

STUDY ON ULTRA CAPACITOR

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PSM Report II

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MAY 2017

STUDENT'S DECLARATION

I admit that this report entitled "Study on Ultra Capacitor for Electric Motor" is my own work
except it is cited from other reference source.

Signature :

Name of Supervisor :

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature :

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Date :

ABSTRACT

Energy storage device is device which have a capable of saving and storing energy in term of electricity. The energy storage device is a very crucial device which have many particular usage because it can be used in variety of application and purpose. In this modern era, usually the energy storage device that being used is a battery. But usual battery have some weakness which it only be used once. For rechargeable battery, it may consume a lot of time to charge it up. So, it is not recommended to be used for emergency or time limited case. With the presence of new technology, there is another energy storage device is created which is the ultra capacitor. In this research, the ultra capacitor is studied to see how fast ultra capacitor can be charge and discharging for electric motor.

ABSTRAK

Peranti penyimpanan tenaga adalah alat yang mempunyai kemampuan untuk menyimpan tenaga dalam bentuk elektrik. Peranti penyimpanan tenaga adalah alat yang sangat penting dan mempunyai banyak kegunaan tertentu kerana ia boleh digunakan dalam pelbagai aplikasi dan tujuan. Dalam era moden ini, biasanya peranti penyimpanan tenaga yang biasa digunakan adalah bateri. Tetapi bateri biasa mempunyai beberapa kelemahan iaitu ia hanya boleh digunakan sekali. Untuk bateri boleh dicas semula, ia pula memakan banyak masa untuk mengecas semula sehingga penuh. Jadi, ia tidak digalakkan untuk digunakan untuk kecemasan atau dalam kes masa yang terhad. Dengan adanya teknologi baru pada masa kini, terdapat satu lagi peranti penyimpanan tenaga yang telah tercipta dicipta iaitu ultra kapasitor. Dalam kajian ini, ultra kapasitor dikaji untuk melihat berapa pantas kadar ultra kapasitor boleh dicas dan menyahcas untuk motor elektrik.

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LIST OF ABBREVIATIONS

EDLC	Electrochemical Double Layer Capacitor
PC	Pseudocapacitor
DC	Direct current
AC	Alternate current

LIST OF SYMBOL

V	Voltage flow
C	Capacitance
Q	Charges flow
U	Energy output
P	Power output
R	Resistance
Vs^{-s}	Rate of voltage flow per second

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Energy storage device is a device which could store energy in term of electricity. This device is important as it is widely used in variety of application. Device used for electric storage today is battery or capacitor. But this conventional device may has weakness which is take some time to charge it. Therefore, we need another energy storage device to replace the function of battery which is ultra capacitors.

Ultra capacitor is used to store electrical energy (electrostatically) rather than chemical state as in batteries. No chemical actions involved which mean it can be used for a long cycle. Ultra capacitors or similarly known as supercapacitors or electrochemical double layer capacitors (EDLCs) are electrochemical capacitors that have higher energy density when compared to common capacitors.

Capacitor are made with a dielectric placed between opposed electrodes to accumulate charges in the dielectric material. The energy is stored by removal of charge carriers which are electrons from one metal plate to another. This charge separation create potential between two plates. Many materials can be inserted between the plates to allow higher voltage to be stored

which lead to higher energy densities for any certain size. For example, aluminum electrolytic capacitor use an aluminum oxide as the dielectric.

For ultra capacitor, it does not have any dielectric but rather utilize the phenomena typically referred to the electric double layer as shown in Figure 1.1. In electric double layer, the effective thickness of dielectric is thin because the porous nature of carbon the surface area is high which translate to high capacitance. When, two different phases contact together, positive and negative charges are set in array at boundary. This array is known as Electric Double Layer (Josie Garthwaite, 2011).

