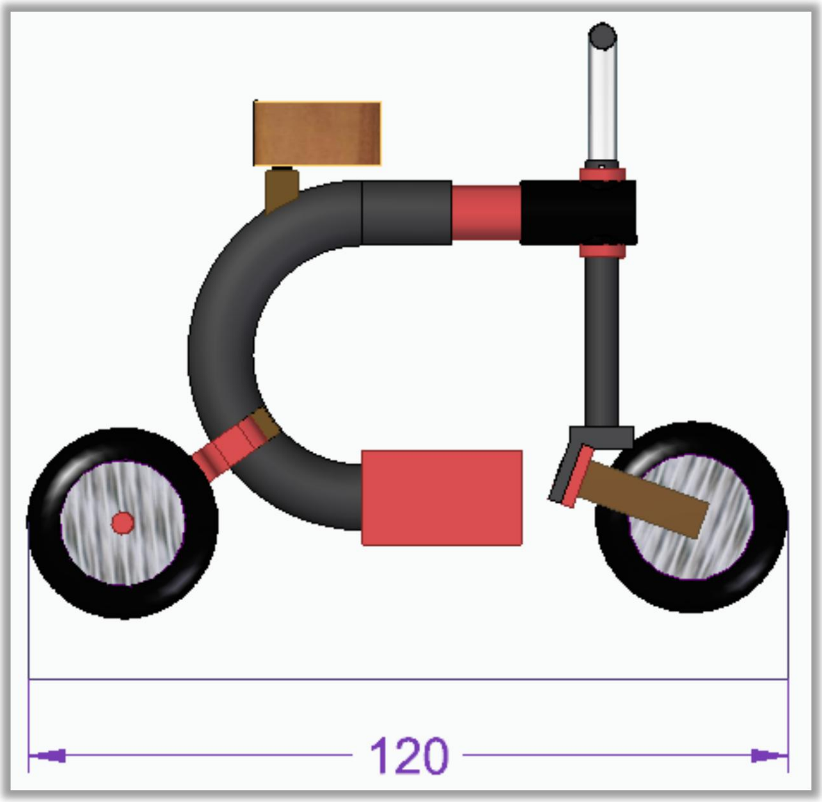

Fig 4.1 : Front view of unfolded bike

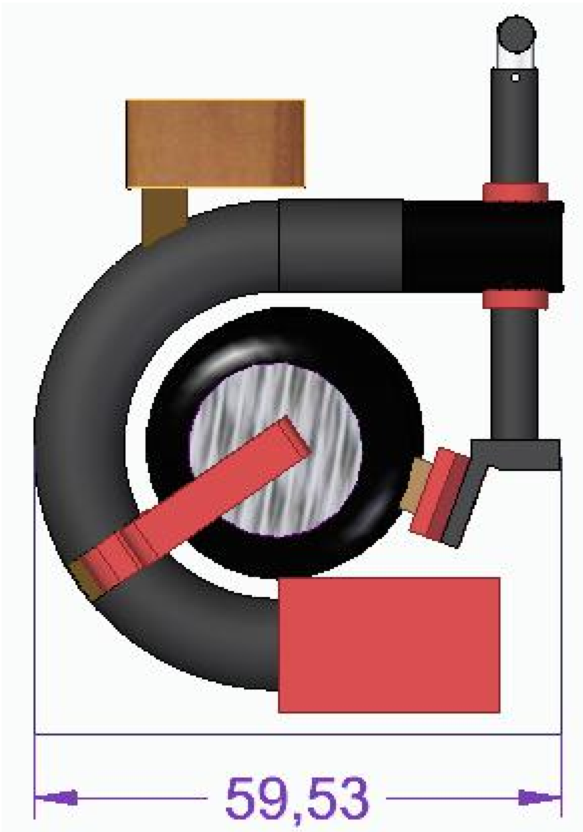

Fig 4.2 : Front view of folded bike

