Empirical Analysis of Energy Optimisation of a Supercapacitor using MAX756 DC/DC Boost Converter

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Abstract- The experiment was required to evaluate the incorporation of a step-up DC/DC converter to boost the energy recovered from a supercapacitor. This involves the use of 8-Pin MAX756 which is manufactured by Panasonic based on CMOS step-up DC/DC switching regulator for small, low input voltage and battery powered system. It accepts low input voltages down to 0.7V and boosts it to a higher selective voltage of 3.3V or 5V with switching frequency up to 0.5MHz and efficiency up to 80% at 200mA. This DC/DC is coupled to capacitor voltage of capacitance of 30F of maximum operating voltage of 2.3VDC with internal resistance of 0.1(Ω) at 1kHz, diameter 18mm, length 35mm, pin diameter 0.8mm and spacing between pins of 7.5mm based on manufacture's specification. Charge and discharge characteristics were performed with and without DC/DC converter and compared to theoretical characteristics. It was found that the charge and discharge rate were similar to the theoretical result. Also, when a DC/DC converter was connected, the result showed that the voltage remained more stable as load was increased and the time of discharge was extended.

Index Terms- Supercapacitor, DC/DC converter, energy back-up devices.

I. INTRODUCTION

The challenge facing the designers of electronic system and other interest group in energy field is the storage of energy being generated for future use for an emergency and peak power demand applications. Many applications rely on stored energy for their operations in the absence of the main energy supply. A typical example is the solar powered car that uses light energy but unfortunately if the source of energy goes off vehicle relied on the backup power which may not last a long time. There are many other devices like the energy back-up devices which give temporary energy support to the system like the uninterruptible power supply which sustains power temporally in the event of power failure from the main [2].

Some other devices use peak power supply for their initialization or start-up which main power will not be able to meet within the short period. Storage power devices are found in most electronic devices such the palm top computers, medical instrumentation, personal data communication, wireless sensor network, and so on. There are different types of energy can be stored in so many forms such as in the vibration, radio frequency, batteries, flywheel and capacitors. The choice of the storage option depends on the application and the capacity of the storage system. The battery is generally used as an energy storage device in many applications for in which peak power demand is not critical but the battery can supply energy for longer period because its high energy density. However, its chemical properties make it unsuitable in some applications [2]. Supercapacitor is another storage device that has ability to store and quickly release relatively large amount of energy and that make them particularly effective energy harvesting applications where there is need for high burst power [3]. Supercapacitor is formed from two current collector substrates that are coated with porous material which are suspended in electrolyte. If a potential is applied the ions are collected on each collector while the thin barrier prevents the charge from moving between then [5]. It is a reversible reaction without chemical reaction in that it can be charged and discharged several times. Supercapacitor or electrochemical double layer capacitor(EDLC) stores charges as electric field and can be used to power solar car because its high capacitance and high energy density. Another energy harvesting device is the fly wheel in which energy is stored in form of kinetic energy by accelerating a cylindrical assembly called a rotor to a very high speed and making the energy in the system rotational energy. It releases energy very quickly and efficiently well when compared to battery. All these energy harvesting devices have some limitations, for instance the capacitor after discharging still have some stored energy in them that need to be improved by using the dc-dc converter. A dc-dc converter is a step up or down switching regulator for small low input voltage power system. It has high power density, efficient and reliable [4]. It can be regulated or unregulated based on presence of absence of stabilisation function. When the dc output is larger than dc source, the switching dc-dc is called boost converter but when the dc output is smaller than the dc input the converter is referred to as buck converter. In this experiment the MAX756 was used to step up voltage as low as 0.7v and convert it a higher voltage. This is to improve the discharge rate of capacitor using a greater percentage of the stored energy.

II. IMPLEMENTATION

The experiment was carried out using MAX756 to boost the energy stored in the super capacitor to ascertain the rate of charging/discharging with theoretical results. The characteristics of the super capacitor practical laboratory experiment to compare them with that of the theoretical characteristics.

In the course of the implementation, the supercapacitor was evaluated, and the experimental observations made by measurements to confirm the manufacturer’s specification of 30F value with internal resistance of 0.1ohms at frequency of 1KHz. Charge and discharge characteristics was carried out and graphs plotted to compare theory and ensured that the components operated over the standard operating voltage range. Load was added to the outputs of the supercapacitor and the effects observed when MAX756 was incorporated.

