PJP/2010/FKM (30B) – S744

DEVELOPMENT OF ELECTRICAL SCOOTER FOR GREEN CAMPUS, IN CASE: PAR DISPATCH VEHICLE

SAFARUDIN GAZALI HERAWAN

FACULTY OF MECHANICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2011

PJP/2010/FKM (30B) – S744

DEVELOPMENT OF ELECTRICAL SCOOTER FOR GREEN CAMPUS, IN CASE: PAR DISPATCH VEHICLE

SAFARUDIN GAZALI HERAWAN
SUHAIMI BIN MISHA

RESEARCH VOTE NO:
PJP/2010/FKM (30B) – S744

FACULTY OF MECHANICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2011

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CENTRE FOR RESEARCH AND INNOVATION MANAGEMENT
PROJECT COMPLETION REPORT

A. PROJECT DETAILS

Project Leader : Safarudin Gazali Herawan

Faculty/Centre : Fakulti Kejuruteraan Mekanikal

Project Title : **Development of Electrical Scooter for Green Campus, In Case: PAR Dispatch Vehicle**

Project Ref. No.: **PJP/2010/FKM (30B) – S744**

Project Focus Area : **a) Green Technology** b) Emerging Technology
c) System Engineering d) Human Technology Interaction

Project Duration : Starts Date **1 July 2010** Final End Date: **31 June 2011**

Budget Approved: RM **14,000.00** Amount Spent : RM **14,000.00**

Project Members : Suhaimi bin Misha (FKM)

B. PROJECT ACHIVEMENT AND PERFORMANCE

OVERALL	**0 – 50%**	**51 – 75%**	**76 – 100%**
Work completion (please state # %)			100%
Financial Utilization (please state # %)			100%

RESEARCH OUTPUT			
I. PUBLICATION (Recorded at UTeM eRepository)	UTeM Press	Index Scopus/ISI	Others
a. No. of Journal Publication (Please attach the first page of publication)			
b. No. of Conference Proceeding (Please attach the first page of publication)			
c. No. of Other type of publication eg. monograph, books, chapters in book			

II. PROTOTYPE DEVELOPMENT	National	International
a. No. of Intellectual Property Rights		
b. Attended product exhibition & competition	2	
c. No. of Industrial Collaboration MoU/NDA/MoA)		

III. HUMAN CAPITAL DEVELOPMENT

Number of Human Capital		On-Going		Graduated	
		Malaysian	Non-M	Malaysian	Non-M
1	PhD Student				
2	Master Student				
3	Undergraduate Student (PSM/SRA)	2		2	
Total		2		2	

IV. ASSETS AND INVENTORY PURCHASED (Cost more than RM 3000 per item)

1. No assets bought more than RM 3000 per item.
2.
3.
4.
5.

DECLARATION OF PROJECT LEADER

I acknowledged UTeM in providing the fund for this research work.

I certify that the information given in this final project report is true to the best of my knowledge.

Project Leader's Signature :

Official stamp :
Name :
Designation :
Date :

ENDORSEMENT BY DEAN or DEPUTY DEAN (RESEARCH), FACULTY/CENTRE
(Please state /comment on the performance of the project)

_____

_____

_____ _____
Signature & Official Stamp Date

Revised date : 4Mac2014

Nota:

1. Sila lengkapkan **Lampiran A : Profil Penyelidikan** (maksimum 5 mukasurat sahaja) dan dihantar bersama borang RND010. Penulisan Profil Penyelidikan mesti berasaskan kepada kertas cadangan projek berkaitan yang diluluskan.
2. Hantar dokumen ke CRIM dalam bentuk cetakan hardcopy dan softcopy MS Words.
3. CRIM akan mengumpul dan membukukan Profil Penyelidikan mengikut jenis geran dan Bidang Fokus UTeM.
4. Penghantaran secara atas talian URIS akan dilaksanakan pada satu masa kelak.