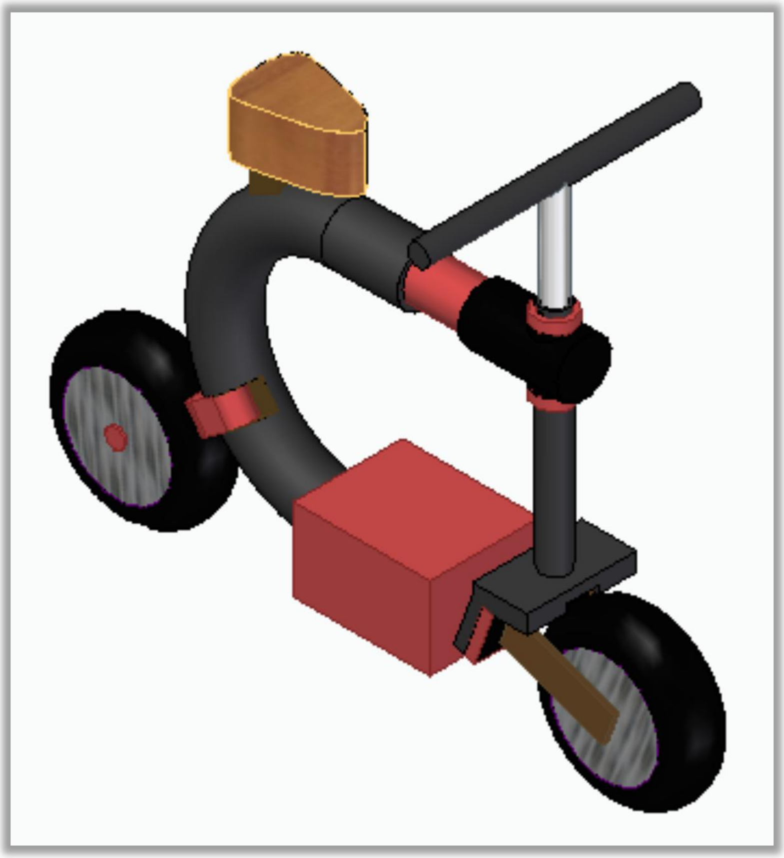

Fig 4.3 : Iso view of unfolded bike

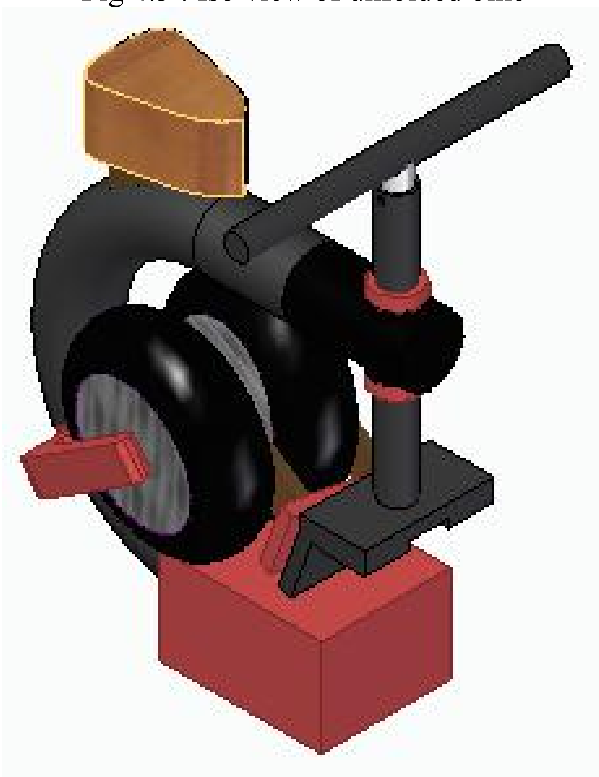

Fig 4.4 : Iso view of folded bike

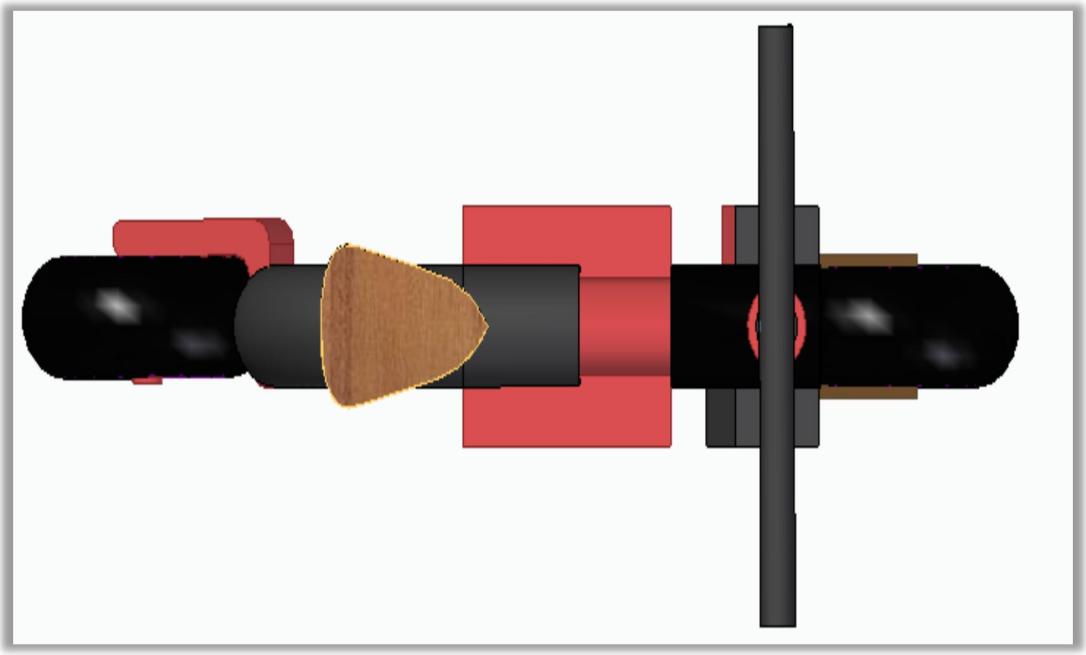