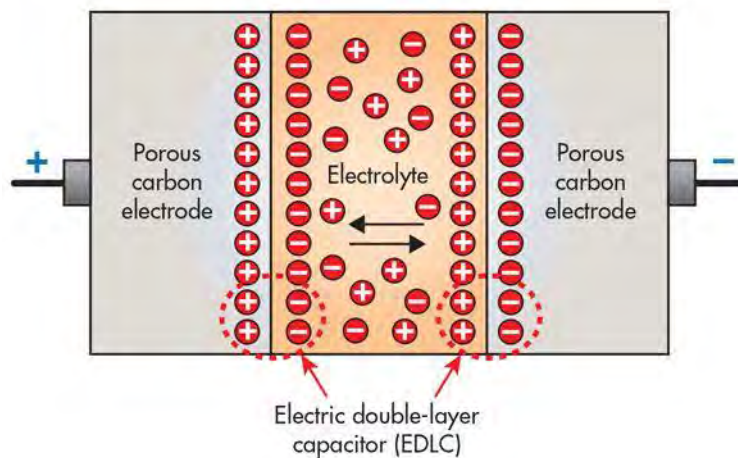


Figure 1.1: Part of ultra capacitor.

Nowadays, ultra capacitors are being developed for transportation which they used a large capacitor to store energy instead of the rechargeable battery banks inside the hybrid vehicles. Other than mobile application, ultra capacitors also may be used in photovoltaic system for renewable energy.

1.2 PROBLEM STATEMENT

Energy storage device is essential is important for nowadays application and purpose. Instead of using battery or conventional capacitor, ultra capacitor is the best choice for energy storage device as it has more advantage. Some of the benefit for using this device instead of battery and capacitor are; it is small (can be carried anywhere easily), cheap and economic and can be used for many cycle (rechargeable). Although there are battery that are rechargeable, but the rate of charging and discharging is slower compare to ultra capacitor. Therefore, ultra capacitor is be chosen to be the new energy storage device due to its endurance and quality rather than battery. But the problem is, how much fast that ultra capacitor could save time for charging compare to the battery. Figure 1.2 shows same ultra capacitor with difference specification from single manufacturer.



Figure 1.2: Ultra capacitor

1.3 OBJECTIVE

The objective of this project are as follows:

1. To study the ultra capacitor.
 - Know the application that used in ultra capacitors.
 - Learn the basic connection on ultra capacitor for charging.

2. To investigate on how (method) to charge the ultra capacitor fast.
 - Ideal voltage input for charging.
 - Time taken for charging the ultra capacitor.

1.4 SCOPE OF PROJECT

The scope of this project are:

1. Only use the same type of ultra capacitor for every experiment that will be conduct. The difference could only be the type of connection which are parallel or in series.
2. Study on the application of electric motor and generator and how on getting a certain speed of motor with its output voltage.

CHAPTER 2

LITERATURE REVIEW

2.1 HOW ULTRA CAPACITOR WORKS

An ultra capacitor functionality are same as capacitor but have different form from an ordinary capacitor. It differs in two aspect which are its plate effectively have a much bigger area and the distance between the plates is smaller. The plates are made from metal that coated with a porous substance such as powdery or activated charcoal which effectively make the area bigger to store more charges.

Chris Woodford (2016) state that for ordinary capacitor, the plate separate by a relatively thick dielectric made from ceramic, plastic film or air. When capacitor is charged, positive charges is form at one plate and negative charges are on the other side of plate. This creating an electric field between them. While in ultra capacitor, there is no dielectrics when compare to ordinary capacitor. Instead, the positive and negative plate are soaked in electrolyte and separated by an insulator made from carbon, paper or plastic. When the plate are charged up, an opposite charge forms on either side of separator creating an electric double-layer.

The capacitance of ultra capacitor is higher as the area of plate increases and distance between plate decreases. When the electric double layer is form, the thickness is could be one

molecule thick compared to dielectric or conventional capacitor. Therefore, supercapacitor will have more capacitance.

