Journal of Al-Azhar University Engineering Sector

JAUES

Vol. 14, No. 53, October, 2019, 1487-1498

BATTERIES FOR UPCOMING ELECTRIC VEHICLE MOBILITY- A LITERATURE SURVEY

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ABSTRACT

The main problems electric vehicles are facing are the batteries, costs and charging facilities. Because of the limit in range of BEVs the cars that going to be introduced into the market most likely will be small city cars. A battery is a device that converts chemical energy into electrical energy and vice versa. Usually it has two terminals–Positive Cathode and Negative Anode. During potential changing (charging or discharging) the system depends upon the chemical reaction of electrolyte (liquid or paste solution). Basically, electrolyte allows the ions to flow between the two terminals (cathode and anode) or the battery active materials which allows current to flow out of the battery to perform required work. The uses of battery are knows no bound. For any electronic devices that needs high energy storage capacity (electric vehicle, electric generator or IPS etc.) or for any device that needs low energy output (portable devices like cell phone, laptop etc.), battery is used for either to storage energy or to act as a power supply. Along with technological improvement the storage capacity, size, life time is improving also the new uses of batteries are also emerging day by day. For our solar car we are using battery for a media to store energy to have continuous output. In order to do that we need specific specification of battery to perform our task successfully which needs clear understanding of its parameters as well as its nature of behavior. In this paper we will try to show the precise purpose and how we are expecting the battery to be executed through our simulated data.

KEYWORDS : Electric vehicles, Electric battery, Dry battery, Flow battery, Fuel cells Lead/acid battery, Lithium ion battery

البطاريات الخاصة بالسيارات الكهربية المستقبلية -دراسة مقارنة

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الملخص :

البطاريات الخاصة بالسيارات الكهربائية المستقبلية - دراسة مقارنة ؛ عماد الدين صالح إمام حسن المشاكل الرئيسية التي تواجهها السيارات الكهربائية هي البطاريات والتكاليف ومرافق الشحن. بسبب الحد الأقصى المسموح به في نطاق قدرة البطارية ، فإن السيارات التي سيتم طرحها في السوق ستكون على الأرجح سيارات المدينة الصغيرة. البطارية عبارة عن جهاز يحول الطاقة الكيميائية إلى طاقة كهربائية والعكس صحيح. عادة ما يكون لديه اثنين من الأقطاب الكاثودية الإيجابية والسلبية الأنودية. أثناء التغيير المحتمل (الشحن أو التفريغ) يعتمد النظام على التفاعل الكيميائي الالكتروليت (محلول سائل أو معجون). بشكل أساسي ، يسمح الالكتروليت الكهربي للأيونات بالتدفق بين القطبين (الكاثود والأنود) أو المواد النشطة للبطارية والتي تسمح للتيار بالخروج من البطارية لأداء العمل المطلوب. استخدامات البطارية مختلفة وغير ملزمة. بالنسبة إلى أي أجهزة إلكترونية تحتاج إلى سعة تخزين عالية للطاقة (مركبة كهربائية أو مولد كهربائي أو مصدر احتياطي وما إلى ذلك) أو لأي جهاز يحتاج إلى إنتاج مخفض للطاقة (الأجهزة المحمولة مثل ا لهواتف المحمولة أو أجهزة الكمبيوتر المحمول وما إلى ذلك) ، يتم استخدام البطارية لتخزين الطاقة أو لتكون بمثابة مصدر الطاقة. إلى جانب التحسن التكنولوجي ، تتحسَّن أيضا سعة التخزين وحجمه ومدى الحياة ، كما تظهر الاستخدامات الجديدة للبطاريات يوًما بعد يوم. بالنسبة

لسيارتنا الشمسية ، نحن نستخدم بطارية لوسائط لتخزين الطاقة للحصول على خرج مستمر. من أجل القيام بذلك ، نحن بحاجة إلى مواصفات محددة للبطارية لأداء مهمتنا بنجاح والتي تحتاج إلى فهم واضح لمعاييرها وطبيعة سلوكها. سنحاول في هذا البحث توضيح الغرض الدقيق وكيف نتوقع أن يتم تنفيذ البطارية من خلال بياناتنا المحاكاة. الغرض من البطارية توفر البطارية الكهرباء عندما:

الكلمات المفتاحية : سيارات الكهربية، البطاريات الكهربية،البطاريات الجافة، البطاريات السائلة، خلايا الوقود،بطاريات الرصاص الحامضية، بطاريات ايون الليثيوم

The purpose of the battery

The battery supplies electricity when the:

1. **Engine is off:** Electricity from the battery is used to operate lighting, accessories, or other electrical systems when the engine is not running.
2. **Engine is starting:** Electricity from the battery is used to operate the starter motor and to provide current for the ignition system during engine cranking. Starting the car is the battery's most important function.
3. **Engine is running:** Electricity from the battery maybe needed to supplement the charging system when the vehicle's electrical load requirements exceed the charging system's ability to produce electricity. Both the battery and alternator supply electricity when demand is high.