Fig 4.5 : Top view of unfolded bike

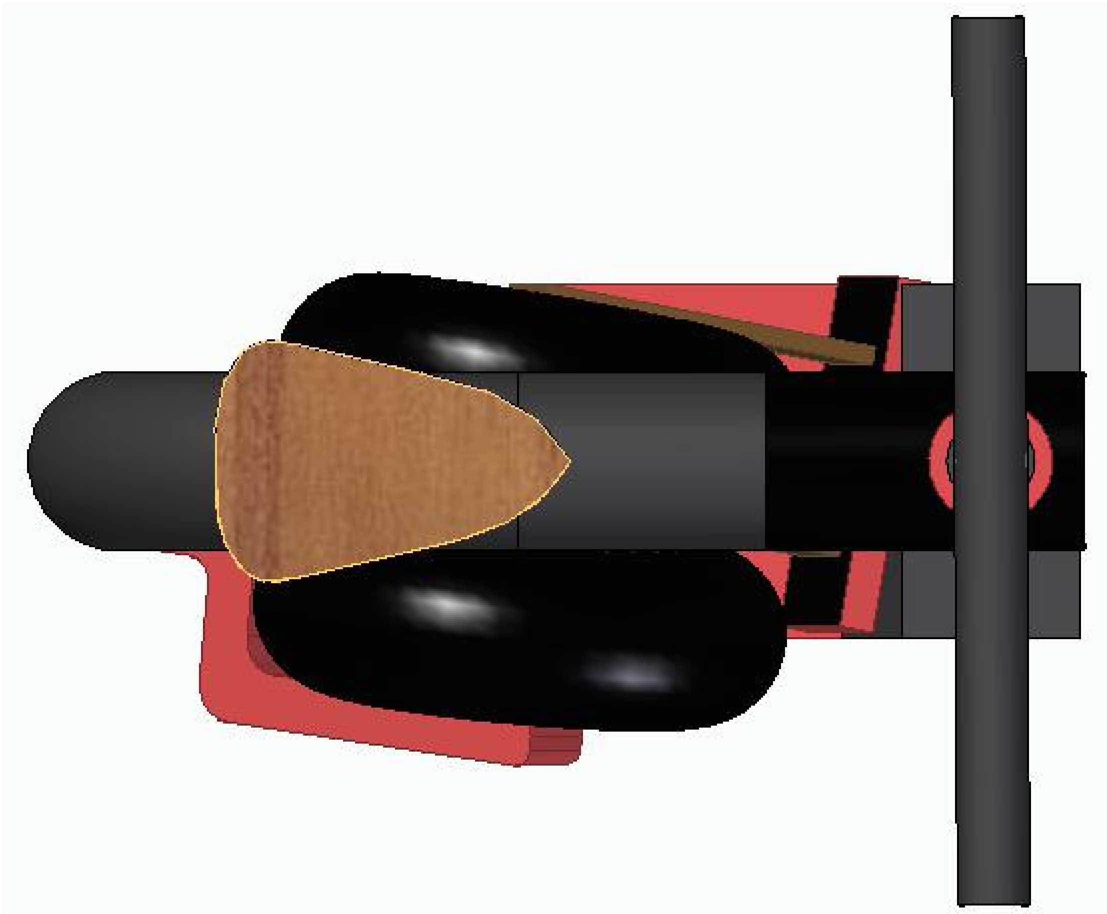

Fig 4.6 : Top view of folded bike

4.2 FABRICATION

The following steps are followed for fabrication:

