Journal of
Mechatronics and Automation

ISSN: 2455-1988
Volume 12, Issue 1, 2025
January–April
DOI (Journal): 10.37591/JoMA

https://journals.stmjournals.com/joma

Research JoMA

Development of an Electric Wheelchair for the Smooth Functioning of Physically Disabled Persons

Arun Kumar Yadav[1,*], Rachit Srivastava[2], Tej Prakash Verma[2], Rajesh Kumar[2]

Abstract

Wheelchairs can be moved manually, with the assistance of a partner, a joystick, or both. For patients with impairments, other pushing or controlling methods aside of a wheelchair are required. People use wheelchairs as they are unable to walk because of an illness, an accident, or a handicap. 15% of people globally have a disability, according to the WHO International Report on Disability. 131.8 million people, or 1.85% of the world's population, are also estimated to use a wheelchair. The recommended wheelchair was developed using a comprehensive approach, which includes design, simulation, and manufacturing. In its most basic version, it looks like a three-wheeled electromagnetic wheelchair with a hub motor that, when supplied by a battery, propels the wheel. For people who are unable to walk, frames and wheels are designed. The primary objective of this endeavor is to create a self-powered wheelchair that is useful, reasonable, and easy to use. Because they lack the physical strength or hand-eye coordination to propel themselves forward on a trike with their arms and hands alone, many persons with disabilities use hand-powered wheelchairs. Any handicapped individual living in either a rural or urban area can afford it.

Keywords: Electric wheelchair, wheel mounting, throttle, chassis, hub motor

INTRODUCTION

Wheelchairs are widely used by people who are unable to walk freely due to an injury, illness, or injury-related disability. The wheelchairs can be moved using both human and automated technology.

Although wheelchairs are available in a variety of styles and are sometimes heavily customised to meet the needs of each individual user, there are frequent variations in this fundamental concept. In recent years, experts have been interested in the issues of rehabilitation.

In the current study, assistive technology is a new sector in which some robotic gadgets may be used to increase the ability of old people or people with disabilities to survive in their daily chores. Researchers' interest in the treatment problem has grown in the past decade.

The current trend of supporting wheelchairs has been thoroughly researched by several academic institutions and enterprises throughout the world (Table 1).

An individual who uses a wheelchair sits within the wheeled mobility equipment. Both human and automatic technologies can be used to move the object. Wheelchairs are used for those who have a disability, illness, or something else that makes walking challenging or unattainable.

***Author for Correspondence**
Arun Kumar Yadav
E-mail: dr.arunkumaryadavee@gmail.com

[1]Associate Professor, Department of Electrical Engineering, Bansal Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India
[2]Assistant Professor, Department of Electrical Engineering, Bansal Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India

Received Date: January 13, 2025
Accepted Date: January 31, 2025
Published Date: February 07, 2025

Citation: Arun Kumar Yadav, Rachit Srivastava, Tej Prakash Verma, Rajesh Kumar. Development of an Electric Wheelchair for the Smooth Functioning of Physically Disabled Persons. Journal of Mechatronics and Automation. 2025; 12(1): 1–27p.

Table 1. Disabled population by sex and residence India 2011.

Residence	Persons	Males	Females
Total	26,810,557	14,986,202	11,824,355
Rural	18,631,921	10,408,168	8,233,753
Urban	8,178,636	4,578,034	3,600,602

Individuals with mobility issues frequently need to utilize a wheel bench. A tricycle is used to power the wheelchair that is part of the automated system. The tricycle's front wheel is what propels it, and a hub motor is attached there for movement. Because they have to drive their wheelchairs for an extended period of time using just their upper limb muscles, handicapped persons who use manual wheelchairs sometimes complain of shoulder ache. There is a need for an automated and effective mobility vehicle that can meet their fundamental needs and that too without the assistance of any other person. Some disabled persons require medical care, and in severe cases, surgery. Recently, a variety of electrical hand bikes with either manual or electrical propulsion have been introduced. The lower half of some people's bodies are paralyzed in India today, and this study describes the advantages of a finger gesture-controlled wheelchair that uses an accelerometer as a sensor to enable physically challenged persons to move from one location to another by just moving their finger. People's lives will be a little bit easier and more comfortable thanks to this wheelchair, also making this wheelchair easily accessible to middle-class individuals.

Chairs with powered motors may be utilized both indoors and on the outside.

They are often prescribed for people who find it difficult to operate a manual chair owing to problems affecting their arms, hands, shoulders, or other parts of their body and lack the leg power to push a manual chair with their foot, which is typically not advised by health professionals. Additionally, patients with cardiovascular issues may also use them. EPWs can provide tilt, slumber leg elevation, seat elevation, and other operated motions that are good for productivity and health.

The wheels of electric powered chairs are propelled by electric motors. They are usually powered by 4 or 5 A deep-cycle batteries that recharge, just like outboard engine boats.

These come in wet and dry varieties; at the moment, dry cell batteries are more common. Older or more portable versions may have a separate charger unit; however, the majority of EPWs feature an on-board charger that can be plugged into a conventional power socket.

Background

We all observe disabled persons in society. They deal with several issues on every day of the year. They are continually in need of assistance from others. They are not self-sufficient. With the project in question, we hope to help them become autonomous.

To serve this demographic, some researchers have repurposed technology initially designed for mobile robots to make "smart wheelchairs". Typically, a smart mobility device consists of either a mobile robot base with a seat attached or a standard electric wheelchair with a computer and a number of sensors. Smart wheelchairs have been created to help riders navigate in a number of ways, including as preventing conflicts while riding and helping with particular activities, (e.g., passing through doorways), and autonomously transferring the user between sites.

A handicapped person who uses a manual wheelchair and drives it with the force of his arm; the repetitive usage of these wheelchairs provides physical strength to the shoulder. However, because users are navigating the wheelchair using only their upper limb muscles, and those who have been using these manual mobility devices for a long period sometimes get elbow ache.

Some disabled persons require medical care and, in severe circumstances, surgical therapy. To avoid such shoulder strain, we devised a wheelchair attachable system that allows us to make a manual wheelchair mobile by employing an electric BLDC Hub motor and its controller. This wheelchair may be used to get to destinations near the disabled person's house, and it will greatly minimise the effort required to drive the wheelchair.

Rationale

In our nation, there are almost 20 million individuals with various impairments. Among these, almost 11 million are locomotory impaired. With 1,046 per 100,000 in rural regions and 901 per 100,000 in the urban population, India has the highest prevalence of locomotive debility. These alarming statistics are a result of low literacy rates, high unemployment rates, and pervasive societal stigma. The greatest method to equip the general public to deal with impairments is to organize awareness campaigns and distribute useful accommodations. Advanced policy and frameworks for the disabled are being developed by government agencies and non-governmental organizations. The wheelchair market in India is still in its infancy and growing at a double-digit rate. This wheelchair will improve comfort and ease people's lives a little. Moreover, we have tried making this wheelchair simply affordable for folks from middle class.

Need for the Project

In our nation, there are almost 20 million individuals with various impairments. Of these, 11 million are locomotory impaired. At 1,046 per 100,000 in rural regions and 901 per 100,000 in the urban population, India has the highest prevalence of locomotive debility. These alarming statistics are a result of low literacy rates, high unemployment rates, and pervasive societal stigma. The greatest method to equip the general public to deal with impairments is to organise awareness campaigns and provide useful accommodations. Advanced policy and frameworks for the disabled are being developed by government agencies and non-governmental organisations.

The wheelchair market in India is still in its infancy and growing at a double-digit rate. This project describes the advantages of a three-wheel controlled wheel chair using an accelerometer which regulates the speed of hub motor with the help of controller to help the physically disabled people move from one place to another. There are a lot of handicapped persons in India these days.

There are people whose lower half of the body is paralysed. This wheelchair will improve comfort and ease people's lives a little. Moreover, we have tried making this wheelchair simply affordable for folks from middle class.

OBJECTIVE

This project's objective is to develop and build a motorized wheelchair using significant factfinding and study on current models, technology, market conditions, and consumer needs. Technology should be used to provide people the greatest possible reimbursement for their limitations. to make wheelchair control easier for the user also, to correct postural issues for comfort or to prevent them from getting worse. In many economies that are developing, just 2 to 5% of individuals enjoy access to rehab facilities. Wheelchairs and other mobility equipment are one of the neglected areas of rehabilitation services.

Many poor nations rely mostly on international aid and have extremely limited capacity to build wheelchairs. Most wheelchairs that are donated do not fit specific demands or endure in areas where the bulk of people reside. Therefore, the primary goal of this project is to develop and create an automated wheelchair that is affordable, user-friendly, and useful that is readily accessible to everyone in need. The generally accepted guidelines for ensuring that people with impairments have equal access to opportunities were established during the United Nations General Assembly 48th session in 1993, enacted through 22 rules.

Benefits of Electric Wheelchair

- They provide independence and freedom of movement, allowing individuals to move around with ease and confidence.
- They also provide a safe and comfortable way to get around, and they are easy to use and maintain.
- Electric wheelchairs could get tailored to a person's requirements and way of life.
- Electric wheelchairs are also a great way to stay active and engaged in life. They can provide individuals with the opportunity to participate in activities.

Maintenance of Electric Wheelchairs

Regular maintenance needs to be done to keep electric wheelchairs in useful operational order.

- The rechargeable batteries, tires, brakes, and various other components should all be inspected frequently.
- Regarding repairs, it is also critical to adhere to the maker's suggestions.
- It is important to have the wheelchair serviced regularly by a qualified technician.