LAMPIRAN A

TEMPLATE
PROFIL PENYELIDIKAN

DEVELOPMENT OF ELECTRICAL SCOOTER FOR GREEN CAMPUS, IN CASE: PAR DISPATCH VEHICLE

Safarudin Gazali Herawan
Suhaimi bin Misha
Green Technology Vehilcles Research Group
safarudin@utem.edu.my
Green Technology

ABSTRACT (120 words)

Electric Motorcycle is a vehicle that is popular among the people of the world, not forgetting the people in Malaysia at present. Excessive fuel consumption from vehicles such as motorcycles can cause the air pollution to the environment. Therefore to solve this problem then arises as an idea to create a green vehicles called "Electric Motorcycles". This is because the use of petrol and diesel as fuel can cause environmental pollution. The Electric Motorcycle was developing to investigate the performance to be achieved. A study conducted to identify the electric motorcycle speed and the performance of the battery power from motorcycle. In order to get the result, the experiment should be run to get the actual result. Electric motorcycle is built using the scrap motorcycle frame and use a hub motor electric powered motorcycle as the driver and powered by 48 volt rechargeable batteries. The main challenge for the completion of this project is to identify the right components for this project are included in scientific research and research methods. Besides that, the safety design is necessary to ensure consumer safety is a priority.

1. INTRODUCTION

Motorcycle is a vehicle with the characteristics of being mobile, quick, convenient, economical and easy to park. It is the best suited for short range transport. According to Chou, J. R. Et al. (2004) Taiwan is densely populated, the motorcycle has become a pretty popular means of transport. In recent years, along with fast expansion and rapid industrial development, the number of motorcycles has increase dramatically. The pollutants such as carbon monoxide (CO) and hydrocarbon (HC) can produce by motorcycle account for approximately 10% of the total annual amount of pollution emissions in world. Therefore, to reduce pollution emission from motorcycle to improve the quality of the environment has become a critical issue that cannot longer be ignored. So, from the issue the electric motorcycle is a solution.

Electric motorcycles are considered a new technical green product and a potential industry for many countries. Conventional transportation or vehicle technologies usually involve the use of fossil fuels for the vehicle. It can produce more pollution to the environment because it can produce carbon dioxide. Rising fuel price are cause mainstream awareness and interest in alternative transportation technology. From the problems, many automobile industries in the world today are working hard to develop more sustainable vehicles in order to combat fuel cost and at the same time also to save the environmental effect when used alternative source as a fuel source. There are many types of sustainable vehicle like car, bus, lorry and motorcycle. It can generate using the alternative fuel such as plug-in hybrid, battery or electric and hydrogen.

In Asia, motorcycle is one of the most popular vehicles due to the pattern of economic development and geographic environment. Based on the previous research done by Collela, W.G (2000), two-wheel motor vehicle which includes motorcycle, motor bikes, motor scooter, moped and motorized-rickshaws represent over 50% of the vehicle fleet in many Asian countries and Malaysia also include the top five popularity used the motorcycle.

Nowadays, electric motorcycle are considered a new green technology of transportation for the 21th century and also regarded as a viable niche market and a potential industry for many countries. It is because by using electric motorcycle the sound pollution can be reduced because it not exhaust from pedalling. Besides that, using electric motorcycle cost to move from one location to one location is cheaper compare it used the fossil fuel. Usually the motorcycle used only in short distance, means that between 0 km until 100 km. Based on the cost of maintenance, the electric motorcycle is higher compare to the motorcycle using fuel because the hub motor and the rechargeable battery is very expensive. But in term of lifetime the electric motorcycle is more efficient than the motorcycle using fuel.

2. RESEARCH METHODOLOGY

Methodologies for this project is to give a clear overview to a reader about the methods in effort to finish up the project. The main purpose in the methodology is to identify the suitable method in order to ansure the objective and also scope of the project is achieved and succeed. In this project also present the methods of testing to identify actual performance of the electric motorcycle including the method to conduct speed test, load test, battery performance, power consumption that will give overall performance of the electric motorcycle by using a hub motor as a primary mover for wheels.