1.1. Battery types

On the basis of charging capability batteries can be of two types: -

1) Primary
2) Secondary

1.1.1. Primary Battery

Primary batteries are non-rechargeable batteries used for one-time purpose and then discarded.

There are many kinds of primary batteries like -

1) Alkaline battery
2) Aluminum-air battery
3) Aluminum ion battery
4) Bunsen Cell
5) Dry cell
6) Zinc-air battery

1.1.2. SECONDARY BATTERY

Secondary batteries are the batteries which are rechargeable unlike primary batteries. Some kinds of secondary batteries are -

1) Flow battery
2) Fuel Cell
3) Molten Salt battery
4) Nickel-Cadmium battery
5) Potassium ion battery
6) Lithium ion battery
7) Lead Acid Cell battery

As our solar car stands on the solar energy and we are going to use this renewable energy as a means of fuel, we need a battery which is rechargeable.

So, basically we are using Secondary batteries.

Consumption of rechargeable batteries are increasing day by day as the field of multipurpose electronic means are developing to meet every possible needs of the people.

Thus we can say that the fields of rechargeable Secondary batteries are vast and different kinds of purpose require different kinds of Secondary battery.
Some of the primary and secondary battery's structure and their uses are being described. Also our required rechargeable battery is explained in brief and why are using it.

1.2. PRIMARY BATTERIES

1.2.1. ALKALINE BATTERY

Basic activity happens in Alkaline batteries is the reaction between zinc and manganese dioxide where zinc power acts as an Anode and manganese dioxide acts a cathode.
Alkaline battery has 'alkaline' electrolyte of potassium hydroxide unlike other battery systems where other active materials are used for electrodes.

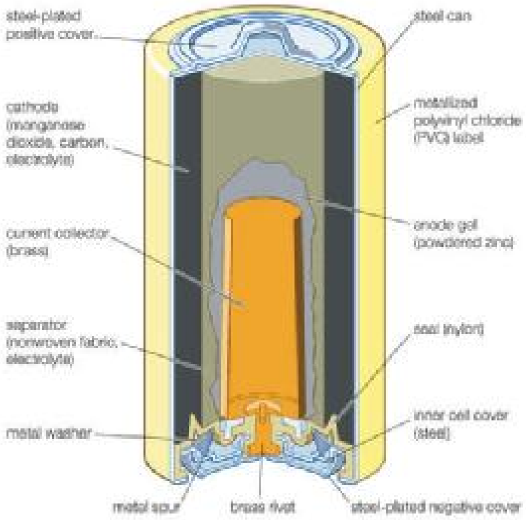

Figure 1: alkaline battery layout

1.2.2. DRY CELL

The basic difference of a Dry Cell is it uses paste electrolyte unlike other battery systems [1].
Its paste electrolyte actually helps to flow current as it has enough moisture and the main benefit of a Dry Cell is its non-spilling behavior as it has no liquid electrolyte which actually make suitable for portable equipment.

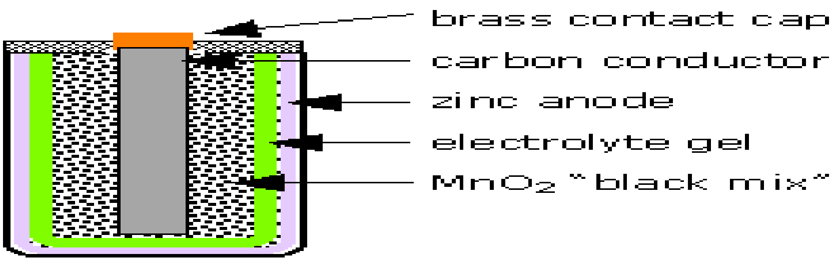

Figure 2: Dry cell battery layout

1.2.1. ZINC-AIR BATTERY

In Zinc-air batteries the active materials are in contact with air where the system is powered by Zinc oxide contacting with oxygen from the air.
The electrolyte is zinc water solution and this battery have high energy density and relatively cheap.