1. Fixing the hub motor to the wheel

The 250-watt BLDC hub motor is to be fixed to a wheel. A 12-inch cycle rim is taken and the spokes are removed. Since the diameter of the motor is smaller than the 12-inch rim, wood is used as a filler medium to support the motor on the rim. The motor is fixed on the rim by screwing the motor to the wood and the wood to the rim.

Fig 4.7 : Hub motor attached to wheel

2. Machining of the swing arm

A CNC machine is used to fabricate the swing arm according to the dimensions. After the model is made in CATIA the model can be CNC cut. A low cost swingarm can also be made by welding rectangular blocks of mild steel but the structural integritywill be lesser due to the welded joints and failure will be faster than expected.

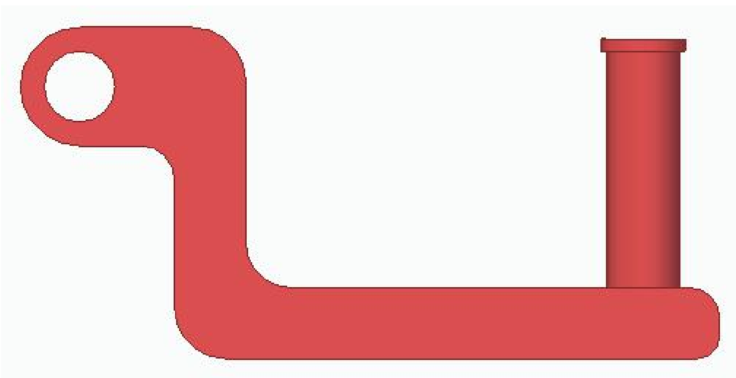

Fig 4.8 : CAD model of swingarm

3. Fabrication of the chassis

Once the hub motor is fixed to the wheel, the next part is the fabrication of the chassis or the frame of the vehicle.A pipe is bent to follow the curvature of the wheel. A slot is cut for the swingarm at an angle and a nut is welded and the swingarm is put into place and bolted. The chassis will have an extended with a small clearance for extending mechanism to work.