3. LITERATURE REVIEW

In 1860, the first electric motorcycle is already found in patents. But in 1920 the electric motorcycle was developed. An electric motorcycle is a motorcycle comprising a frame and a platform for the

rider [14]. Motorcycle designs have been created in some of the earliest forms of motorcycles and motorcycle is identified as scooters. It was created late 1894 by Hildebrand and Wolfmuller world's first production motorcycle. This motorcycle is had a step-through frame, with its fuel tank mounted on the down tube, its parallel two-cylinder engine mounted low on the frame and its cylinder mounted in line with the frame. It was water cooled and had a radiator built in to the top of rear fender.

Production of the motorcycle only built a few hundred, and the high price and technical difficulties made the venture a financial failure [2]. Since 1900, after generation by generation compete to produce motorcycle from steam engine to gasoline engine and the finally today their passion to compete is to produce a green vehicle after realize the deterioration of fossil fuel to earth. In this report a green vehicle is refer the electric motorcycle.

Nowadays, in 2000 electric motorcycle have updated because have many research and development (R&D) to improve the electric motorcycle based on the design and performance. It is because nowadays the electric motorcycle also has the high cubic centimeters (CC) such as Zero S and Cowboy. The user demand of the electric motorcycle is increase from one year to another year. Usually the performance of the electric motorcycle depends on the selecting the component.

4. FINDINGS

The experiment on the electric motorcycle describes the performance of the vehicle. The speed test of the electric motorcycle shown that the highest speeds that can be achieved is around 44.0 km/h. The minimum speed that can be achieved is around 33.4 km/h. This speed is meet the requirement of the Road Transport Department that the maximum speed that electric motorcycle can achieved in Malaysia is below 45km/h. The maximum distance of electric motorcycle can move from fully charge to battery getting weak is around 13km.

Usage of this electric motorcycle is save the user finance cost compared to the conventional motorcycle where user only to paid around RM 3.60 each month for every day usage. If far better compared to the vehicle that are using fossil fuel.

In any designed of a product, there must be a weakness that cannot be avoided likewise this electric motorcycle. Here is some recommendation for improving the design and performance of this vehicle. The first point is regarding to the recharging batteries process. Undeniably, as an electric vehicle those are using battery as a power source need to recharge after it getting weak or exhausted. But sometime, recharging the battery is wasted our time if someone are need to used the vehicle immediately and unfortunately the batteries is weak. It is because time to charging process is around 1 hour. So, use battery charging process in the car system is suitable concept to followed. The rotating of the car engine is not waste but fully using to drive an alternator to rechage the battery. The same concept also can be applied on the Electric Motorcycle where the rotation of the tire must not waste easily. So, the batteries can self-rechargeable without need to plug-in to the wall switch.

The next point is selection of the suitable battery is very important thing to this project. In this project, selection of Lithium-ion battery is suitable followed the requirement of the hub motor. There are four important thing need to know before select the suitable battery which is hub motor input voltage, hub motor power consumption, hub motor maximum current drain and lastly expected running time by the batteries. Battery capacity is depended on how long user needs to run the device (hours), which can be calculated using this formula:

$$Battery\ capacity\ (Ah) = \frac{Device\ wattage(watt)}{Battery\ voltage} \times time\ to\ run(Hours)$$

Therefore, using this formula when user need to run the electric motorcycle for long distance, user need to increase the battery capacity. Other than that, a battery cannot take any current drain, so the important thing is need to know maximum discharging current of the battery and hub motor. The maximum discharging current of the battery must be higher than the hub motor requires.

Lastly, the point is regarding to suggest used the transmission. The electric motorcycle is less torque for climbing hills. In this project should be modified to use another transmission. This is because using it can increase the torque transmission by altering the ratio of the drive and driven gear. Transmission that can be used as a chain, belt or something appropriate. When using the transmission it same with conventional motorcycle but in term of system is diffferent. Using the transmisson also can increase the speed of electric motorcycle and at the same time can reduce the power consumption from battery.