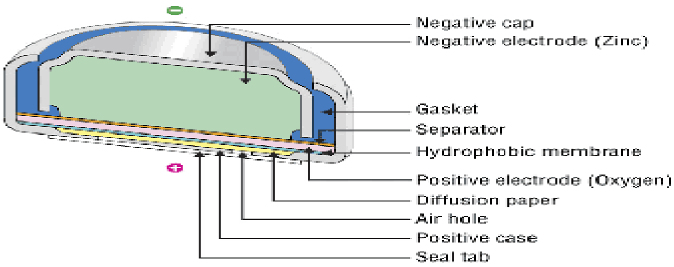

Figure 3: zinc-air battery layout

1.3. SECONDARY BATTERIES

1.3.1. FLOW BATTERY

The basic system of Flow battery has two separate electrolytes for anode and cathode and they are being separated by an ion-exchange membrane.

The ion-exchange membrane confirms the flow of current in the system. Separated by the membrane both of the liquids circulate in their own respective space [2].

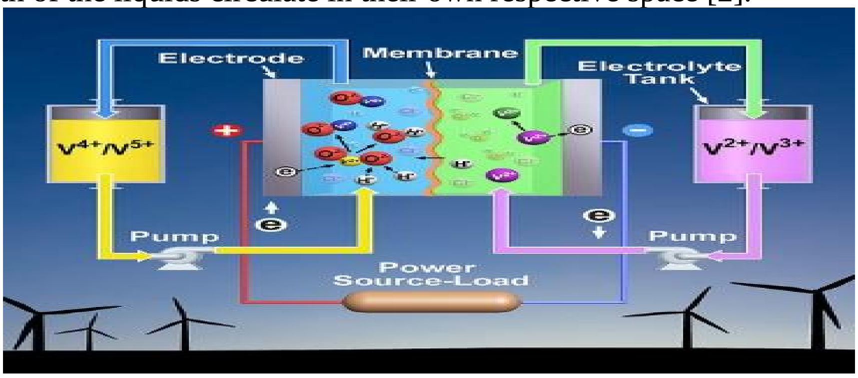

Figure 4: flow battery layout

1.3.2. FUEL CELL

Unlike other batteries Fuel Cell does not have any built in media through which it can produce required energy rather it is a device that converts chemical or fuel energy into electrical energy. Natural Hydrogen gas is the most common fuel but for greater efficiency hydrocarbons are also being used.

From the anode side Hydrogen fuel are inserted and natural air are being inserted form the cathode side. Excess fuel from the anode side and excess water are being pushed out form the system. This system requires constant source of fuel [3].

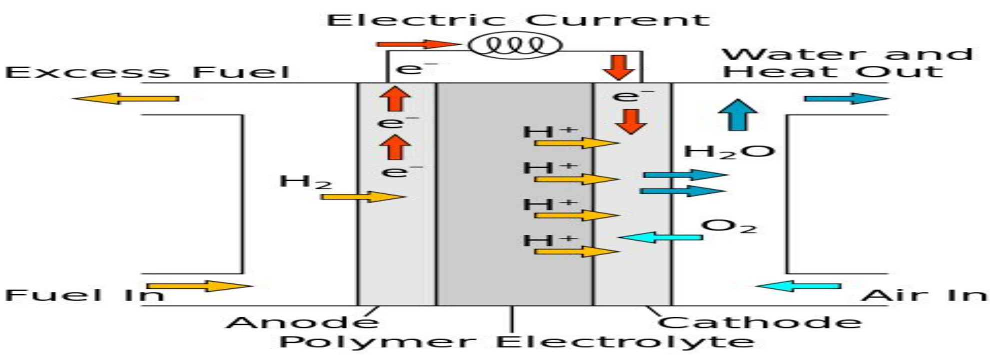

Figure 5: fuel cell battery layout

1.3.3. Lead/Acid Battery

Lead/acid (Pb/A) batteries are the oldest type of battery used in vehicles.

The battery negative electrodes contain elementary lead (Pb) while the positive plates have lead dioxide (PbO2) as active material in charged state.

The electrodes are immersed in an electrolyte of Sulphur acid (H2SO4). When being discharged the lead of the negative electrodes and the lead dioxide of the positive electrode reacts with the Sulphur acid.

Lead sulphate is formed on the electrodes and the electrolyte loses its dissolved sulphuric acid and becomes water [4].