Project Management

This project included both mechanical design and electrical component connections to create an electric tricycle (Table 2).

LITERATURE REVIEW

Many disabled people in today's world find it difficult to perform movements or daily activities. These people are primarily dependent on others for support. They can, however, become self-sufficient and conduct certain everyday chores on their own with the use of assistive technologies. Wheelchairs are the most often used assistive aids. Wheelchairs are simply chairs with wheels that can allow persons who are unable to walk due to disease, disability, or injury, get around. However, many disabled people with weak limbs and joints are unable to move the wheelchair. Therefore, they and rest of the society may benefit significantly from smart wheelchairs [2].

Smart wheelchairs are electric-powered wheelchairs with several auxiliary components, such as a computer and sensors, that assist the user or guardian accompanying the wheelchair in moving it comfortably and effectively. Wheelchairs with fresh characteristics are made possible by recent developments in machine learning, artificial intelligence, and sensor technologies.

The purpose of this project is to examine the present state of the art in Smart Wheelchairs and to discuss future research in this area [3]. Before reaching a final selection on the major project, a quick investigation was made to determine existing efforts on the linked topic. We could only discover a few earlier projects dealing with voice synthesis processing. After our project proposal was accepted, we worked hard to find the resources we needed. We had to look up the topics on various websites and books [4–9].

Table 2. Work division for project.

Designed Part/Components	Members	Remarks
Design of Wheelchair	All group members	Discussion was made in group regarding the dimension and structure.
Base of Frame/Chassis	All group members	This part need lot of measurement, calculation and trial for exact fit
Motor Placement	All group members	
Motor Spoke Assembling	All group members	
Components Connections	All group members	

Related Work

Over the past 20 years, there have been several research projects conducted globally:

1. The low-cost automated wheelchair developed by MITRE Corporation was conceptually altered from the manual wheelchair in 1994, and its practical application was achieved in 1995 [9, 10].
2. Based on electrooculography (EOG), Barea et al. [9] presented an eye-control approach to control a motorised wheelchair in 2002.
3. On the basis of an EMG (electromyogram) signal, motorised wheelchairs in were invented 2002 over muscle control wheelchairs. However, the welfare of those who are less fortunate cannot be served by implementing this complex idea [4].
4. Simpson unveiled an EPW in 2004 that was equipped with a laptop, a variety of sensors, and a joystick. The wellbeing of common people still comes second to the experimental research as this EPW's high sensitivity is still restricted [4].
5. In 2009, Rofer unveiled a joystick- or head-joystick-based control device that was both sensitive and pricey for the average person in underdeveloped nations [7].
6. In 2013, Kalantri put out a model for a head-movement-based control system based on gesture detection. It is not currently being used practically [8].

Kink Phillip II of Spain

The term "invalid's chair" refers to the first wheelchair that was specifically made with mobility and handicap in mind. It was created in 1595 with King Phillip II of Spain in mind. The chair included nothing but wheels at the ends of the legs, an extendable backrest, and a platform for the legs.

It could not move on its own, so the King probably had servants to follow him about all the time [8].

First Self-Propelling Chair

The first self-propelled chair was created in 1655 by 22-year-old paraplegic jeweller Stephan Farffler on a three-wheel chassis. He used a crank and cogwheel mechanism to drive the chair. But because it featured hand cranks installed at the front wheel; the machine looked more like a hand cycle than a wheelchair [5].

The Folding Wheelchair

Harry Jennings, an engineer, created the initial foldable, tubular steel wheelchair in 1932. The very first wheelchair that is still in use today was that one. That wheelchair was made for Herbert Everest, a Jennings' friend who was paralysed. Together, they established Everest & Jennings, a business that had a long period of global dominance in the wheelchair industry.

Hand Powered Wheelchair

Disabled people are currently using hand-powered tricycles to enable mobility in a rural community throughout the world. 20 persons with impairments operated a hand-powered wheelchair with specific modifications over a distance of a few hundred km on routes in various parts of Lithuania. Marathon is a daily obstacle that persons with physical limitations must conquer, covering between 40 and 60 km in the sweltering sun or pouring rain. The non-profit organization "Change Was Accepted: Disabled Persons Company" has been working on the project for over 12 years. Redesigning lots of compensating devices, such as wheelchairs, and creating unique propulsion file attachments, significantly increase the speed of a wheelchair [1].

Electric Tricycle Wheelchair

The present hand-powered tricycles can be converted to the Electric Tricycle's design with little alteration. An electric motor, a driving system, and steering controls, and a power source make up the design. Due to the inability to employ a combustion engine due to high fuel prices and the accessibility of energy in Mahadaga, an electric motor was selected [6].

The best source of electricity for battery recharge is the solar array that powers the Handicap Centre. The drive system or method of power transmission was the first part of our design that was discussed. The tricycle's back wheel must get power from the electric motor.

Second, a motor control strategy was chosen. To enable operation by people with limited dexterity, the motor speed and brake controls were integrated into a straightforward mechanical joystick. A steering device that inhibits the tricycle's hand-power capabilities has been installed in place of the hand-power system.

Third, a battery pack provides the motor with electricity. The aforementioned parts (motor, gearbox, controls, and batteries) were made to fit on top of hand-powered tricycles that were already in use. The components required to transform a hand-powered tricycle into an electric tricycle are easy to install [10].

HISTORY OF ELECTRIC WHEELCHAIR

People with restricted mobility, particularly those with disabilities, can today stay mobile more easily via advancements in electric wheelchair equipment.

The electric wheelchairs that are currently on the market are the result of a long and rich history of transformation, where they went from being a simple mobility aid to a cutting-edge way to travel pleasantly and easily [11].

Here is a timeline showing how electric wheelchairs have changed through time, starting with their invention and ending with the first time one was offered for sale.

Short History of Electric Wheelchair

It is difficult to determine when the wheelchair was first mentioned, although several historians have found inscriptions and other proofs that suggests mobility aids were used as early as the 6th century AD in China and ancient Greece. King Philip of Spain (1529–98), who was plagued by severe gout and found it difficult to move, commissioned an inventor in 1595 to develop a complex chair that would make mobility easier.

1783: The Electric Wheelchair was Invented

In 1783, the Bath wheelchair was created, becoming the first wheelchair. Over the course of the first half of the 19th century, this wheelchair, which was created by an investor named John Dawson, outsold all others. However, the wheelchair was allegedly quite unpleasant, necessitating several chair upgrades in the latter 19th century. In 1869, the wheelchair's first patent was issued.

The 1800s: The Early Wheelchair

According to historians, a patent application for a wheelchair with casters and a back push function was made in 1869. This is mainly thought to be the first memory of this sort of model being constructed, based on this crude representation of a wheelchair.

The End of the 19th Century

Investors first used rubber wheels in the late 18th century, between 1867 and 1875, and incorporated them into the wheelchair's design. Rubber wheels were perceived to resemble bicycle wheels from the same era. Importantly, this prepared the way for push rims, which let people move about more independently. But it was not until 1881, or at the end of the 18th century, that this development occurred.

1916: Introducing the Motorised Wheelchair

A powered wheelchair supposedly made its debut in London in 1916, which was one of the most significant advancements of the 19th century.

1932: The Modern Folding Wheelchair

Harry Jennings, an engineer, created and tested the prototype for the contemporary foldable wheelchair in 1932. Its design closely resembles that of current products on the market. In reality, Jennings would build and launch one of the most competitive wheelchair firms to exist in its time thanks to a connection with Herbert Everest.

1953: The Beginning of Electric Wheelchairs

Mobility would soon become powered by motors, despite the fact that the push rim and other innovations enable users to independently drive the wheelchairs.

Depending on the user's personal circumstances, manual wheelchair can be of limited use. Electric propelled buggies were not a reality until George Klein's invention in 1953, despite initial trials in 1916. Originally, Klein and his team invested in motorized wheelchairs to aid veterans returning injured from World War II.

As an early demo of the motorized wheelchair, Klein's design featured heavy wheels with limited steer and turning. It was later mass-produced, demonstrating market demand for a more sophisticated, powered wheelchair option.

IMPORTANT DATES IN ELECTRIC WHEELCHAIR HISTORY

- Wheelchairs were fitted with spoked wheels for the first time in 1900.
- The first powered wheelchair was used in London in 1916.
- The first foldable wheelchair was created in 1932.
- The first widely available electric wheelchair hit the market in 1953.

Modern Electric Wheelchairs

The wheelchair market has only expanded in recent years. The wheelchair has grown more important and relevant today compared to its early demand in the late 1950s, which was fuelled by Everest and Jennings' fame. In fact, the wheelchair has been deemed a fundamental human right by the World Health Organisation due to its importance to society's continuous wellness and health. This is so that individuals who have a variety of infirmities and restricted mobility can reclaim part of their freedom [12]. Over the past a decade's time, the market has asked for comfort, reliability, and originality.

The way we view mobility may alter as a result of new technology. This may, for instance, entail smaller turning circles or a more agile design so that wheelchairs can fit in more confined areas. Battery weights and sizes have gradually increased throughout time. For instance, LITH-TECH uses batteries that are much lighter than lead acid batteries, which were more common in the 1990s and the early 2000s.

Electric Wheelchair Market

An electric wheelchair is a wheelchair with motors with wheels and batteries that provide the power needed to move a wheelchair in the desired direction with the least amount of physical energy.