5. CONCLUSION

In this report, the project was represent clear views consist of several chapters which are introduction, literature review, methodology, result and discussion and the last one is conclusion and recommendation. After completed this project, this project objective is achieved to analyze the performance of electric motorcycle and also to determine the maximum capacity of battery for long distance travel. Build an electric motorcycle is a big challenge because it is one of the challenges to save the world from pollution and excessive fuel consumption. It is because electric motorcycle also in the green technology vehicle. In the mean time, this electric vehicle become an example and good beginning of UTeM' s members to applied green technology and saving a lot of finance cost with replace the conventional vehicle to electric vehicle.

ACHIEVEMENT

i) Human Capital Development
   2 PSM student.
ii) Exhibition and award:
   1. The most innovative product in Hari Penyelidikan FKM 2011.
   2. Silver award in UTeMEX 2012.
iii) Presented in Malaysia Hari Ini (MHI) TV3 on 16 January 2013.

REFERENCES

[1] Akihiro, T. (2001). *Development of nickel/metal-hydride batteries for EVs and HEVs*. Power Sources 100. Pp 117-124,
[2] Bishop, J. D. K. *et. al.* (2011). *Investigating the Technical, Economic And Environmental Performance Of Electric Vehicles In The Real-World: A Case Study Using Electric Scooters*. Power Source 196. Pp 10094– 10104
[3] Brodd, R.J. (2009). *Encyclopedia of Electrochemical Power Source.* 1st Edition USA : Broddarp of Nevada Inc. ms 254-261
[4] Carl, V. (2009). "Build Your Own Electric Motorcycle". 1st Edition. New York: Mc Graw Hill.
[6] Chou, J. R.and Hsiao, S. W. (2004). *Product Design and Prototype Making For An Electric Scooter*. Material Design 26.pp 439-449

[7] Chou, J. R.and Hsiao, S. W. (2005). *An Anthropometric Measurement for Developing An Electric Scooter*. Industrial Ergonomics 35. pp 1047-1063
[8] Colella, W.G. (2000). *Design Features, And Performance of A Fuel Cell-Powered Scooter*. Power Sources 86. pp 255-260
[9] Dhar, S. K. (1997). *Nickel/metal hydride technology for consumer and electric vehicle batteries*. Power Sources 65. Pp 1-7.
[10] Hsu, Y. Y. and Lu, S. Y. (2010). *Design And Implementation Of A Hybrid Electric Motorcycle Management System*. Applied Energy 87. pp 3546-3551
[11] Justin, D. (2011). *Brushless DC Motor Design and Build*. Carlifonia Polytechnic State University: Tesis Bachelor.
[12] Linden, J. D., Thomas B. R. (2002). *Handbook of Batteries*. 3rd Edition New York: McGraw-Hill. ms 3-27
[13] Moseley, P. T. and Cooper, A. (1999). *Progress towards an advanced lead–acid battery for use in electric vehicles.* Power Sources 78. Pp 244-250.
[14] Walker, M. (1998). *The Art of The Motorcycle.* Pp1-13
[15] Siddique, A. K. et al. (2004) *Thermal management of Li-ion battery with phase change material for electric scooters: experimental validation.* Power Source 142 pp 345-353.
[16] Shigley, J. E and Mischke, C. R. (2003). *Mechanical Engineering Design*, 6th Edition, Mc Graw Hill.
[16] http://www.ebikes.ca/hubmotors.shtml
[17] www.ananda.com.cn

DEVELOPMENT OF ELECTRICAL SCOOTER FOR GREEN CAMPUS, IN CASE: PAR DISPATCH VEHICLE

ABSTRACT

(Keywords: *Electric motorcycle, Battery; Green Technology*)