Energy is released during the chemical reaction and when energy is added the process will reverse. The overall reaction is:

$Pb + PbO_2 + 2H_2SO_4 \longleftrightarrow 2PbSO_4 + 2H_2O$

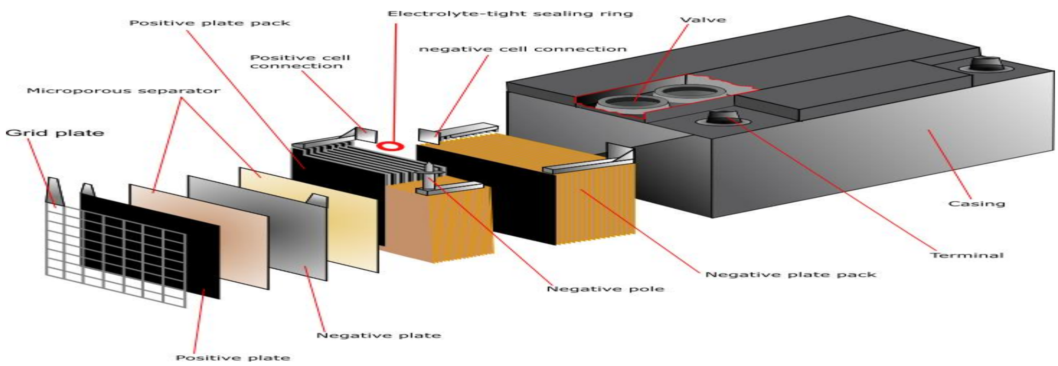

Figure 6 : lead acid battery layout

1.3.3.1. Advantage

- Able to supply high currents.
- Maintain a large power-to-weight ratio.
- Low costs.
- Proved technology.
- Low amount of maintenance required in advanced sealed batteries.

1.3.3.2. Disadvantage:

- Low energy-to-weight ratio.
- Low energy-to-volume ratio.
- Environmentally unfriendly (Pb & acid).
- Limited depth-discharging level

1.3.4. Nickel Metal Hydride

There are four types of nickel based batteries that use nickel in the positive electrode of the battery; the nickel iron (Ni-Fe), nickel zinc (Ni-Zn), nickel cadmium (Ni-Ca) and nickel metal hydride (Ni-MH).

The Ni-Zn and Ni-Fe batteries are not considered to be an option for EVs because of their short lifecycle and low specific power (Chau et al. 1999). Ni-Ca is the most mature technology of the cadmium based batteries.

It has similar specifications compared to the Ni-MH (Larminie and Lowry 2003).

The advantage of the Ni-MH battery is that it uses no cadmium and is therefore environmental friendlier.

The battery considered to be an option for a BEV in this research is the Ni-MH.

The battery uses hydrogen absorbed in a metal hydride at the positive electrode.

Nickel ox hydroxide becomes nickel hydroxide during discharge. At the negative electrode hydrogen is released from the metal producing water and electrons during discharge. The overall reaction is written as:

$MH + NiOOH \longleftrightarrow M + Ni(OH)_2$

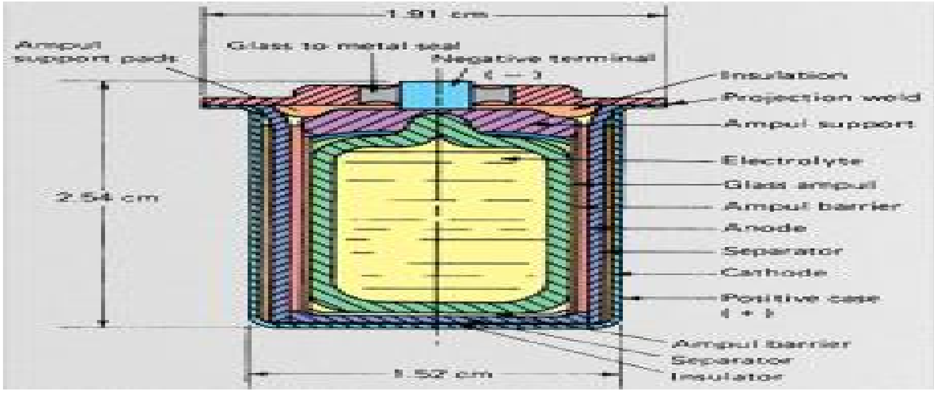

Figure 7 : nickel metal hydride battery layout

1.3.4.1. Advantage

- Reasonable Specific Energy.
- Reasonable Specific Power.
- Much longer cycle life than lead acid Safe.
- Abuse-tolerant Disadvantage

1.3.4.2. Disadvantage

- High Cost.
- Heat Generation at High Temperatures.
- Low cell efficiency.
- Need to control Hydrogen Losses.