2.2 CHARGE AND DISCHARGE OF ULTRACAPACITOR

To store or add energy in ultra capacitor, it need to be charge just like the battery. But to charge ultra capacitor, we must have to deliver a large amount of current at a wider range of voltages. This is because ultra capacitors often start at zero volts and the voltage is proportional to the coulombs of charge (Yogesh Ramadass, 2013). In charging or discharging process, the ultra capacitor can be mounted in two ways which are in series or parallel circuit. In series circuit, it will increase the value of overall voltage but reduce its capacitance. On the other hand, for parallel circuit the voltage of ultra capacitor will be always the same as the ultra capacitor's voltage itself but the capacitance will increase much more than in the series circuit. Theoretically, the value of voltage and capacitance can be calculate by using formula as shown below:

- For series circuit:

$$\text{Voltage,} \quad V_T = V_1 + V_2 + V_3 \dots + V_n$$

$$\text{Capacitance,} \quad \frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \dots + \frac{1}{C_n}$$

- For parallel series:

$$\text{Voltage,} \quad V_T = V_1 = V_2 = V_3 = V_n$$

$$\text{Capacitance,} \quad C_T = C_1 + C_2 + C_3 \dots + C_n$$

As the energy storage mechanism of the ultra capacitor is not a chemical reaction, the charging and discharging process of ultra capacitor can occur at the same rate. Many ways are possible to charge the ultra capacitor. But since the ultra capacitor voltage is relatively limited compared to the application requirement, it is important to connect the ultra capacitors in series to achieve the voltage required. The charging method could be either through constant current or power charging through direct current (DC) source or alternate current (AC) methods.

2.3 ENERGY AND POWER OUTPUT OF ULTRACAPACITOR

Capacitance of ultra capacitor is the capability of the ultra capacitor to store electric charges. Usually, every product of ultra capacitor have stated its capacitance to the customer. But in theoretically, the capacitance can be calculated by using formula below:

$$C = \frac{Q}{V}$$

where C = Capacitance (F)

Q = Charges flow (C)

V = Voltage (V)

The energy stored in an ultra capacitor is expressed in term of the work done by the battery. The work to move a charge element from negative plate to positive plate is equal to voltage on ultra capacitor. The voltage represents energy per unit charge and it is proportional to the amount of charge on the ultra capacitor. To determine the energy output from the ultra capacitor, we begin with the basic formula of energy storage on capacitor:

$$dU = Vdq$$

$$dU = \frac{q}{C}dq$$

$$U = \int_0^Q \frac{q}{C}dq$$

$$U = \frac{1}{2} \frac{Q^2}{C}$$

Substitute the derive voltage equation from $C = \frac{Q}{V}$ to become $Q = CV$ into above equation and we will get:

$$U = \frac{1}{2} \frac{C^2 V^2}{C}$$

$$U = \frac{1}{2} CV^2$$

where $U =$ Energy (J)

$C =$ Capacitance (F)

$V =$ Voltage (V)

$Q =$ Charge (C)

Power in ultra capacitor describe the speed at which energy can be deliver from ultra capacitor to the load. According to Wen Hua et al (20016), the theoretical power value in ultra capacitor can be calculated by using equation below:

$$P_{max} = \frac{V^2}{4 \cdot R_T}$$

where P_{max} = Maximum power output

V = Voltage supply or delivered (V)

R_T = Total resistant also known as equivalent series resistant (Ω)

Theoretically, if the ultra capacitor have higher vaue of voltage and low equivalent series resistance, it will deliver more power to the load.

2.4 ADVANTAGES AND DISADVANTAGES OF ULTRA CAPACITOR

In application of ultra capacitor, there are many advantage and disadvantage of using ultra capacitor instead of other energy storage device such as battery. As we all known, battery and ultra capacitor are served to provide energy but the ultra capacitor have its own specialty and characteristic that can be serve more efficiently when using it.

One of the characteristic that ultra capacitor is selected to be used is because of it has higher specific power than any other energy storage device This is proven by Stefen Workstetter, 2015 as shown in Figure 2.1. It has the ability to charge and provide energy constantly. This unique characteristic had made the ultra capacitor used widely in high power and regenerative braking application. Besides, the ultra capacitor are extremely efficiently in storing energy even in under high load conditions which is up until 80% efficiency.