Electric Motorcycle is a vehicle that is popular among the people of the world, not forgetting the people in Malaysia at present. Excessive fuel consumption from vehicles such as motorcycles can cause the air pollution to the environment. Therefore to solve this problem then arises as an idea to create a green vehicles called "Electric Motorcycles". In the era of modernization, there are a lot of vehicles produced using alternative fuels such as hybrid, electric, solar and others. This is because the use of petrol and diesel as fuel can cause environmental pollution. The Electric Motorcycle was developing to investigate the performance to be achieved. Besides that, electric motorcycles will also be used as a vehicle in the main campus. A study conducted to identify the electric motorcycle speed and the performance of the battery power from motorcycle. In order to get the result, the experiment should be run to get the actual result. Electric motorcycle is built using the scrap motorcycle frame and use a hub motor electric powered motorcycle as the driver and powered by 48 volt rechargeable batteries. The main challenge for the completion of this project is to identify the right components for this project are included in scientific research and research methods. Besides that, the safety design is necessary to ensure consumer safety is a priority.

Key Researchers:
Safarudin Gazali Herawan (Principal Researcher)
Suhaimi bin Misha

E-mail: safarudin@utem.edu.my
Tel. No.: 06-2346717
Vote No.: PJP/2010/FKM (30B) – S744

ACKNOWLEDGEMENTS

Alhamdulillah, with His Mercy and Blessings, this study was finally completed. The authors pleasure to express thank to Dato' Professor Dr. Mohamad Kadim bin Suaidi, as a Director of Centre of Research and Innovation Management (CRIM) and Professor Dr. Md Razali bin Ayob, Dean of Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) and Ministry of Higher Education for giving us opportunity to conduct this research.

The authors are grateful to Professor Madya Dr. Ir. Abdul Talib bin Din, Deputy Dean of Research and Post Graduate Study, Faculty of Mechanical Engineering, also Staffs of the Faculty of Mechanical Engineering, and Centre of Research and Innovation Management, UTeM, for their assistance and co-operation in carrying out the research in one way or another.

May Allah reward and bless all of them. Finally the authors are expressing our sincere gratitude to Allah once again who made the research to complete.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Motorcycle is a vehicle with the characteristics of being mobile, quick, convenient, economical and easy to park. It is the best suited for short range transport. According to Chou, J. R. Et al. (2004) Taiwan is densely populated, the motorcycle has become a pretty popular means of transport. In recent years, along with fast expansion and rapid industrial development, the number of motorcycles has increase dramatically. The pollutants such as carbon monoxide (CO) and hydrocarbon (HC) can produce by motorcycle account for approximately 10% of the total annual amount of pollution emissions in world. Therefore, to reduce pollution emission from motorcycle to improve the quality of the environment has become a critical issue that cannot longer be ignored. So, from the issue the electric motorcycle is a solution.

Electric motorcycles are considered a new technical green product and a potential industry for many countries. Conventional transportation or vehicle technologies usually involve the use of fossil fuels for the vehicle. It can produce more pollution to the environment because it can produce carbon dioxide. Rising fuel price are cause mainstream awareness and interest in alternative transportation technology. From the problems, many automobile industries in the world today are working hard to develop more sustainable vehicles in order to combat fuel cost and at the same time also to save the environmental effect when used alternative source as a fuel source. There are many types of sustainable vehicle like car, bus, lorry and motorcycle. It can generate using the alternative fuel such as plug-in hybrid, battery or electric and hydrogen.

In Asia, motorcycle is one of the most popular vehicles due to the pattern of economic development and geographic environment. Based on the previous research done by Collela, W.G (2000), two-wheel motor vehicle which includes motorcycle, motor bikes, motor scooter, moped and motorized-rickshaws represent over 50% of the vehicle fleet in many Asian countries as shown in Figure 1.1 below. Based on the Figure 1.1 Malaysia also include the top five popularity used the motorcycle.