1.3.5. Lithium-ion

Lithium-ion batteries have the potential to become the dominant battery technology in BEVs and HEVs.

They rapidly developed the last years for the use in small consumer electronics like cell phones and notebooks.

Most BEVs that are coming to the market the next years will be equipped with lithium-ion battery packs.

Examples of BEVs that use lithium-ion batteries are the Tesla Roadster, the Think City and the Mitsubishi iView.

Lithium-ion batteries are very suitable as high performance EV batteries because of the main characteristics of lithium metal.

Of all the different metals lithium has the highest standard potential and electrochemical equivalent.

This indicates it has the highest specific energy potential (in Wh/kg) of all metals and on a volumetric energy basis (Wh/l) it is only inferior to aluminum and magnesium (Linden and Reddy 2002).

Lithium is also very light, the lightest of all metallic materials.

The specifications of the battery can vary according to the materials that are used on the anode or cathode.
The commercially available batteries usually use lithiated carbon as anode, but some companies are experimenting with other materials.
Altair Nano developed a battery with a Nano-structured lithium titanate anode (LiTiO) instead of lithiated carbon.
An advantage of this design is the speed at which electrons can leave or fill up the Nano-structured grid.
The LiTiO battery can be charged rapidly and also has a longer cycle life than most other lithium based batteries (Altair Nano 2009).

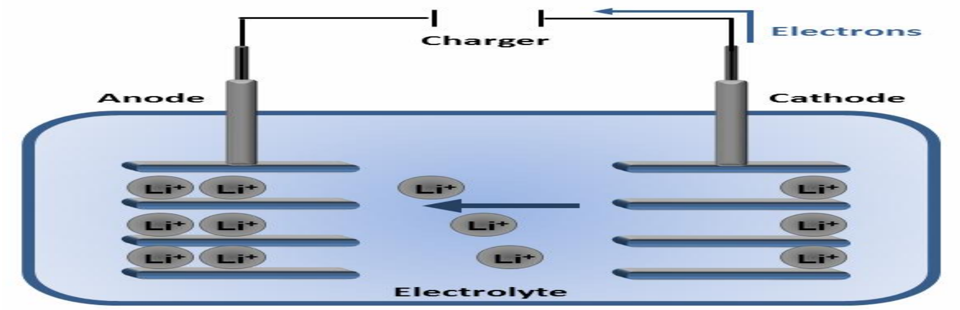

Figure 8 lithium ion battery layout

1.3.5.1. Advantage

- High Specific Energy.
- High Specific Power.
- High Energy Efficiency.
- Good High temperature performance.
- Low Self-Discharge.

3.3.5.2. Disadvantage

- Needs Improvement in: Calendar and Cycle life.
- Abuse Tolerance.
- Acceptable Cost.
- Higher degree of Battery safety

3.3.6. Metal air

Most metal air batteries can't be recharged by simply reversing the current as can be done with the other batteries mentioned in this chapter.
Instead the electrodes of the battery have to be replaced by new ones.
Metal air batteries are mechanically rechargeable batteries and are comparable with fuel cells.
A mayor advantage of the metal air batteries is that the battery only consists of one reactant.
The other reactant is oxygen which does not have to be carried in the battery.
The metal air battery therefore has a weight advantage over other types of batteries.
There are a few metal air batteries being developed of which the zinc air battery is the only one that is commercially available.
The aluminum air, magnesium air, iron air and lithium air battery are still under development of which some but look promising for the future.

The zinc air battery has been available for years, for example in hearing aids. The large energy density of the battery is very useful in small devices needing a long lasting battery. The zinc in the battery reacts with air, forming zinc oxide. The overall reaction is as follows:
$2Zn + O_2 \rightarrow 2ZnO$