For movement, these chairs do not need any help from people. The market for electric mobility scooters is expected to expand at an annualized rate of growth (CAGR) of 8.4% to reach $ 6,845.2 thousand by 2030.

Electric wheelchairs, power wheelchairs, mechanized wheelchairs, or electric-powered wheelchairs are wheelchairs that run on power, mostly from motors and batteries. An electric wheelchair is powered by rechargeable batteries. The wheelchair's motor, which moves the joystick, ball, and wheels, is driven by these batteries.

Because of the increased demand for electromagnetic wheelchairs, technological breakthroughs are now expected. This is explained by the fact that in order to sustain the weight of obese individuals, equipment has to be stronger and more durable. Additionally, fewer caretakers now physically interfere with patients' movements due to developments in technology. The patient may easily adjust the wheelchair seat, and the wheelchair's automatic control or remote control operates the gadgets. Additionally, wheelchairs with artificial intelligence have been introduced to the market, allowing people with impairments to control them by making different facial expressions, such sticking out their tongues and raising the brows [13, 14].

Therefore, it is anticipated that the need for technical advancements in this equipment to increase comfort and safety will generate profitable business.

According to estimates from the World Health Organization (WHO), 2–4% of people worldwide are dependent on caretakers, while 15% of people around the globe are handicapped (Table 3).

DESIGN OF BODY WORKS

Chassis/Frame of Body

Wheels, body, seat, steering/handle system, speeds controller, battery, motor, chain, brake system, lights, and chassis/frame, among the additional parts, make up this electric tricycle for the disabled.

The currently available three-wheelers have substantial chassis/frames and large-sized wheels. In order to achieve the criterion, superfluous weight was therefore minimized during design. Iron pipes strengthened with angle bars are used to construct the three-wheeler chassis. The chassis can support the appropriate payload up to 120–130 kg.

Additionally, the overall length and width are somewhat diminished. Finally, iron pipes with a 19 mm diameter and a 2 mm thickness are used to create the chassis. In Figure 1, chassis design has been shown with the help of solid works, the length is 34 in and the width is also 34 in.

Wheel Mounting

Originally called a swing fork or pivoted fork, a swingarm is an instrumental or double-sided mechanical device that couples the back wheel to its body and enables vertical rotation. Attaching the rear wheel to the vehicle's chassis and providing support for it are the swingarm's key duties (Figures 2 and 3).

Figure 1. Chassis.

Table 3. Electric wheelchair market highlights.

Aspect	Details
By Product Type	• Centre Wheel Drive • Front Wheel Drive • Rear Wheel Drive • Standing Electric Wheelchair • Others
By Region	• *North America* (US, Canada, Mexico) • *Europe* (Germany, UK, France, Italy, Russia, Rest of Europe) • *Asia Pacific* (China, India, Japan, South Korea, Australia, Rest of Asia Pacific) • *LAMEA* (Latin America, Middle East, Africa)
Key Market Player	Invacare Corporation, Karma Medical Products Co., Ltd, Matsunaga Manufactory Co., Ltd, Meyra Group, Miki Kogyosho Co., Ltd, Nissin Medical Industries Co., Ltd,

Figure 2. Fork for wheel mounting.

Figure 3. Cabin for rear wheel and fork.

The electric tricycle's wheels will be mounted on this style of angle fork. For both Hub Motor wheel mounting and Free wheel mounting, there is a 5 in space between each fork. One or both of one of the rear wheels of an electric tricycle wheel can be propelled, and the front wheel gets used for steering [15].

The back wheels are called delta, and the front wheel is called tadpole. A swing arm is welded for front wheel mounting, and the spacing between swing arms for wheel mounting is 4 in, as shown in Figure 4.

Mathematical Calculation

Weight of wheelchair with person =130 kg
Efficiency mechanical efficiency=85%
Wheel radius=0.27 m
Speed=25 km, linear distance travelled $=2\pi r=2\times3.14\times0.27=1.695$ m

1. Speed=25 km/h
   Speed= $(25\times1000)/3600=6.9$km/h
2. RPM
   RPM= (Total distance covered per hour)/ (Linear distance)
   $=25000/1695\times60=884.95$

3. Power P=(m×g×v× rolling resistance) +(air density × coefficient of drag × area × v^3)
   P=(130×9.81×6.9×0.00)+(1.225×1.8×0.30×6.9^3)
   P=217.3W
4 Torque = r*f
   η=85%
   η=(P_{output}/P_{input})
   P_{input}=217.3 W
5. Power output=η×P_{input}
   T×ω=0.85×217.3
   ω=(2πN/60)=(2×3.14×328)/60
   ω=34.33
   τ=(0.85×217.3)/34.33
   τ=5.38 Nm

COMPONENTS

Brushless DC Motor or Hub Motor

It is also known at a BLDC motor or a hub generator. They are generally brushless motors with many independent coils and an electrical circuit. The motor rotates because the electronics create force in each coil by turning the current on and off. The electric motor uses electricity by a rechargeable lithium-ion battery [16–19].

A wheel hub motor is a direct-drive electric motor installed in the tricycle's wheel. Wellington Adams of St. Louis invented the first wheel hub motor in the year 1884. He planned to integrate an electric motor inside the wheel of the vehicle, albeit it was connected by intricate gearing. Hub motors have the significant benefit of requiring minimal to no maintenance. Hub motors come in two different kinds: gearless hub motors, which have no gearing and attach the lower RPM motor stator's axle simply to the bike; and geared hub motors, which use mechanical planetary gears to slow down the higher speed of the motor (Figure 5). They are both completely independent drive systems that keep all of their components inside the motor casing. Contrarily, gearless hub motors have no moving components other than their bearings, therefore there is essentially nothing to wear out. They can very much survive forever as long as they do not corrode or lose their bearings.

Figure 4. Front wheel swingarm.

Figure 5. Hub motor.

BRUSHED AND BRUSHLESS HUB MOTOR

Because "brushless" hub motors are more robust than their "brushed" counterparts and need less maintenance overall, all modern e-bikes prefer to use them. Due of their scarcity, they are rather pricey. But, in the long run, they appear to be quite dependable, both in terms of price and effectiveness. They operate somewhat differently, as is explained below.

Brushed Hub Motors: A brushed hub motor has tiny metal "brushes" that transmit electricity to the commuter, the motor's spinning component. It takes this contact about 3000 miles to wear out the brushes, at which point they need to be replaced. While this replacement is not very expensive, it is difficult to manage the process oneself. Although using brushless motors has the benefit of requiring fewer expensive and complicated controllers, it is nevertheless recommended since once a motor has been opened for maintenance, it cannot be changed back to the original standard.

Brushless Hub Motors: Because there is no physical contact between any motor parts inside a brushless motor, there is almost little chance of wear and tear, resulting in an almost endless lifespan for the motor. Three separate windings may be used in these motors thanks to their more advanced controllers, and each winding receives power in accordance with its location during the movement. The movement does not halt when the motor passes one winding because the controller switches the power to another winding. These motors are currently extremely common. The hub motor in this automated wheelchair is 36 V, 350 W, with 16 in of bending copper wire inside. Maximum speed is 20 km/h.

Working of Hub Motor

Hub motors are usually brushless motors, frequently referred to as brushless direct current motors or BLDCs, which use a computer chip and six or more independent coils in place of the commutator and brushes. The circuit alternately turns the coils' power on and off, generating forces in each that cause the motor to rotate. The brushes create friction, hinder a typical motor, create some noise, and waste energy since they keep pressing on the axle [20].

That is why brushless motors are often more efficient, especially at low speeds. Getting rid of the brushes also saves having to replace them every so often when friction wears them down.

A hub motor operates on the basis of a highly electronic phasing changer, also known as a switching circuit. It regulates the timing and sequence of stator winding energization to produce a rotating magnetic field and rotate the rotor based on the position sensor data. The main component of electric vehicle components is the wheel hub motor assembly and the management system, which are classified as car parts.

With a permanent magnet linear synchronous electric vehicle hub motor and a switching reluctance hub motor that can be operated using PWM and AC frequency control, the system stands out by its unique design that combines a motor system, braking system, and suspension system into one. High efficiency, low noise, long lifespan, robust matching, relatively easy construction, effortless assembly, full functionality, independent suspension, safety, and dependability are all features of this flawless product design. It also has no axle, transmission, or other mechanical components, and tires can be placed directly on the body with zero transmission consumption and 100% rotation efficiency.

Controller

One of the key components of an automated wheelchair is the controller, which acts as the motor's brain and regulates speed, start, and stop. It is linked to every other electronic component, including the battery, motor, throttle, and display (speedometer). A controller is made up of peripheral components and primary chips (microcontrollers) (resistors, sensors). Inside the controller, there are typically circuits for the PWM generator, AD, power, power device driver, signal collection and processing, and over-current and under-voltage protection (Figure 6).

The motor speed may be adjusted too readily via the speed regulator mechanism. The speed feedback system, motorized driver, speed control pack, and speed setting device make up the control system. Either a very efficient brushless motor or a motor is used for the speed control system. The regulator primarily functions as a voltage and current controller to prevent the battery from charging excessively. We selected batteries because they are simple to charge and maintain and because most batteries need between 14 and 14.5 V to be completely charged. Hall sensor communication, drive measurement, PWM output to the motor, protection against overvoltage and excess current, and thermal protection are among the primary functions of the motor computer [21].