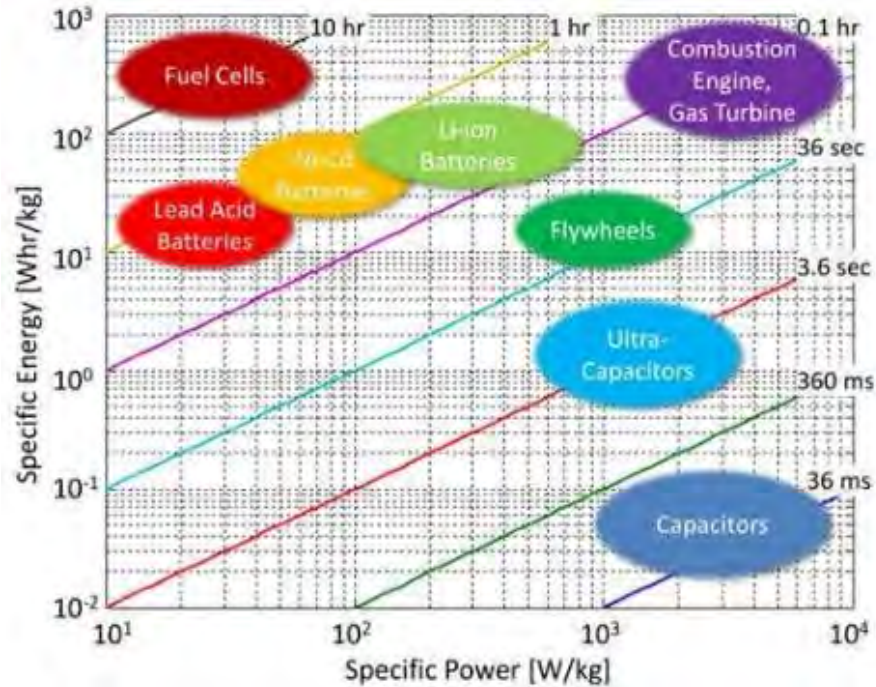


Figure 2.1: Graph comparison of specific power against specific energy among storage energy devices (Stefan Workstetter, 2015)

Besides, based on Marco et al, 2005 as shown in Figure 2.1, the ultra capacitor has long lifetime. It can withstand for about 10 to 20 years and about 1 million to 100 million charge and discharge cycles depends on how its usage and condition while for most battery, it can only be recharge up to 200 to 1000 times only (Marco et al, 2005). Even after undergo a lot of cycle, it have low rate of degradation in performance if it being used in operation condition. If there is increase in operating temperature or voltage, it may reduce the lifetime. But it is hardly to make the operating temperature of ultra capacitor to become higher or lower because ultra capacitor itself has wide operating temperature range which is starting from -40°C to 70°C .

Table 2.1: Ultra capacitor and battery comparison (Marco et al, 2005).

	Ultracapacitors	Batteries
Charging time	Fraction of a second to several minutes	Several hours
Self-discharging	Hours to days	Weeks to several months
Power density	> 1000 W/kg	<500 W/kg
Energy density	< 5 Wh/kg	10 – 100 Wh/kg
Charging /discharging efficiency	85% -98%	70% - 85%
Cycle life	$10^6 - 10^8$	200 – 1,000

Moreover, the ultra capacitor is more safe when in operation compared to battery. This is because, when there is extreme over-voltage conditions, the ultra capacitor shows no hazard risk. Compared to lithium and lead based high power battery, they have the risk of self ignition to explosion. This shown that the usage of ultra capacitor is safer in operation and can reduce the injury or damaging other component that located near the ultra capacitor.

On the other hand, the disadvantages of ultra capacitors is it had low amount of energy stored per unit weight (Wh/kg) compared to electrochemical batteries. So the ultra capacitor only can be used for low energy demand. If the product need to use large energy demand, there will be combination of ultra capacitor and battery.

Lastly, for choosing which energy storage device such as battery or ultra capacitor have their own interest based on what a product want or its certain functionality.