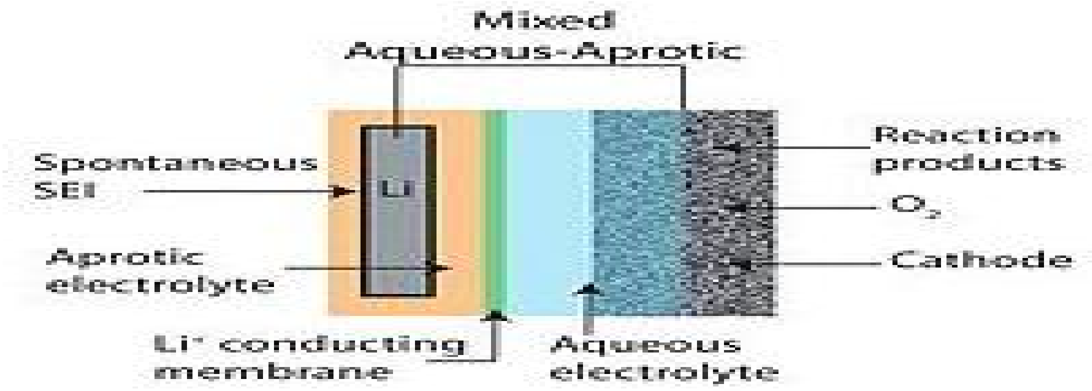

Figure 9 : metal air battery layout

1.2. BATTERY PARAMETERS

State of Charge (SOC) (%) –

SOC is an expression of the present battery capacity as a percentage of maximum capacity. SOC is generally calculated using current integration to determine the change in battery capacity over time. It can also be explained as –

$$SOC = \frac{\text{Available capacity}}{\text{Nominal capacity}}$$

Depth of Discharge (DOD) (%) –

The percentage of battery capacity that has been discharged expressed as a percentage of maximum capacity.
DOD is actually the opposite of SOC.

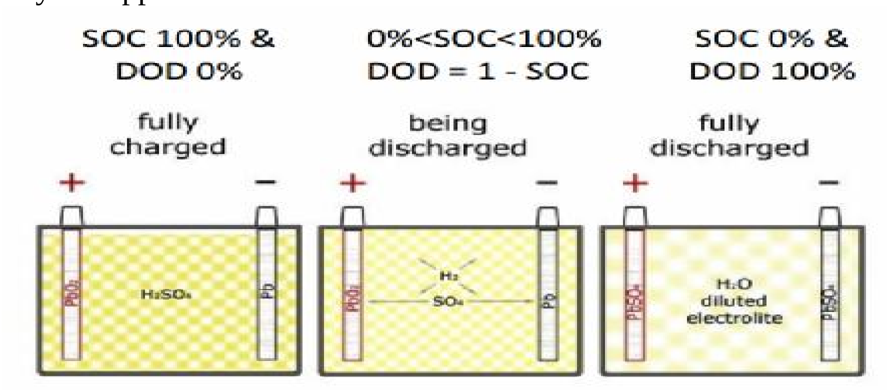

Figure 10 : shows depth of discharge

Terminal Voltage (Vt) –

The voltage between the battery terminals with load applied. Terminal voltage varies with SOC and discharge/charge current.

Open-circuit voltage (Voc) –
The voltage between the battery terminals with no load applied. The open-circuit voltage depends on the battery state of charge, increasing with state of charge.

Internal Resistance (Rs)–
The resistance within the battery, generally different for charging and discharging, also depends on the battery state of charge.
As internal resistance increases, the battery efficiency decreases and thermal stability is reduced as more of the charging energy is converted into heat.

Nominal Voltage (V) –
The reported or reference voltage of the battery, also sometimes thought of as the "normal" voltage of the battery.

Cut-off Voltage –
The minimum allowable voltage of the battery is known as Cut-Off-Voltage. It is this voltage that generally defines the "empty" state of the battery.

Capacity or Nominal Capacity (Ah for a specific C-rate) –
The kilometric capacity or the amount of matter transform capacity during an electrolysis reaction, the total Amp-hours available when the battery is discharged at a certain discharge current (specified as a C-rate) from 100 percent state-of-charge to the cut-off voltage.
Capacity is calculated by multiplying the discharge current (in Amps) by the discharge time (in hours) and decreases with increasing C-rate.

Energy or Nominal Energy (Wh (for a specific C-rate)) –
Nominal capacity is basically the "energy capacity" of the battery, the total Watt-hours available when the battery is discharged from 100 percent state-of-charge to the cut-off voltage.
Energy is calculated by multiplying the discharge power (in Watts) by the discharge time (in hours). Like capacity, energy decreases with increasing C-rate

Energy Density (Wh/L) –
The nominal battery energy per unit volume, sometimes referred to as the volumetric energy density.
Specific energy is a characteristic of the battery chemistry and packaging. Along with the energy consumption of the vehicle, it determines the battery size required to achieve a given electric range.