Working of Controller

Through the power circuit, the controller transmits the working voltage to the external device, such as the switch +5 V, headlamp +5 V, etc., after the battery has been connected. Depending on its throttle or PAS input, the PWM sends a matching pulse pattern to the MES (metal-oxide-silicon transistor) bringing about circuit.

The MOSFET drive circuit controls the turn-on and turn-off of the MOSFET circuit to control the motor speed. The under-voltage circuit prevents batteries from draining when the voltage falls below the value established by the controllers; the PWM circuit then cuts its output.

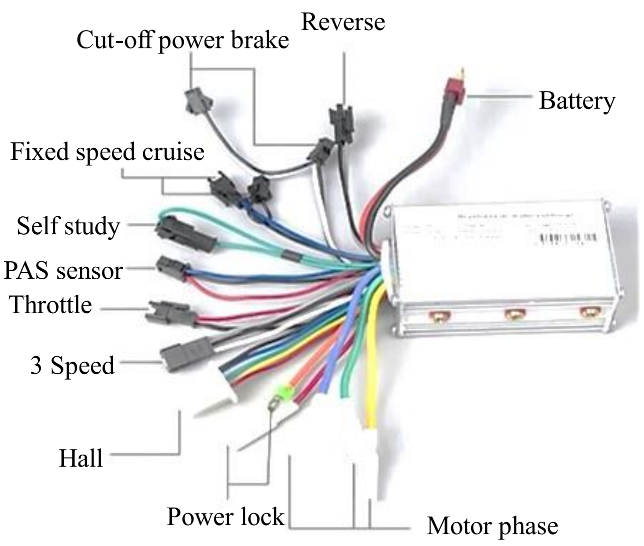


Figure 6. Brushless controller (6 Tube, 350 W).

The over-current protection circuit limits the working of the controller, battery, motor at an over higher current. An electric bike controller's key job is to receive all of the inputs from the various electric parts (such as the throttle, speed sensor that exists, display, battery, motor, etc.) and then decide what signals should be sent back to the motor, battery, and display. The controller's design will differ from its other many protective features (Figure 7).

Throttle

The way a motorbike or scooter moves when in the throttle mode, is comparable. The motor supplies power and moves you and the bike ahead when the throttle is opened. In our project, we used a universal forward-and-reverse throttle with a 60 cm cable.

The throttle fits handle bars with a diameter of around 22 cm. With a reverse take switch just next to the throttle, it is simple to operate and can be done quickly and very effectively.

A throttle is yet another potential tool for regulating speed. A joystick can result in severe hand and wrist pain since the user must keep it firmly in place all the time, according to customer requirements study. Using a "boat-style" throttle that would remain in place rather than swing back to a neutral position up on release is one approach to get around this drawback. In a manner similar to the Smart Drive, this would also allow the user to choose a speed and then let off of the throttle, freeing both hands for steering. For the user to immediately stop the motor with this design, a kill-switch would need to be extremely visible and accessible (Figure 8).

It is a technology that detects the driver's preferred speed and turns it into a signal to regulate the power assist's pace. The hub motor receives power when the throttle is engaged, allowing the wheelchair and power assist to travel with the user while allowing the driver to adjust the vehicle's pace as needed.

Here, a twist throttle is utilized to drive the hub motor. It is connected to a controller and used as an input device. The wire's length is 1.56 m, and the handle's inner diameter is 2.2 cm. It has three pins or wires: red for the positive pole, black for the negative pole, and green for signal.

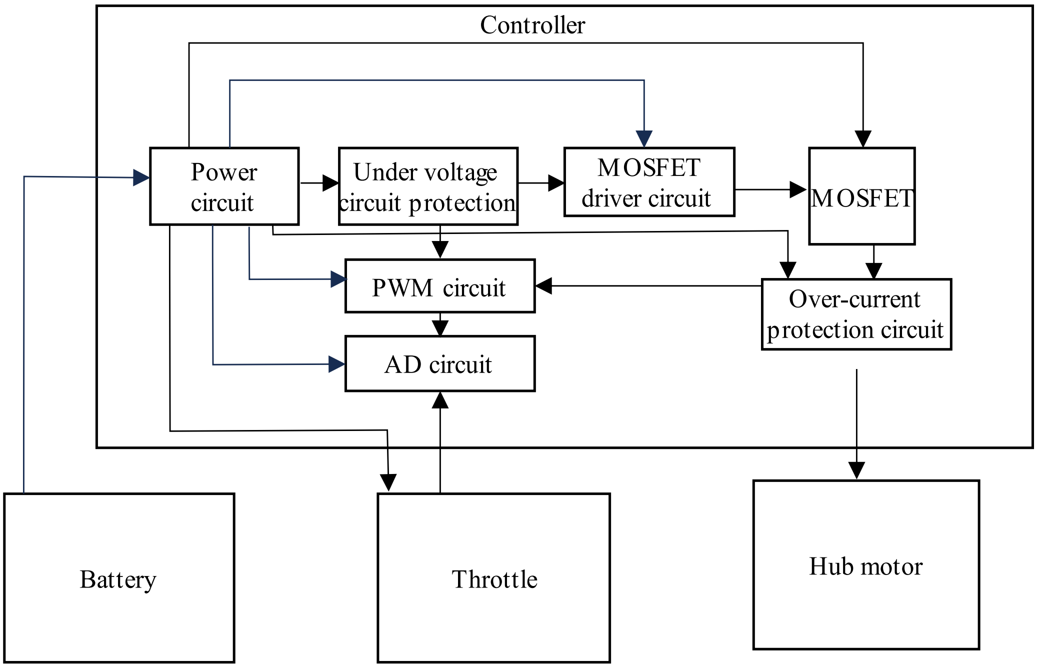


Figure 7. Working of controller.

Figure 8. Throttle.

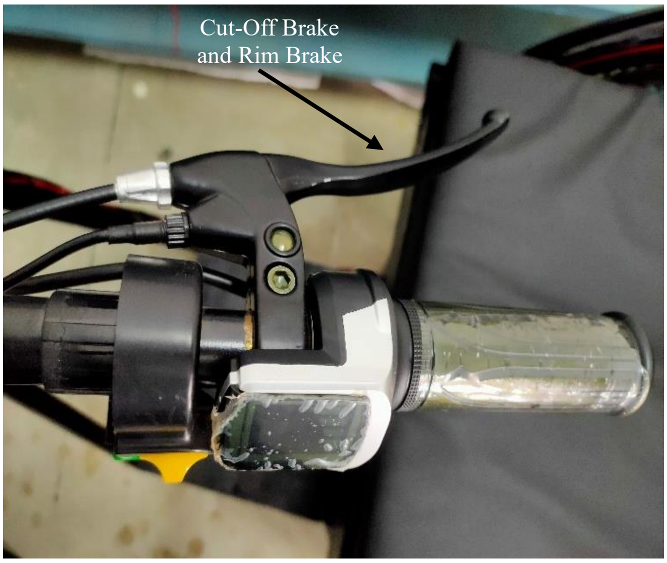


Figure 9. Cut-off brake and rim brake.

Braking

E-brakes have been included to our project. The e-brakes are a crucial component of our system, typically, e-bikes utilize them. They turn off the motor's power. When the lever is pushed, the regenerative braking system is also activated. By use of a lever that, when pushed, creates current and stops the wheel from moving, the brakes are connected to the controller (Figure 9).

There are mainly three types of braking system in Electric Vehicles:

1. Dynamic Braking,
2. Plugging Braking, and
3. Regenerative Braking.

Dynamic Braking: Using an electric traction motor as an engine to slow down a vehicle, such an electric or diesel-electric locomotive, is known as dynamic braking. It is referred to as "regenerative" if the power is fed back into the supply line, and "rheostatic" if the created electrical power ends up as heat in braking grid resistors.

Plugging Braking: By reversing the supply terminals regarding the separately excited motor, the supply voltage helps the counter or back emf turn the current. In order to restrict the amount of current that runs smoothly, this in turn requires the circuit to have exterior resistance.

Regenerative Braking: Regenerative braking systems (RBSs) are a kind of kinetic energy recovery system that slows down a moving item through transforming its kinetic energy into potential or stored energy. This improves fuel economy [2]. Kinetic energy recovery systems are another name given these systems. RBSs may convert energy using a variety of techniques, including as hydraulic, electromagnetic, flywheel, and spring. An electromagnetic-flywheel hybrid Regenerative braking (Rb) has also surfaced in more recent times. Because each form of Regenerative Braking System (RBS) uses a different energy conversion or storage technique, its applications and efficiency vary.

Horn and Headlight

A horn is a device that makes noise and is commonly found on bicycles, automobiles, and motor vehicles. It emits a honking or beeping noise to alert other drivers to its presence or approach, or to attract attention to a potential hazard. Whereas headlights' main purpose is to illuminate the road in order to promote safe and fatigue-free driving. As a result, the headlights and light sources are crucial pieces for safety (Figure 10).

Battery

A **lithium-ion battery** or **Li-ion battery** (abbreviated as **LIB**) is a type of rechargeable battery. Electric cars and portable devices equally frequently utilize lithium-ion batteries. The batteries feature minimal self-discharge, a high capacity for energy, and no memory effect (except from LFP cell). For all-electric, plug-in hybrid, and hybrid electric vehicles (HEVs), energy storage technologies, often batteries, are necessary. In this project, Lithium-ion Battery is used to make electric wheelchair.

Types of Energy Storage Systems

All-electric motor vehicles, PHEVs, and HEVs use the following storage systems for energy.