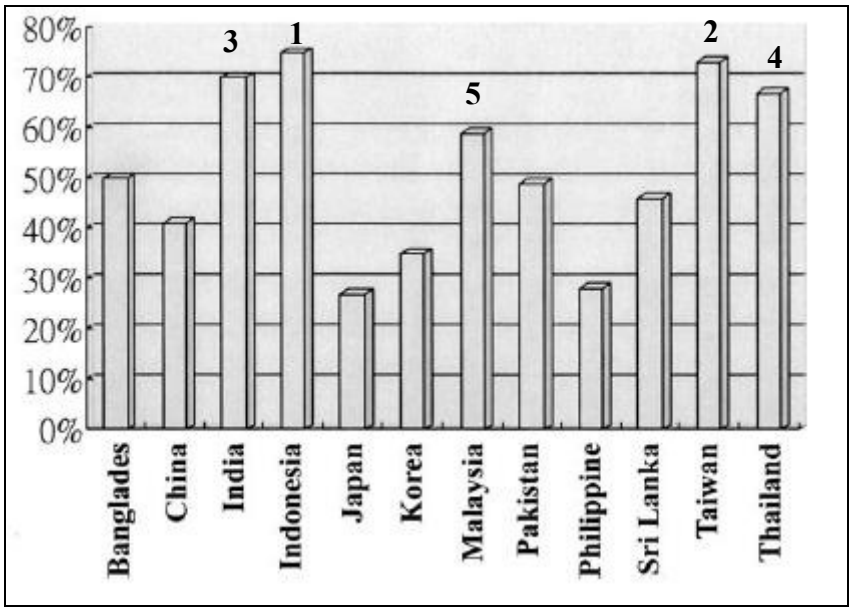

Figure 1.1: Popularity of motorcycle in Asia

Nowadays, electric motorcycle are considered a new green technology of transportation for the 21th century and also regarded as a viable niche market and a potential industry for many countries. It is because by using electric motorcycle the sound pollution can be reduced because it not exhaust from pedalling. Besides that, using electric motorcycle cost to move from one location to one location is cheaper compare it used the fossil fuel. Usually the motorcycle used only in short distance, means that between 0KM until 100KM. Based on the cost of maintenance, the electric motorcycle is higher compare to the motorcycle using fuel because the hub motor and the rechargeable battery is very expensive. But in term of lifetime the electric motorcycle is more efficient than the motorcycle using fuel.

1.1 Background of Electric Motorcycle

In 1860, the first electric motorcycle is already found in patents. But in 1920 the electric motorcycle was developed. An electric motorcycle is a motorcycle comprising a frame and a platform for the rider [14]. Motorcycle designs have been created in some of the earliest forms of motorcycles and motorcycle is identified as scooters. It was created late 1894 by Hildebrand and Wolfmuller world's first production motorcycle shown in Figure 1.2 below. This motorcycle is had a step-

through frame, with its fuel tank mounted on the down tube, its parallel two-cylinder engine mounted low on the frame and its cylinder mounted in line with the frame. It was water cooled and had a radiator built in to the top of rear fender.

Figure 1.2: First Electric Motorcycle [14]

Production of the motorcycle only built a few hundred, and the high price and technical difficulties made the venture a financial failure [2]. Since 1900, after generation by generation compete to produce motorcycle from steam engine to gasoline engine and the finally today their passion to compete is to produce a green vehicle after realize the deterioration of fossil fuel to earth. In this report a green vehicle is refer the electric motorcycle.

Nowadays, in 2000 electric motorcycle have updated because have many research and development (R&D) to improve the electric motorcycle based on the design and performance. It is because nowadays the electric motorcycle also has the high cubic centimeters (CC) such as Zero S and Cowboy. The user demand of the electric motorcycle is increase from one year to another year. Usually the performance of the electric motorcycle depends on the selecting the component.

.

1.2 Main Components

Electric motorcycle has some main component that can establish the electric vehicle. The main components are an important part to make it move with two wheels that use an electric motor to move. It is because the main part is related to each other's to make sure the electric motorcycle can move. This section describes the description of the important component that include as an electric motor scooter. An electric motorcycle consists of the battery to provide the electrical energy. Electric hub motor to drives the wheels and also the controller that regulate the energy flow to the electric hub motor.