1.2.1 TYPES OF BATTERY MODEL

There are various types of battery model and process to calculate their parameters varies accordingly.
Thus, it is high time to select an appropriate battery model from these models need clear understanding to calculate their parameters and we need to find a simple way to avoid difficulties.
Some battery models are explained below

1.2.2 SIMPLE BATTERY MODEL

A Simple battery model consists of a source voltage which series with the internal resistance (Rs) and finally terminal voltage of the battery (Vo).
In this model the two parameters Rs and Vout where Vout can be measured through open circuit voltage and the internal resistance can be measured from open circuit voltage as well as from fully charged battery with load connected [5].

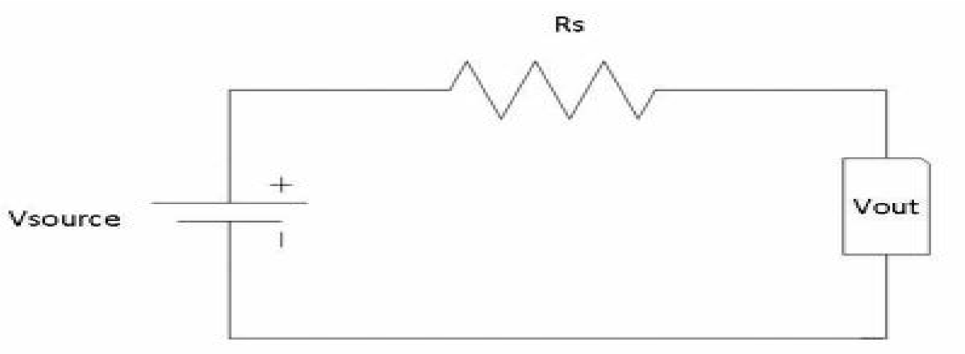

Figure 11 : simple battery model

1.2.1. THEVENIN BATTERY MODEL

Thevenin battery model is a commonly used battery model which consists of a no-load ideal source voltage which series with the battery internal resistance Rs along with capacitance Co over resistance Ro and finally the terminal voltage

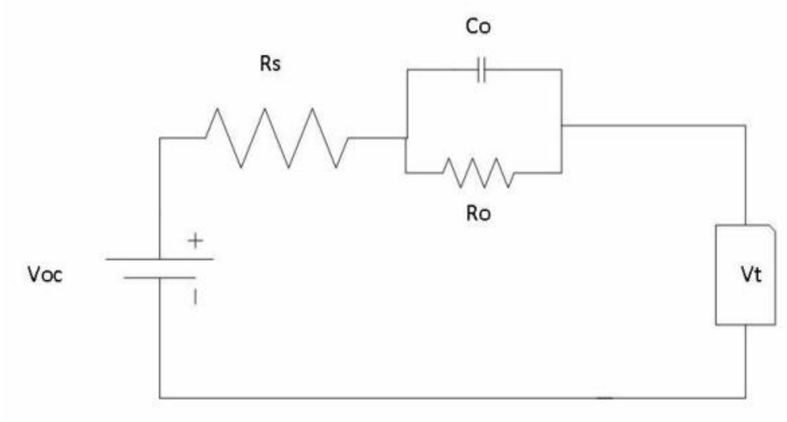

Figure 12 : Thevenin battery model

Here, Capacitance Co is nothing but the capacitance between electrolyte and active materials and resistance Ro is the battery overvoltage due the contact resistance of active materials to electrolyte.

If Ick flows through the whole circuit then and the voltage across the Co or Ro is Vo, then [Vt = Voc - (Ick*Rs +Vo)].

1.2.1 RANDLE'S BATTERY MODEL

This model consists of a source voltage which series with the internal resistance Ri along with the capacitance Cs over Rs where Cs and Rs are the transient effect due to the ion shifting for different concentration the current densities of the active materials.

Finally, the Capacitance C is to store the overall charge and R represents a self-discharging resistance.

Here, the transient effects (Cs) and (Rs) are responsible for the change of Soc while (C) and (R) are function of Soc.

Thus accurate estimation of Soc requires careful estimation of time constants.

If the voltage across the transients (Cs and Rs) is Vcs and the voltage across C or R is Vf and the current across the resistor Ri is Ii then

$$Vcs = \frac{IiRs - Vcs}{CsRs}$$

$$Vf = \frac{IiR - Vf}{CR}$$

$$Vf = \frac{Ii}{C}$$

$$Vo = Vcs + Vf + IiRi$$

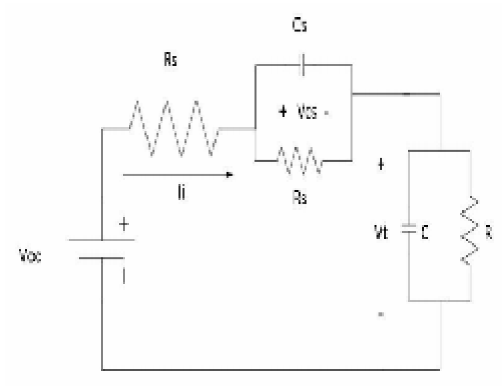

Figure 48: Randel's battery model

1.2.1 COPPETI BATTERY MODEL

Here, C represents as the storage capacitor which stores the overall charge the battery that finally sends the charge to the battery's terminal point.