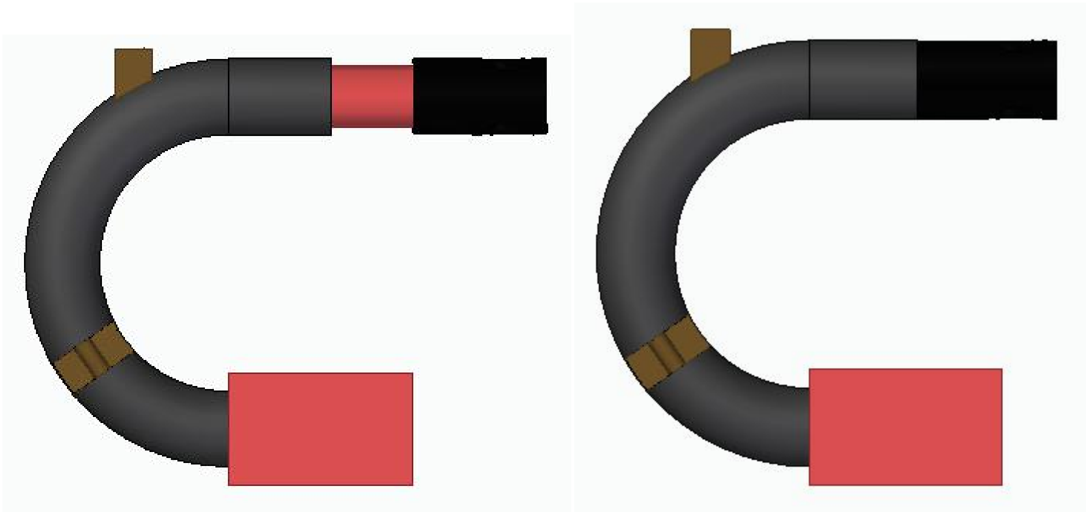

Fig 4.9 : Extending mechanism of the chassis

4. Fixing the front wheel and handlebar

The front wheel of 12-inch is fixed onto the fork of the vehicle. The fork is of a latch mechanism to facilitate axial rotation. The nuts and bolts are all tightened using suitable tools. The handlebar is fixed on the top and is tightened according to the alignment of the wheel. The handle bar is fixed using the cup and cone fixtures and ball bearings. The collars are given to fix the handle bar and allow rotating motion to the handle.

5. Fabrication of the battery box

A high grade sheet metal is used to fabricate the battery box. The sheet metal is welded onto the frame of the vehicle. It encloses two 12V lead acid batteries and a controller. It also acts as the footrest. The base of this battery box has a contact patch will will facilitate the wireless charging feature and also has a provision for regular charger port.

5. Electrical connections

The throttle is place on the right side of the handlebar. The necessary connections between the throttle, controller, motor and batteries are made.the wires are neatly packed inside the chassis ans sealed off the brakes connection is also made .