Lithium-Ion Batteries

Due to its high energy per mass compared to other electrical energy storage methods, lithium-ion batteries are presently employed in the majority of portable consumer gadgets, including mobile phones and laptops. In addition, they feature a high power-to-weight ratio, minimum self-discharge, high energy economy, and outstanding high-temperature efficiency. While most lithium-ion battery components may be reprocessed, the cost of material recovery remains a problem for the industry.

Figure 10. Horn and headlight.

The US Department of Energy is supporting the Lithium-Ion Battery Recycling Prize to develop and demonstrate workable strategies for gathering, categorizing, storing, and shipping used and discarded lithium-ion batteries for later recycling and material recovery (Figure 11).

Lithium-ion batteries currently constitute the most commonly used rechargeable battery chemistry. Batteries made of lithium ion fuel the devices we use every day, such as smartphones and electric automobiles. One or more lithium-ion cells and a protective circuit board form a battery made of lithium ion.

Components of Lithium-ion cell

- *Electrodes:* The ends of a cell that are positively and negatively charged is attached to the present collectors.
- *Anode:* The negative electrode.
- *Cathode:* The positive electrode.
- *Electrolyte:* A liquid or gel that conducts electricity.
- *Current collectors:* At each electrode of the battery that is linked to the terminals of the cell are conductive foils. The battery, the gadget, and the energy source that powers the battery are all connected by the cell terminals.
- *Separator:* A permeable polymeric layer that keeps the electrodes apart while allowing the transfer of lithium ions from one side to the other (Figure 12).

Working of Lithium-ion Cell

In a lithium-ion battery, lithium ions (Li^+) pass internally from the cathode to the anode. Electrons flow in the opposite direction in the external circuit. This migration creates the electrical current which runs the device, which is powered by the battery. During discharge, the battery's anode discharges lithium ions to the cathode, generating an electron flow that serves to power the associated device. On the other hand, the cathode releases lithium ions and the anode absorbs them when the battery gets full.

Figure 11. Lithium-ion battery (LFP).

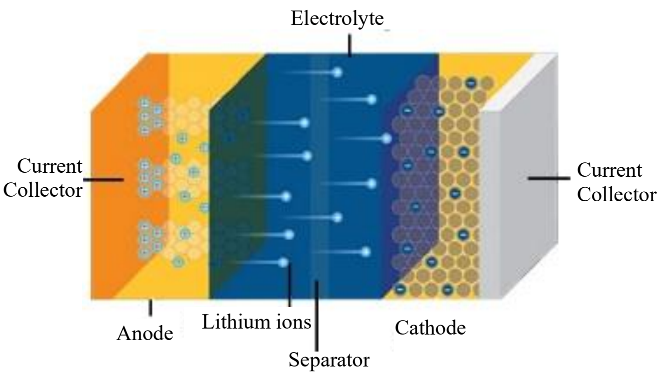


Figure 12. Lithium-ion cell.

Compared to earlier battery systems, lithium-ion batteries provide a higher power density for longer battery life in a lighter vessel charge faster, and retain a charge longer. If you have some idea of how matters work, they can work for you much more productively.

Battery Model

The battery model is developed based off a constant voltage source, V_{OC}, in series with an internal resistance, R_{int}=0.1 Ω, as described by Figure 13. This model relies on a power loss calculation to determine the battery output current as described by Equations:

$P_{ideal} = P_{actual} + P_{loss}$

$P_{ideal} = IV_{oc}$

$P_{actual} = IV_{oc} - I^2R_{int}$

$P_{loss} = I^2R_{int}$

Figure 13, describes the battery model and loss model calculation in the Simulink Electric Vehicle model. By integrating the electrical current over time and comparing it to the energy capacity variable established at the beginning, so the battery's state of charge (SOC) is found.

LFP Battery

A graphite carbon electrode that has metallic backing serves as the anode in LFP batteries, while lithium iron phosphate ($LiFePO_4$) performs as the cathode. LFP is a polyanion compound made up of many negatively charged elements, in contrast to many cathode component materials. In contrast to the 2D slabs of nickel, manganese, and cobalt, its atoms are placed in a crystalline structure to form a 3D network of lithium particles (Figure 14).

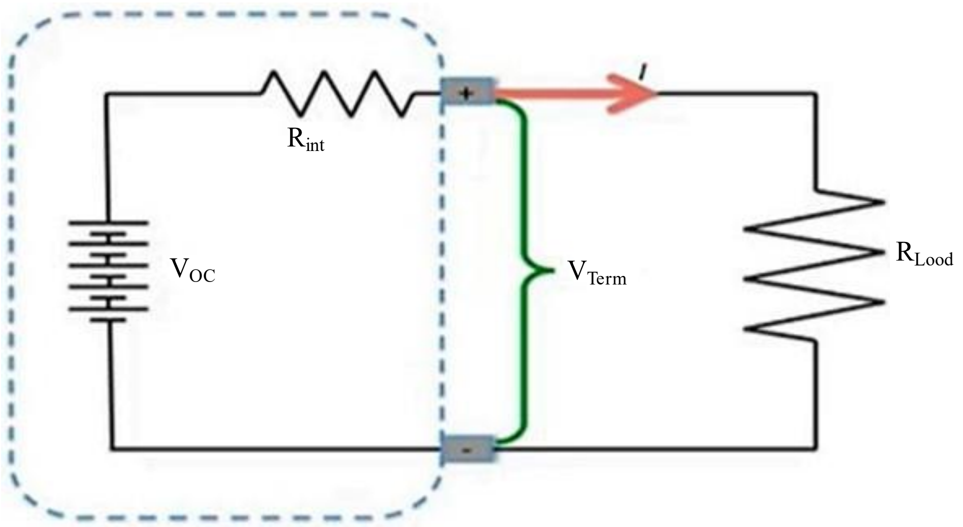
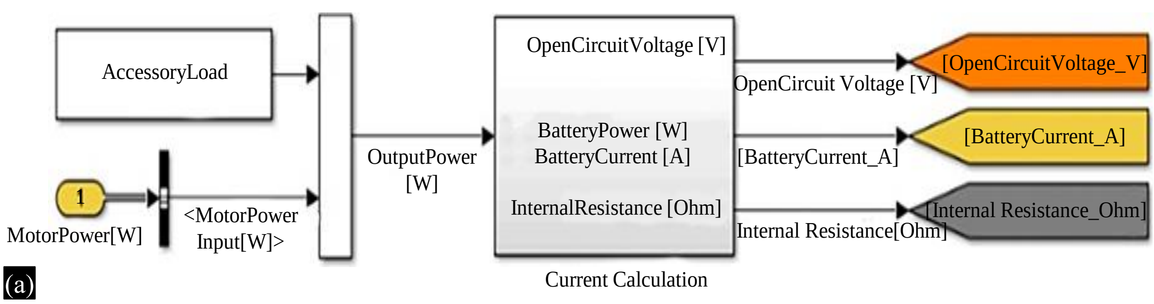


Figure 13. Battery model with internal resistance, MathWorks: 2020.



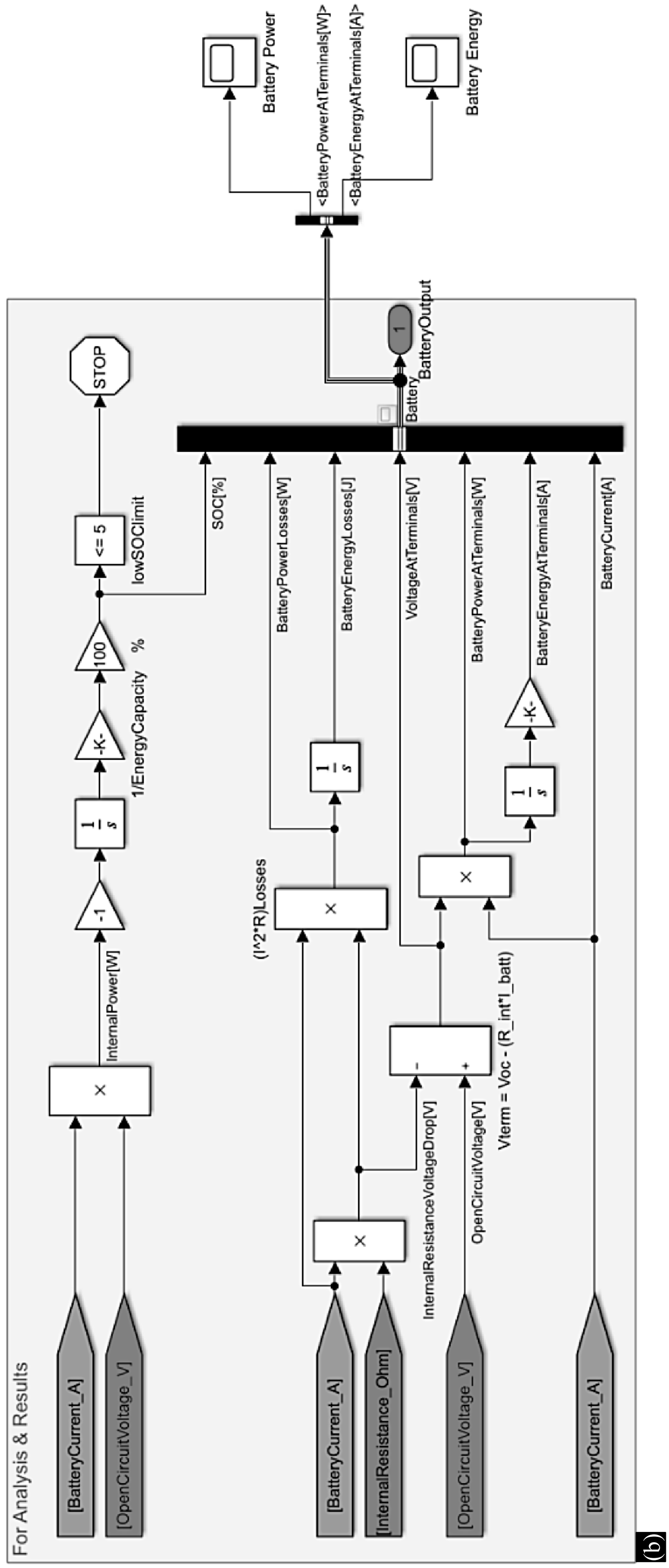


Figure 14. (a and b) Battery model with SOC and power loss calculations, MathWorks: 2020.