This Capacitor series with the polarization capacitor Cp and the battery's internal resistor R.

The whole circuit current is I actually opposite to the polarization current. Hence, we take two assumptions – If Vout < n*V [V is constant]

By taking time constant – Vout = n {Vc(t) +Vcp(t)}

Where:

Vc is the voltage across C

Vcp is the voltage across Cp or R

$$\frac{d}{dt} Vc = \frac{-I(t)}{C(t)}$$

And if Vout > nV then –

$$Vout = n\,\{Vc(t) + R(t)*I(t)\}$$

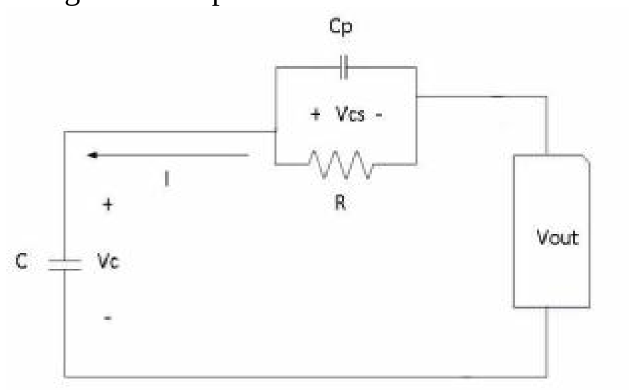

Figure 13 : COPPETI BATTERY MODEL

Our proposed battery model is basically Thevenin model considering the voltage across the parallel components a constant voltage Vd.

Here we are following the perspective of simple battery model by considering all the parameters as constant, function of SOC (State of Charge).

Where –

-Voc = f(SOC) = b1 SOC +b0

-P=Vt*I

-Vt = Voc - Vd - IL*R

$$-\,I = \frac{(Voc - Vd) - \sqrt{(Voc - Vd)^2 - 4Rp}}{2R}$$

-Vd = X1*SOC + X0

-Rs= Y1*SOC + Y0

The parameters which are function of SOC (VOC, Vd, Rs) will be extracted later on from the experimental values and then injected in the battery model for verification purpose.

1.2.1 FLOWCHART WITH BLOCK DIAGRAMS

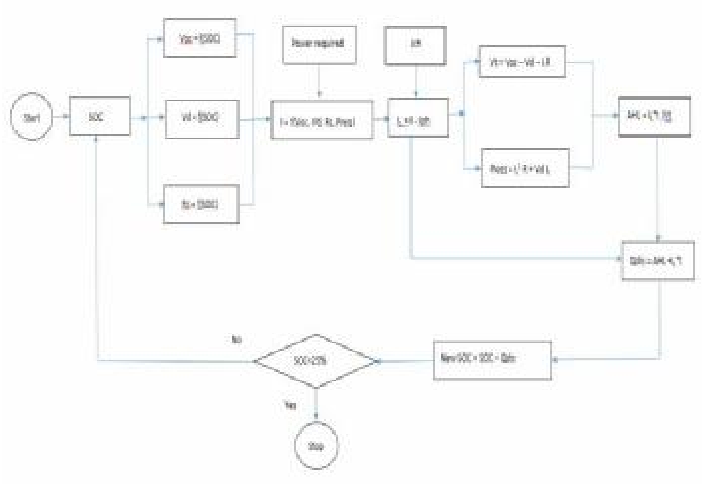

Figure 14: battery flow chart

CONCLUSION

Lithium ion battery is the best for electric cars

The most commonly used type of batteries, the lithium-ion battery, are more environmentally friendly.

1- Batteries have reduced maintenance requirements for the car.

2- The power used to charge the battery is not derived from purely hydroelectric sources.

3- Produces no exhaust gases in operation.

4- Maintenance-free, display no memory effect (loss of capacity when repeatedly charged after partial discharge).

5- Have a low self-discharge rate and are regarded as safe and long-lived

6- High Specific Energy. High Specific Power

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