4.3 WORKING

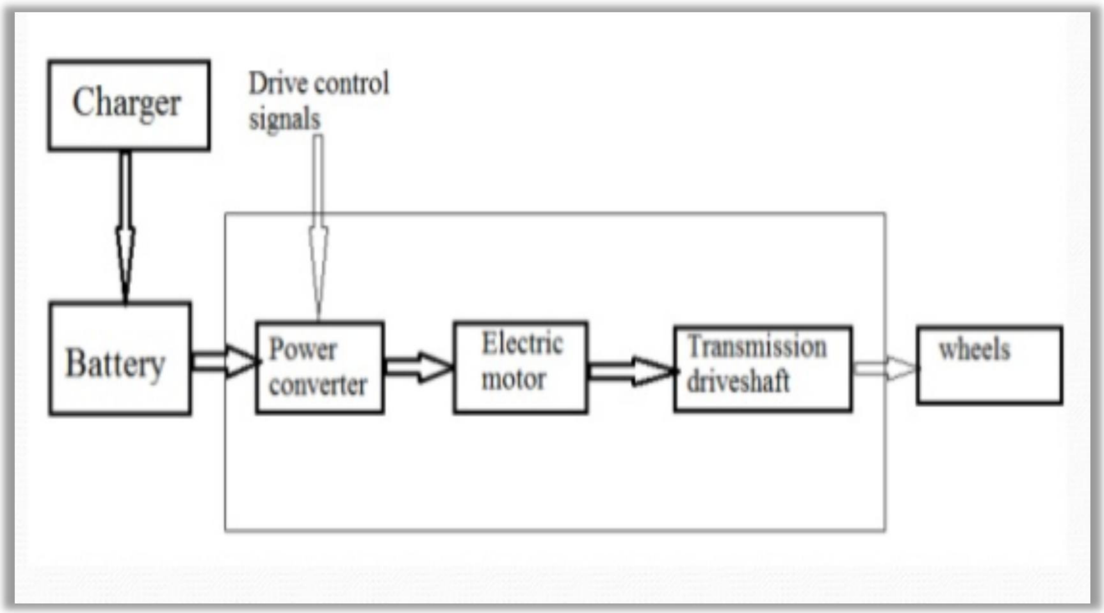

Fig 4.10 : Block diagram of working of basic E-bike

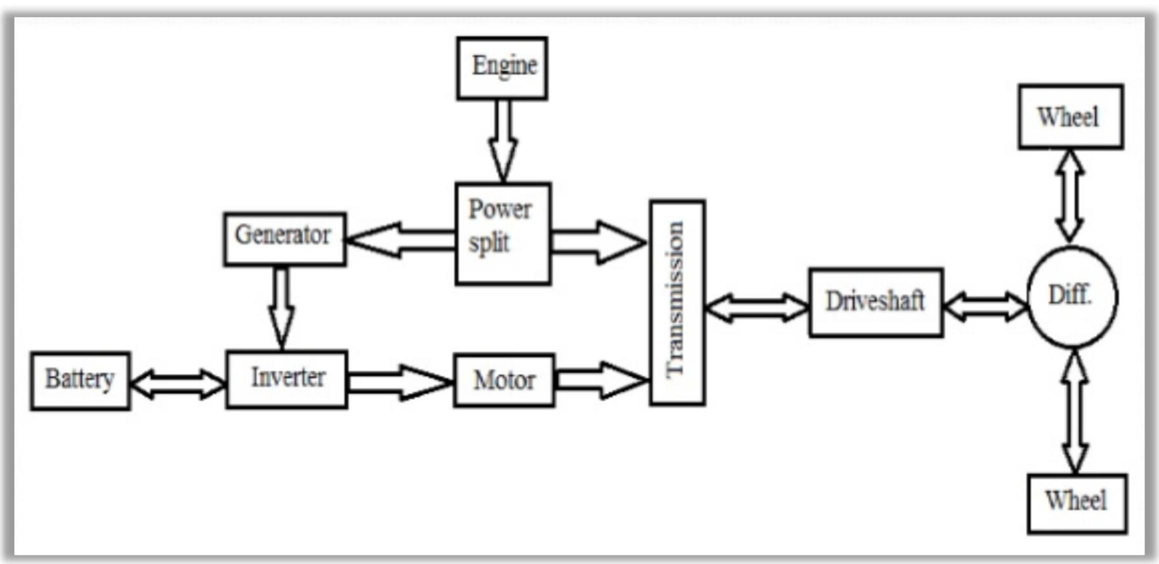

Fig 4.11 : Block diagram of Advanced E-bike system

The working of foldable electric bike can be explained mainly in two parts,

1. Electric working

The electric working is mainly consisting of batteries, brush less DC motor and the controller. The batteries are connected to the brush less DC motor through the controller. The controller is connected to the throttle and to e-brakes. As the batteries are charged by 220V and 2amps power supply, they will power the brush less DC motor. The throttle controls the speed of the brush less DC motor. As we accelerate the throttle, the speed of the vehicle is increased or decreased by varying the current supply through the controller. Whenever the e-brakes are applies to the bike the circuit will be broken and the power supply to the motor will be cutoff.

2. Mechanical working

The mechanical working has the Foldable joints which help us to fold the bike after use and store it in any place or carry it anywhere. This bike also has a quick release lock which holds the frame together when the bike is open and ready to ride, and will allow the frame to close into compact form whenever needed. The bike can be turned on using a key in key slot, and can be accelerated with the help of throttle. The rear wheel will start rotating which will drive the front wheel and the bike moves forward. When the riding of bike is done, we can fold the bike into compact form and can be stored anywhere and can be charged and reused.

5. EXPENDITURE DETAILS

SL NO	COMPONENT NAME	NO OF COMPONENTS	COST IN Rs.
1	Hub motor	1	4000
2	Battery	2	1400
3	Controller	1	700
4	Mild steel	8kg	600
5	Rim with tyre	2	700
6	Throttle	1	200
7	Brake set	1	300
8	Battery charger	1	450
9	Cut-off key	1	100
10	Seat	1	150
11	Misc.	-	1500
Total			10100

Table 5.1 : Expenditure table

6. DISCUSSION

Foldable E-bikes are more than thirty times as energy efficient as cars . As a transport mode they have great potential to decrease emissions and congestion. They enable ride in high speed despite strong headwind or hilly conditions where regular cyclists would decrease their speed significantly. Due to the decreased human force needed for propulsion, longer rides are also easier making it an alternative to replace for example car commuting. Combining Foldable E-bikes with bike pools also opens up their use to a broader audience as the initial cost decreases. The lack of ownership also means that the users do not have to worry about getting their E-bike stolen or to pay for maintenance. Foldable E-bikes can also be a natural extension to public transport. For commuters there might be a reduction in walking and waiting time to or between public transport station. E-bike stations would also increase the transport network size. Say that an E-bike station is placed at a bus station; the area covered by 10 minutes of E-bike ride from that spot is about fifteen times as large as if the person would walk as seen in Figure . Another benefit with E-bike station is that they can be placed more closely to where people start and end their journeys, such as homes or workplaces, than what is possible with for example tram and bus stations.