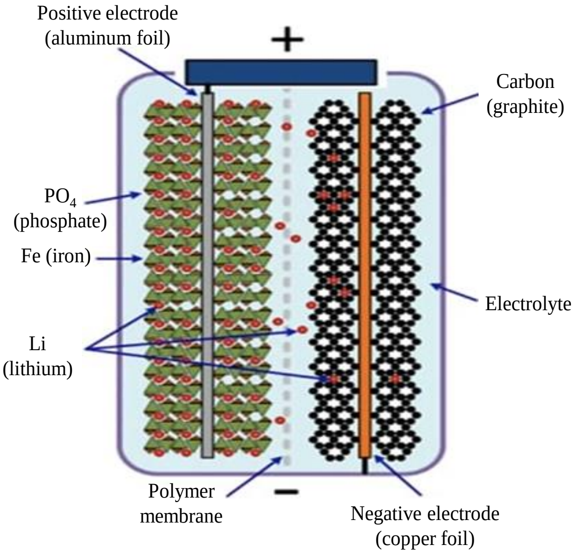


Figure 15. Working of LFP battery.

Like other lithium-ion (Li-ion) battery life, the LFP battery charges and discharges by switching between the positive and negative electrodes. In contrast to manganese oxide or cobalt oxide, pico is a non-toxic substance. At a greater charge cycle, LFP batteries might offer a steady voltage in the 2,000–3,000 level. Connected cells are only one component of LFP batteries; another is a mechanism that keeps the battery within safe limitations. To maintain safety and increase the battery's lifespan, a battery management framework (BMS) safeguards, regulates, and keeps an eye on the battery's health under any operating conditions. In this project we have used LFP battery of rating 36 V, 6 Ah (Figure 15).

Why LFP Battery is Better?

One advantage of batteries made from lithium is that they are drastically more efficient than lead acid devices. Compared to lead acid batteries, which can only use 50 to 70% of their full output at any one moment, lithium batteries utilize 80 to 100% of their available power. One complete charge of a lithium battery is all that is necessary; they do not need to be trickle- or continuously-charged. This will increase the battery's lifespan and allow you to use it longer. Even more capacity can be created with high energy density. Low Service: regular discharge is unnecessary and there is no remembering.

Our batteries weigh an average of 1.5 kg, making lithium batteries far lighter than the conventional wheelchair batteries. Lithium batteries can withstand a wide range of charging and discharging cycles. A high-quality lithium battery from Lith-tech will typically last 3 years or 1,000 uses. Lithium batteries are also very simple to charge, either straight into the battery or off the chair. This function is available on all Lith-Tech chairs. Additionally, rather of needing two batteries, all of our chairs may operate on only one. Consequently, you may use one while it is charging and the other while it is mounted on the chair, ensuring that you never go without a wheelchair.

Comparison of LFP and NMC Battery

Although NMC and LFP are both lithium-ion batteries, their cathode materials are different. NMC uses lithium, the metal manganese and cobalt oxide as its electrode material, whereas LFP uses a lithium and iron phosphate chemistry. The anode in both battery types is made of graphite. Therefore, G/NMC and G/LFP are widespread and, in some ways, more accurate abbreviations for these battery types.

The separator, the protective barrier that develops between the graphite anode and electrolyte, is the foundation upon which NMC and LFP batteries erect their stability. The collapse of this buffer coating is the initial stage of a chain cycle called thermal runaway, which is prevalent in graphite-based cathodes (Table 4).

Table 4. LFP vs. NMC.

Parameter	Lithium-Iron Phosphate (LFP)	Nickel Manganese Cobalt (NMC)	Comparison
Voltage Weight Energy Density Volume Energy Density	3.2 V 90–120 Wh/kg 300–350 Wh/l	3.6–3.7 V 150–250 Wh/kg 500–700 Wh/l	NMC Batteries are lighter and more compact
Typical Cycle Life Calendar Life	2000–3000 cycles 8+ years	500–1000 cycles 3–4 years	LFP Batteries will deliver more cycles over a longer calendar life
Thermal Runaway Onset Thermal Runaway Increase	~195˚C 210˚C	~170˚C 500˚C	NMC batteries have lower thermal runaway thresholds and will burn hotter
Fire/Fumes	Produces Fumes	Catches Fire	LFP is Quite safer

Calculation of Battery

1. Battery Charging Current Calculation:
   Taking 10% of Battery Capacity:
   6 Ah×10%=0.6 A
   Consider 2 A loss while charging
   Total =2.6 A
2. Charging Time Calculation:
   Fully discharge to fully charged:
   T= Battery (Ah)/Charging Current
   T=6 Ah/2.6 A=2.3 h
   Battery Loss: 40%
   Total Battery Ah=(6+2.4)=8.4 Ah
   T=8.4 Ah/2.6 A=3.2 h
3. Battery Discharging Current Calculation:
   10% of Battery Ah is Core.
   Battery discharging Current =6 Ah×10%=0.6 A
   Backup Time =6 Ah/0.6=10 h
4. Calculation for Battery Protection:
   To determine the MCB (Miniature Circuit Breaker) rating for this setup, we need to calculate the maximum current drawn by the motor.
   Power (P) = Voltage (V) × Current (I)
   Therefore, Current (I) = Power (P)/Voltage (V)

Using the given specifications, we can calculate the current drawn by the motor as follows:
Current (I) =250 W/36 V=6.94 A
So, the maximum current drawn by the motor is 6.94 A.

To select the appropriate MCB rating, we need to choose a value that is greater than the maximum current draw of the motor. To give a margin of safety, it is conventional to select an MCB rating that is 1.5 times the maximum current drawn.

Therefore, the recommended MCB rating for this setup would be:
MCB rating =1.5×6.94 A=10.41 A

In practice, you would need to choose the next highest standard MCB rating that is available, which would likely be a 16 A DC MCB or Fuse Link.

Charger

A battery charger is a device that provides electric current to a portable battery or a secondary cell, which supplies energy (Figure 16).

Journal of Mechatronics and Automation
Volume 12, Issue 1
ISSN: 2455-1988

For recharging the electric wheelchair's battery, we utilise an AC/DC adapter. The adapter's input rating is AC 100–240 V, 50/60 Hz, max 1.6 A. The adapter's output rating is DC 42 V, 2.0 A (Figure 17).

MANUFACTURING COST ESTIMATION AND ANALYSIS

With the help of cost report created for all components that went into the assembling of Electric Wheelchair, we get a clear understanding of all the money that is being spent on this project (Table 5).

Figure 16. Charger.

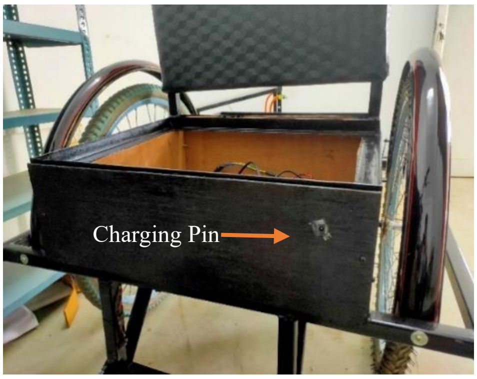


Figure 17. Charging pin to charge battery.

Table 5. Cost and estimation.

S. N.	Parts	Price (Rs.)
1.	Hub Motor + Controller	9000
2.	Battery	6000
3.	Rim	200×3=600
4.	Tires	250×3=750
5.	Iron	2000
6.	Throttle	1000
7.	E-Brake + Rim Brake	700
8.	Headlight + Horn + Indicator	800
9.	Seat + Cabinet Work	1100
10.	Handle + Mud Guard	800
11.	Charger	1500
12.	Painting	200
13.	Other Expenses	3000
	Total	**27,450**

We get a clear understanding of all the money that is being spent on the Electric Wheelchair with the help of the cost report created for all the components that went into the assembling of the Electric Wheelchair, and with the help of these reports, if the project undergoes any further development, the changes can be made accordingly to focus on quality while keeping the competition that is already present in the day-to-day market. After taking account of all of the factors that went into the development of the Electric Wheelchair and the reports, we determined that there is a good chance that our Electric Wheelchair model can be developed further under the right direction and control. This would allow us to expand the supply of job opportunities and positively impact the many benefits that come with the widespread use of electric vehicles (Figures 18–21).