1.2.1 Hub Motor

Hub motor is an electric motorcycle that is built in into a hub of the wheel and drives it directly [4]. Hub motor is an electric motor that turns a wheel without the use of a transmission. This is same with auto transmission. This is accomplished because a hub motor is built directly into the wheel hub which is the point around which the wheel rotates. All the motor principle is to convert electrical energy to mechanical energy. Hub motor can run on electricity from a rechargeable battery.

The hub motor is steadily emerging as the standard drive method for e-bikes, scooters, solar cars, and many other light electric vehicles [11]. With a hub motor conversion, there is no need for external mounting brackets and drive chains to support a motor and transmission. It is because all of this is contained inside the wheel which mounts on bike like any other wheel. There are two basic categories of hub motor like direct drive and geared.

Direct Drive Hub Motor

The direct hub motor is simple design. Direct hub drive has no internal gears or other moving parts except the actual case which rotates around the axle on sealed bearings [4]. The coils are wound around an assembly that is fastened to the axle and remains stationary. The outer ring of the case has a ring of magnets that rotate in closeness to

the electromagnets formed by the coils. As the coils are energized in a specific pattern by the motor controller, the magnets are attracted and repelled causing the wheel to rotate. The outer case directly drives the wheel of the bike. In direct drive motor is divide by two parts which is hub motor rotor and hub motor stator shown in Figure 1.3.

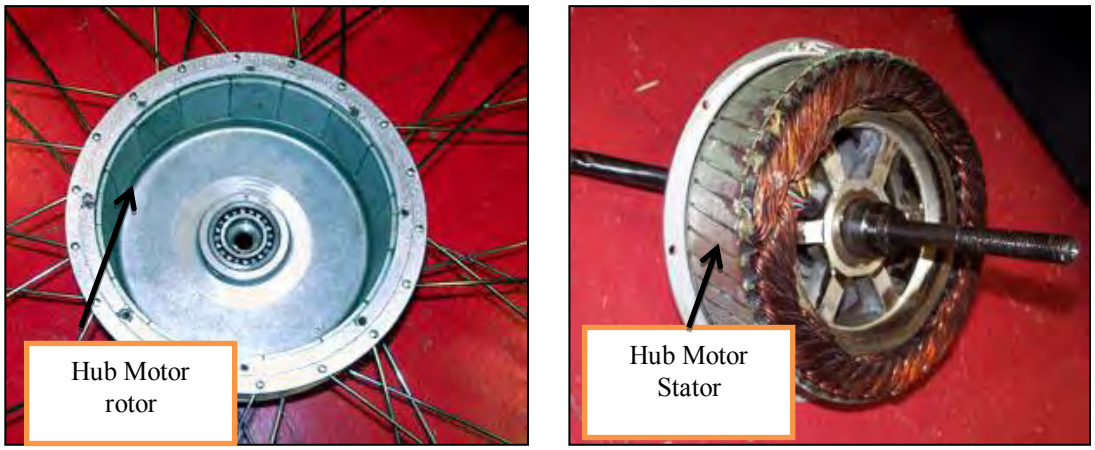

Figure 1.3: Direct hub Motor [11]

Normally these are radial-flux Brushless DC (BLDC) machines that have an array of permanent magnets on the inside surface of the hub [11]. The stator windings are attached to the axle, and the hub is made to rotate by alternating currents through these windings. In a DC hub motor, the magnets are on the axle, and the windings are actually spinning on the inside of the hub. When the electrical potential is applied across the electrical connection, current flows through the motor. A carbon brush transmits electricity to the spinning windings via a commutator plate. The commutator rotating along with the rotor, complete the connection for each different set of winding in the stator.