Weaknesses and uncertainties

This report is an exploratory study and hence contains a lot of assumptions that vary with system design, location, etc. It should thus be noted that results might vary significantly from a real-life E-bike pool. It has been tried throughout the calculations to have a good safe margin to ensure that the drawn conclusions are valid even though the system has high usage and long travel distances. In addition uncertain design parameters, there are a number of other uncertainties that may have affected the results. The used solar irradiation data is from two years only and is thus not representative of the long-term average irradiation. There is also an uncertainty in the irradiation data itself, especially as Sweden is located in the edge of the satellite's field of view. The data uncertainty is in the range of ±10%. Furthermore, there is an uncertainty introduced due to the interpolation of irradiation during some of the winter months. However, as the irradiation is low during that period, even though theuncertainty might be high, the effect on yearly energy yield is low. The total energy use during an E-bike trip is dependent on the rider's weight, the route chosen and the wind. These will in turn be dependent on station locations and pricing which means that the reality of an E-BSS (bicycle sharing system) will look different than the computed results. A factor that has not been accounted for in the calculations is that the usage of the Foldable E-bikes will vary with season and weather. It is likely that the use will be higher during summertime than wintertime and that more people will use the bikes when the weather is good. These user characteristics follows the solar irradiation well which could lead to higher grid independency than presented in this report.

One assumption made during the calculations is that battery charging is possible at all time. This will only be the case if battery heating of some sorts is implemented. It is also assumed that the charging power is constant during the charging cycle which is not the case for an actual Li-ion battery. The power electronics is assumed to have a MPPT function built in, this is usually incorporated in grid-tie inverters but not in all charge controllers for off-grid applications. There are also two parts of the E-BSS that has been excluded in the calculations; the energy use by the locks and the terminal. Locking can however be made energy efficient so that power only is needed during the movement of the lock. The terminal has been excluded as it may be designed in very various ways. From a low-power computer without monitor that lets the user check out a bike via a phone application to a large monitor with a full-size computer. If an E-BSS is being designed and the terminal and locking energy use is known it is however easy to include. A rule-of-thumb for Gothenburg is that one square meter of solar panel can supply about 23 W of power as the yearly average. As stated earlier, this report is exploratory and contains many assumptions. However, due to the sensitivity analysis made the results are likely to be valid even though many parameters would change in reality.

The energy system

What has been shown is that placing solar panels on the stations' roofs can result in net electric energy production from the stations to the grid with relatively small panel areas (0.2-0.8 m2/E-bike). A modal shift from for example commuting or bus would therefore not only decrease the energy use and emissions, but potentially also lead to net generation of electricity. If for example an E-BSS would be built in Gothenburg with the same size as the current BSS, that could potentially save several hundred tons of CO2 annually if the E-bike trips replaces some fossil fuel powered transport modes. In addition to that, a couple hundred MWh of solar energy would be fed to the grid. Choosing to build an off-grid solution can be useful in some cases such as temporary installations but is not seen as a viable large-scale system design. This is due to the fact that for an off-grid system to be operating over a long period of time, it must be designed to function the days with the lowest solar irradiation. The excess energy during days of high solar irradiation is thus not utilised. Using an on-grid solution with solar panels and a buffer battery seem as the best design. First and foremost, it makes it possible to design a system where the grid energy exchange is minimized while still enable excess solar energy production to be fed to the grid. A counter-argument towards placing solar panels in urban environment is that more energy would be generated by placing them on a shadow-free surface such as a rooftop nearby. Although that is true, a large share of the energy is still available and several factors make it beneficial to keep the panels on the stations' roofs. First and foremost, it enables origin marking of electricity and increased system efficiency, as the electricity does not need to be converted to Alternating Current (AC) as often as an on-grid system without a buffer battery would. A second reason is that if an E-bike station is going to be built; placing a roof with solar panels over the docking spaces will not affect the area used. Placing the solar panels elsewhere would thus mean that more area is needed. It might also not be economically feasible to pay for a second piece of land. Lastly, placing solar panels in an urban environment means that it is exposed to a lot of people every day. This is an opportunity that can be seized and used to educate people on solar energy and energy systems. Monitors could be set up showing for example the instantaneous power and power balance or the daily energy yield. Another educational strategy could be to produce education material towards school classes that can use online data to do labs.