RESULT

Quick Details of Product

- *Max Speed:* 20–25 kmph.
- *Max Range:* 15–20 km.
- *Pay Load:* 120 kg.
- *Motor:* 36 V/250 W BLDC.
- *Battery:* 36 V/6 Ah LFP Battery.
- *Charging time:* 2.5 to 3 h.
- *Wheel size:* 22 in.
- *Display:* Colourful Smart Display.
- *Weight of Body:* 20–25 kg (Figures 22–25).

Project Picture

Advantages

- They provide people independence and mobility, enabling them to walk around with ease and confidence.
- Additionally, they offer a convenient and safe means of transportation, and they are simple to operate and maintain.
- Electric wheelchairs may be altered to suit the demands and way of life of the user.
- Another excellent approach to be active and involved in life is with an electric wheelchair. People may be given the chance to engage in activities thanks to them.

Disadvantages

- Regular maintenance is necessary to keep electric wheelchairs in excellent operating order.
- Regular battery inspections are crucial, in addition to checks on the tyres, brakes, and other parts of the vehicle.
- The frame is particularly hefty since iron tubing is employed in the chassis construction.

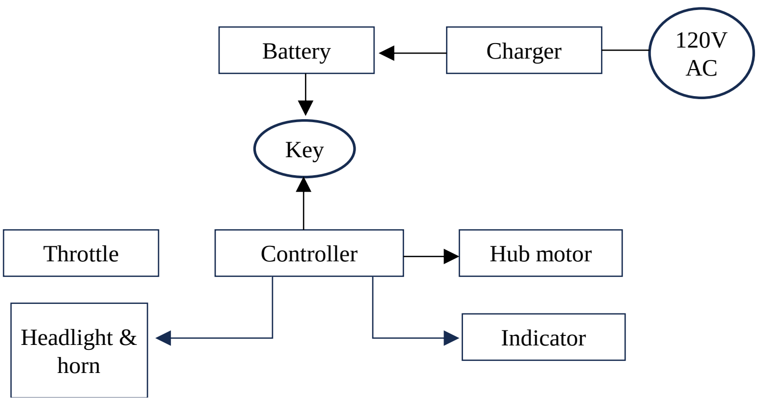


Figure 18. Block diagram of electric wheelchair.

Journal of Mechatronics and Automation
Volume 12, Issue 1
ISSN: 2455-1988

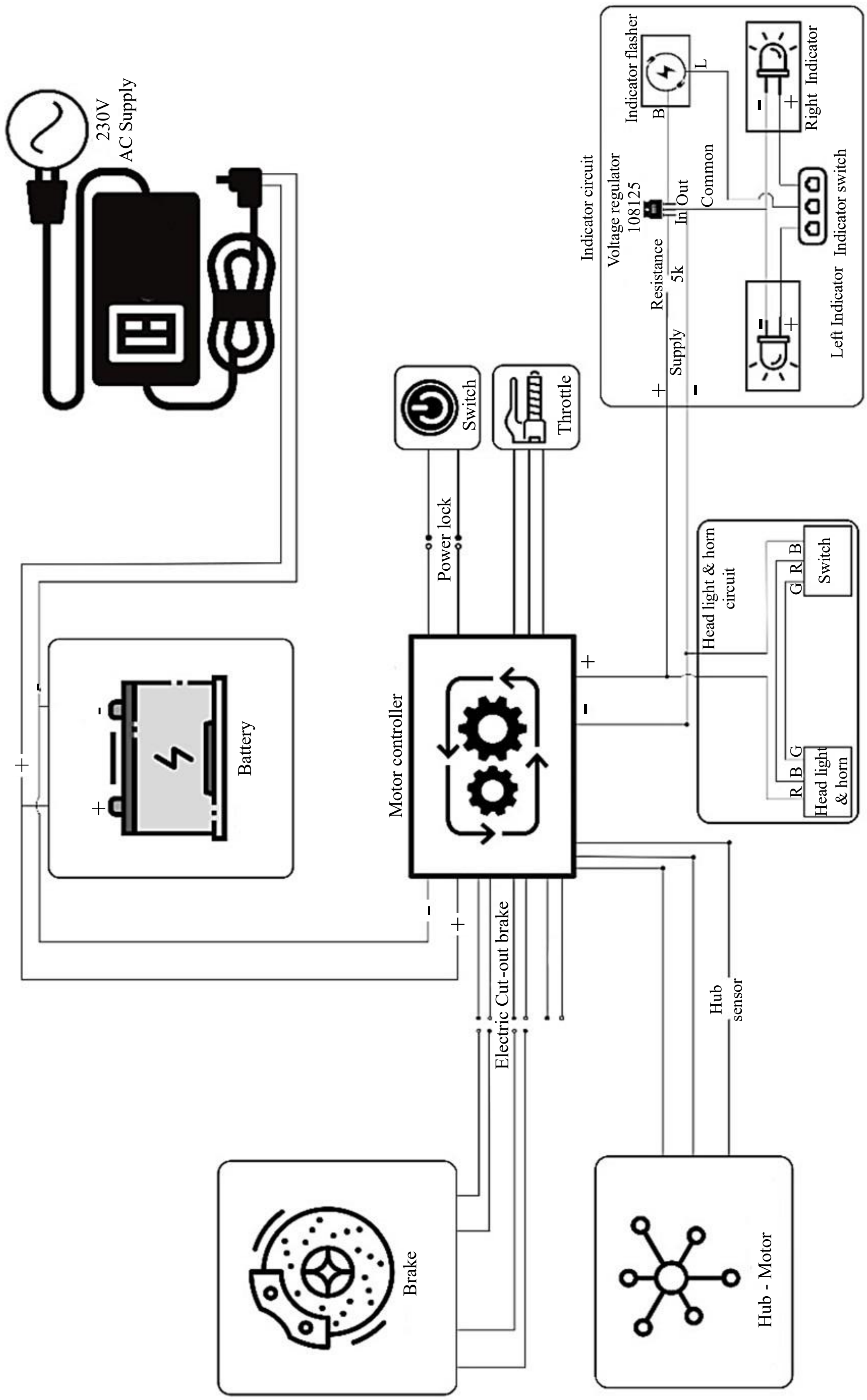


Figure 19. Circuit diagram of electric wheelchair.

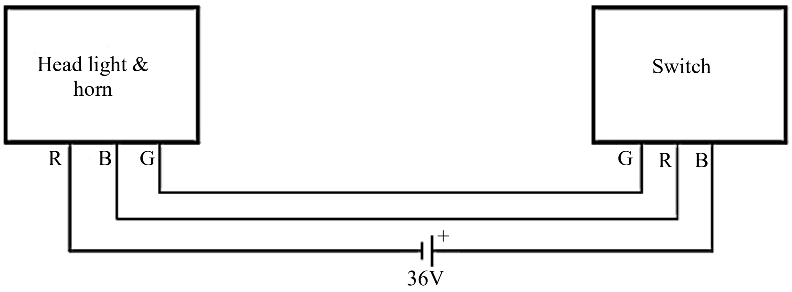


Figure 20. Circuit diagram of head light and horn.

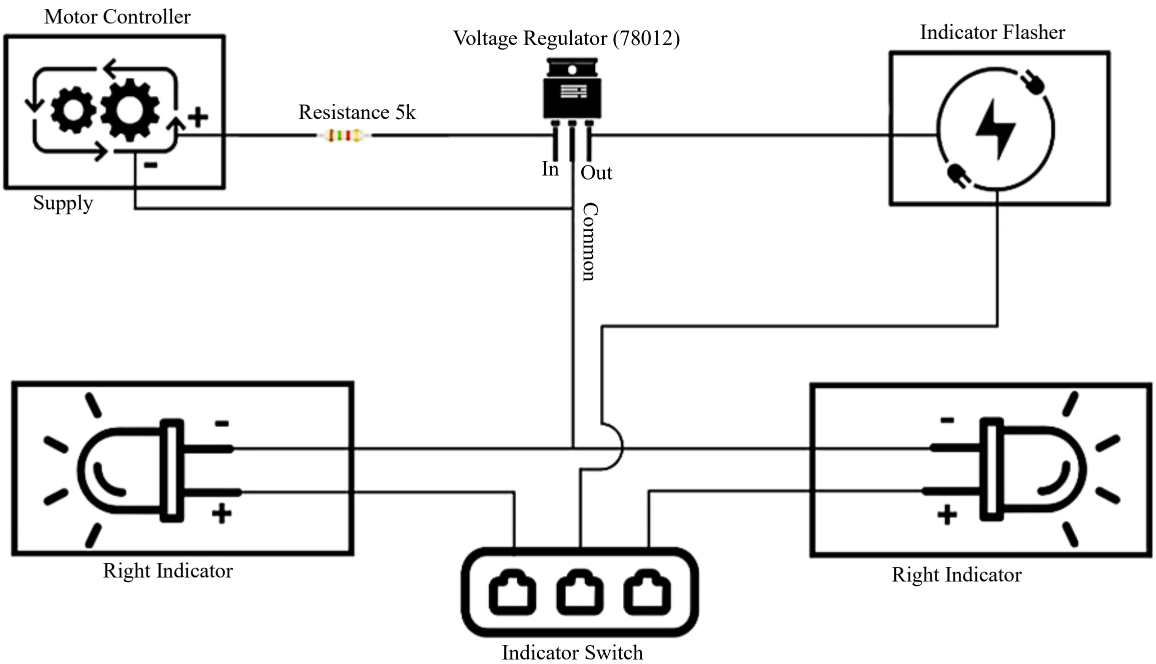


Figure 21. Circuit diagram of indicator.