Geared Hub Motor

Geared hub motor shown in Figure 1.4 has gearing inside it to reduce the high speed of a fast and efficient motor to the low speed of the wheel [11]. From the outside, a geared hub motor is usually smaller in radius but wider than a direct drive hub. On the

inside, they can take a variety of different forms although most frequently they have a run fast motor that drives the center of a planetary gear set linked to the rotor.

Some gears are made of nylon, and these are more likely to fail than metal gears but are quieter and lighter in weight The geared hub concept has advantages from weight which a transmission drives and packages it into the simple looking and easy to install hub motor. The weight normally less than an equivalently powerful direct drive hub motor and they often have superior torque outputs. According to the Heinzmann USA Company the geared hub motor can produce up to 80 Newton-meters (Nm) of torque, compared to about 35 Nm for typical direct drive hub motor.

Figure 1.4: Geared Hub Motor [11]

1.2.2 Battery

Battery is a device that produces electricity that has one or more electrochemical cells convert stored chemical energy into electrical energy [12]. There are two types of battery which is primary (disposable batteries) and secondary (rechargeable batteries).

Primary batteries usually used once and discarded. It is suitable for low current usage or intermittently usage. It is because the primary batteries cannot be rechargeable.

Secondary batteries are the rechargeable batteries. They are known as secondary cells because their electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shaped and size. It depends on the capacity of the batteries. Rechargeable batteries have lower total cost of used and environmental impact than disposable batteries. Rechargeable batteries have higher initial cost, but can be recharge with low cost and used many times.

There are five main types of rechargeable battery now in common use for powering electronic and electrical equipment:

1) Sealed lead-acid (SLA)
2) Rechargeable alkaline-manganese (RAM)
3) Nickle-Cadmium(NiCad)
4) Nickel-metal hydride (NiMH)
5) Lithium-ion(Li-ion)

Battery Performance

Secondary batteries are basically device which stored electrical energy in chemical that batteries are different from one another mainly in term of amount of electrical energy they can stored and deliver [3]. Broadly speaking the larger physical size of a battery, the more electrical energy it can stored. Specific unit usually used of batteries in ampere –hours (Ah) or for small batteries in miliampere-hours (mAh).

SLA Battery

Moseley, P. T. (1999), states that sealed lead acid batteries are a development of the familiar flooded lead-acid battery used for many years in cars and trucks. Figure 1.5 shown it have a positive electrode of lead oxide, a negative electrode of porous metallic lead and sulphuric acid as the electrolyte. The SLA form uses a gel type electrolyte rather than liquid and electrodes made from lead alloys designed so that

during charging, it normally never reaches the stage where gas is generated. The main advantage of lead acid is that they have high discharge rate and they are relatively low price compared to others. Example application used of SLA battery is emergency light, solar power system and electrical vehicle.

Figure 1.5: Lead acid Battery [13]

RAM Battery

Dhar, S. K. et al. (1997), state that the rechargeable alkaline- manganese battery is a recent development from the alkaline manganese zinc primary battery. Based on Figure 1.6 it like the primary battery it uses a manganese dioxide positive electrode and a potassium hydroxide electrolyte, but the negative electrode is a special porous zinc gel designed to absorb hydrogen during the charging process. Rechargeable alkaline batteries can have a high recharging efficiency and have less environmental impact than disposable cells. Examples of application of the RAM battery are portable emergency light, toys, portable radio and others.

Figure 1.6: RAM Battery [9]

NiCad Battery

The nickel–cadmium battery (NiCad battery) is a type of rechargeable battery. Dhar, S. K. et al. (1997) emphasized nickel oxide hydroxide as a positive electrode and metallic cadmium as negative electrodes, with potassium hydroxide as the electrolyte. Like SLA, NiCad can be used in virtually any position. They have a higher energy density than SLA up to double and also much longer life (1000 cycles). Figure 1.7 below shown the NiCad Battery 300mAh 1.2V can used in the electric vehicle when it combined in series. Besides that, this combined with their relative low cost makes them very popular for powering compact portable equipment. There are several example the application is used the NiCad battery such as portable tools, portable transceiver and test equipment.