In order to get as low amount of battery depletions as possible, a simple charging strategy could be implemented. When a user wants to check out an E-bikethe bike with the most charge is unlocked. To ensure that the user has sufficient charge for a ride — and that the battery is well maintained there could also be a lower value of the battery level set where the E-bike is kept locked until it has sufficient charge. Another method to decrease the occurrences of depletions is to increase the charging current. In this report, 2 A was used but in reality it could be increased to e.g. 5 A. A problem regarding battery charging arises in cold temperatures as Li-ion batteries should not be charged when the temperature is getting close to zero degrees. One solution is to keep the batteries in a heated cabinet at the station. This would not only allow safe charge during cold temperatures but could also supply fully charged batteries at all times if there are more batteries than Foldable E-bikes in the system. It has been shown however that battery depletion on a grid-connected system without battery swapping is likely not a problem despite high use (10.8 trips/(E-bike & day)). The need for a battery cabinet is thus not seen necessary from that perspective. A drawback with the cabinet solution is that the user must remember to take out the battery and mount it onto the E-bike and then vice versa on each ride. An alternative solution to charging cold batteries is to have a heating blanket built in the battery casing that would heat the battery using electric energy. The charging would then start when the battery is warm enough. Both solutions require extra input of energy that has not been accounted for in the calculations in this report. The need for battery heating is also dependent on the chosen season the pool should be operating. For full year operation it was shown that heating will be needed approximately 30% of the time.

The operational perspective

The economic perspectives of E-BSS have not been studied in this report. Foldable E-bikes for pool purposes are not currently mass-produced. A part of the investment cost of an E-BSS will thus go to development and the cost thus increases relative regular BSS. Of course it is possible to use off-the-shelf Foldable E-bikes and convert them for pool use. Using common Foldable E-bikes could however lead to increased vandalism and theft. If no operator is willing to take the investment and operation cost themselves, further research should be made on business models on solar powered E-bike pools. It should be noted that it is possible to get revenue from the excess solar energy by selling it to electricity trading companies. The revenuefrom this is however low compared to the total system cost as one kWh fed to the grid gives about 1 SEK. That means that the revenue would be between 300-800 SEK per bike and year at 2-3.8 m2 solar panel per E-bike. One aspect that should be discussed thoroughly before setting up an E-BSS is safety. Users may not have driver's license and may thus not know basic traffic regulations needed to ride safely in city centers with busses,trams cars and pedestrians around. This is obviously already the case for regular BSS, but with higher speeds and accelerations, the risk of accidents increases. Another issue is helmets. It is unlikely that all users that would like to wear helmets when riding are willing to carry their own around. Some kind of helmet sharing or foldable helmet for sale could thus be considered. The possibility to ride in high speed with Foldable Ebikes (up to 25 km/h with electric drive) is possibly an issue. Depending on user behavior, it might be necessary to limit the speed as 25 km/h is too high speed on for example a crowded, shared bicycle and pedestrian lane. As users of regular BSS more often use their bike downhill than uphill, redistribution uphill is needed. A topic of future research can thus be to see if, and by how much, E-bike pools can decrease the need for redistribution relative regular BSS. If an E-BSS is built it is recommended to publish data as open and detailed as possible. It gives others the opportunity to perform research or business around the Ebike pools. The trip distribution profiles in this report have for example been computed from open data published by Transport for London. The stations could also serve as public charging poles for private Foldable Ebikes. As there are many charging connectors on the market there is probably need for supplying a wide range of connectors to ensure that they may be used. The stations could also include several types of electric vehicles. This could be Foldable E-bikes with children seats, electric cargo-bikes or bicycle trailers that can be connected to the Foldable E-bikes.

7. CONCLUSION

There are three key issues that must be addressed when developing a bike sharing system, they are the operator, the user and the citizens that lives and uses the city. Designing a sustainable system requires two approaches, cost reduction, looking for cost effective production processes, but also requires add value design features, and both of them can represent extra services for the operator to charge or saving costs in maintenance. The third millennium is human requirements to thought and new energy. The present design is a unique method for protection, production and management of energy. Use of this technology can be increase in a huge range. The unique advantages of this machine is easy transportation without any acoustic and chemical pollution. In the future by use of this technology for automobiles, trains, planes and shuttles can be so effectual and effort. The design of the foldable e-bike was based on the standard data available. Compared to the foldable e-bike existing in the market, our e-bike is economical and occupies less space. The weight of our ebike is light than other e-bikes available in the market, Though the material used is mild steel, overall design being sturdy, compact and simple, it can be used for both town side and villages.

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