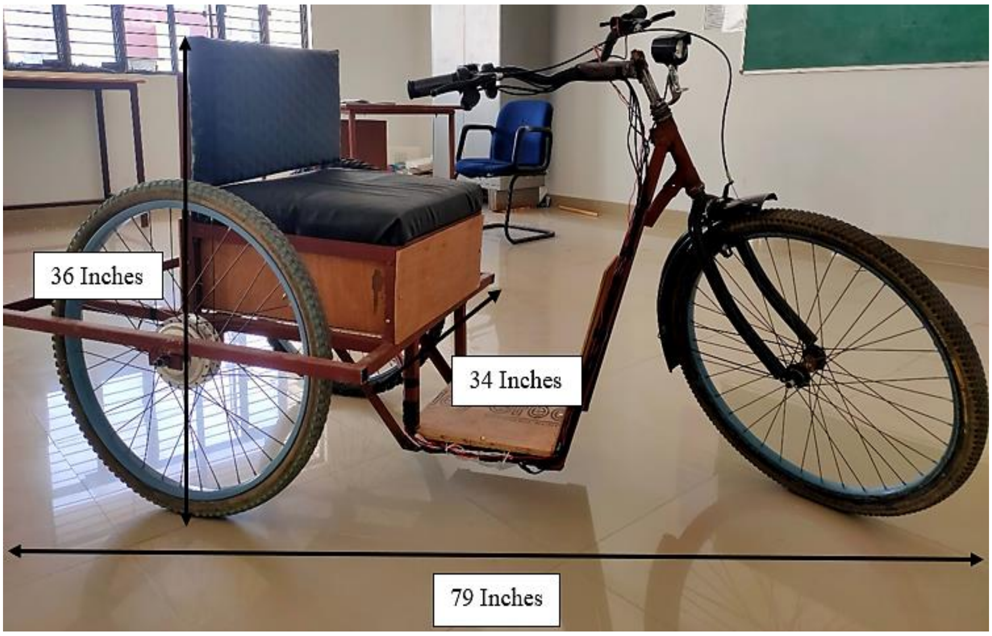


Figure 22. Electric wheelchair.


Figure 23. Front body of electric wheelchair.


Figure 24. Rear body of electric wheelchair.


Figure 25. Side view of electric wheelchair.

CONCLUSION AND FUTURE SCOPE

Conclusion

In this project, Electric Wheelchair Chassis has been designed for the Brushless DC (BLDC) hub motor mounting. Apart from that, a battery cabinet with 280×240×80 mm dimensions has been designed and fabricated for providing battery protection. A seat measuring 18 in×22 in is supplied for the user's comfort, and the entire body is painted in a slick black hue to give the electric wheelchair a more aesthetically pleasing appearance. A charging connection and charger are also included to recharge the battery, and the electric wheelchair only requires 2.5–3 h to fully charge before it can be used for transportation for about 15–20 km. This wheelchair can go between 20 and 25 kmph and can support a weight of 120 kg. For a person with a physical disability, controlling the wheelchair is relatively simple. The maintenance cost is also considerably lesser and the reliability is also much higher for the day-today operations. The increased utilization of internal combustion engine (ICs) vehicles rapidly nowadays is one of the main reasons behind rising in the average global temperature. One of the main factors of global warming is the pollution which the transportation industry causes.

So, in this growing market, Electric Wheelchair can also be a game changer. Because, all the measures have been taken to make wheelchair as cheaper as possible. The design was fabricated for an approximate cost of 28000 INR.

As a learning experience, the effort was certainly a hit.

- We learned about drilling, welding, painting, and most importantly, team work. We have all worked together for successful making of this project. People with impairments gets to their destinations with ease attributable to the automation of wheels.

Future Scope

The total body size and chassis may be further altered to make this wheelchair smaller, which will decrease the overall body weight of the chair. To make off-road travel more comfortable, suspension can be added. A solar panel could be used to charge batteries.

The safety of the wheelchair user and other users can also be guaranteed by the use of sensors like IR, ultrasonic, and touch sensors. With the help of GSM module, other systems, such as GPS, may be used to locate the location of a person using a wheelchair. In an emergency, an SMS can be sent to a predetermined number.

REFERENCES

1. Guha A, Krishna B, Sam GM, Sherrilyn MS. Low-Cost FGC Electric Wheelchair. Int Res J Adv Sci Hub. 2020; 2(6): 55–59.
2. Chatterjee S, Roy S. A low-cost assistive wheelchair for handicapped & elderly people. Ain Shams Eng J. 2021; 12(4): 3835–3841.
3. Shaikh AS, Gaikwad SN, Patil MR, Bandgar RT. Handcycle Attachment for Wheelchair-A Evaluation. Int Res J Mod Eng Technol Sci. 2021; 3(2): 290–294.
4. Simpson R, Lopresti E, Hayashi S, Nourbakhsh I, Miller D. The smart wheelchair component system. J Rehabil Res Dev. 2004;41:429-42. doi: 10.1682/jrrd.2003.03.0032. PMID: 15543461.
5. Yüksel M, Losch S, Kroffke S, Rohn M, Kirchner F. BLDC wheel hub motor and motor controller performance test of a concept electric robotic vehicle in HIL according to real driving characteristics. In 2015 IEEE 9th International Conference on Electrical and electronics Engineering (ELECO). 2015 Nov; 613–617.
6. MathWorks Student Competitions Team. (2021). MATLAB and Simulink Racing Lounge: Vehicle Modeling. [Online]. GitHub.
7. Rofer T, Mandel C, Laue T. Controlling an automated wheelchair via joystick/head-joystick supported by smart driving assistance. 2009 IEEE International Conference on Rehabilitation Robotics, Kyoto, Japan. 2009. pp. 743–8. DOI: 10.1109/ICORR.2009.5209506.
8. Kalantri RA, Chitre DK. Automatic wheelchair using gesture recognition. Int J Eng Adv Technol. 2013 Aug;2(6):146-50.
9. Barea R, Boquete L, Mazo M, López E. Wheelchair guidance strategies using EOG. J Intell Robot Syst. 2002;34:279-99. doi: 10.1023/A:1016359503796.
10. Arun Kumar Yadav, Ganesh SNV, Vinod Kumar Singh. Study of Stator Voltage Control Method for Induction Motor Torque Control using MATLAB Simulation. Journal of Microcontroller Engineering and Applications (JoMEA). 2017 Apr; 4(3): 18–24. ISSN: 2455–197X.
11. Arun Kumar Yadav, Vinod Kumar Singh, Ganesh SNV. Study of Direct Torque Control of Three Phase Induction Motor by Matlab. Trends in Electrical Engineering (TEE). 2018 Mar; 8(1): 1–6. ISSN: 2249–4774 (Online), ISSN: 2321–4260 (Print).
12. Rahul Kumar Gaur, Rakesh, Arun Kumar Yadav. Improvement of efficiency of electric power flow through unified power flow controller (UPFC) over transmission line. International Journal of Power Electronics Controllers and Converters (IJPECC). 2019; 5(1): 36–43. ISSN: 2456–1614.
13. Arun Kumar Yadav, Girish Chandra Yadav. Role of Solar Energy in New Trends of Generation of Electrical Energy. Journal of Power Electronics & Power Systems (JoPEPS). 2020; 10(1): 31–36. ISSN: 2249-863X (Online), ISSN: 2321–4244.
14. Ashutosh Gupta, Arun Kumar Yadav. Mathematical Education visualizing with printing 3-D Technology. International Journal of Software Computing and Testing (IJSCT). 2020; 6(1): 33–38. ISSN: 2456–2351.

15. Arun Kumar Yadav, Rachit Srivastava, Anurag Dwivedi, Gudlesh Kumar. Battery Charging by Solar & Wind System with Supplying Power to Inverter. International Journal of Electrical Machines & Drives (IJEMD). 2021; V-7(I-2): 33–39. DOI (Journal): 10.37628/IJEMD.
16. Yadav AK, Srivastava R, Dwivedi A, Kumar R. Emergency control traffic light. Int J Anal Electr Mach. 2021;7(2).
17. Arun Kumar Yadav, Arvind Kumar. Power Transmission Flow Control of Power System Equipment with Unified Power Flow Controller. International Journal of Automatic Control System (IJACS). 2021; 7(1). DOI:10.37628/IJACS.
18. Yadav R, Kumar A, Yadav AK, Yadav R. A comparative analysis of light fidelity (Li-Fi) with other communication mode. Trends Optoelectro Opt Commun. 2022;12(3):24-30.
19. Saurabh Verma, Anurag Verma, Sunil Kumar, Shivanshu Verma, Arun Kumar Yadav, Anurag Dwivedi. A Critical Review on Wind Energy. Journal of Alternate Energy Sources & Technologies (JOAEST). 2022; 13(3): 17–21. e-ISSN: 2230–7982 ISSN: 2321–5186.
20. Suryakant Yadav, Ashutosh Kumar Anshu, Anil Verma, Arun Kumar Yadav, Abhishek Yadav, Archana Pal. A Review: Solar Power Generation. Journal of Refrigeration, Air Conditioning, Heating and Ventilation (JORACHV). 2022; 11(1): 18-24. ISSN: 2394–1952.
21. Kumar P, Kumar R, Himanshu SK, Agrawal TP, Verma A, Yadav AK. An overview of electricity generation by solar & its tracking system. J Therm Eng Appl. 2022;9(3):24-33.