III. LABORATORY RESULTS

Table 1.0; Results of Charging Characteristics of a Super Capacitor

Time (S)	V (V)	I (A)
0.00	0.18	0.46
30.0	0.57	0.44
60.0	0.85	0.4
90.0	1.07	0.38
120	1.25	0.37
150	1.38	0.35
180	1.49	0.34
210	1.58	0.33
240	1.65	0.32
270	1.71	0.32
300	1.76	0.31
330	1.80	0.31
360	1.83	0.31
390	1.86	0.30
420	1.88	0.30
450	1.90	0.30
480	1.92	0.30
510	1.93	0.30
540	1.95	0.30
570	1.96	0.30
600	1.97	0.30
630	1.97	0.29
660	1.98	0.29
690	1.99	0.29
720	1.99	0.29
750	2.00	0.29
780	2.00	0.29
810	2.00	0.29
840	2.01	0.29
870	2.01	0.29
900	2.01	0.29
930	2.01	0.29
960	2.02	0.29
990	2.02	0.29

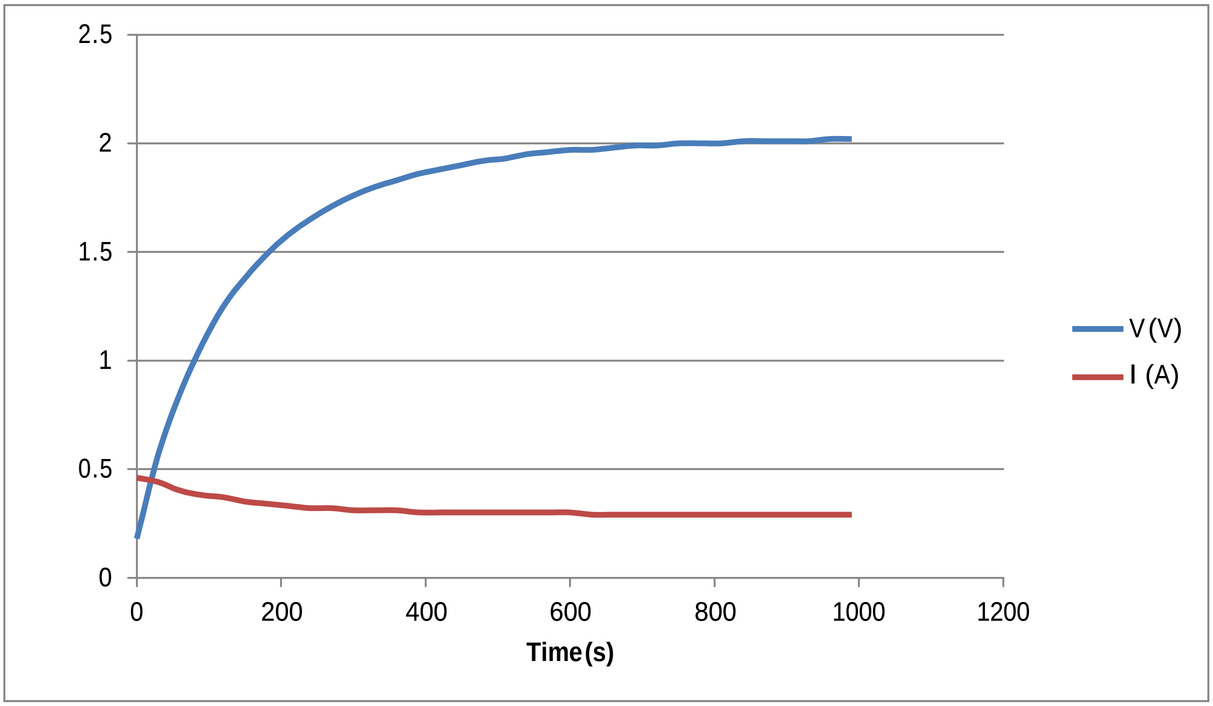

Fig 1.0 Charging Characteristics of a practical Super Capacitor

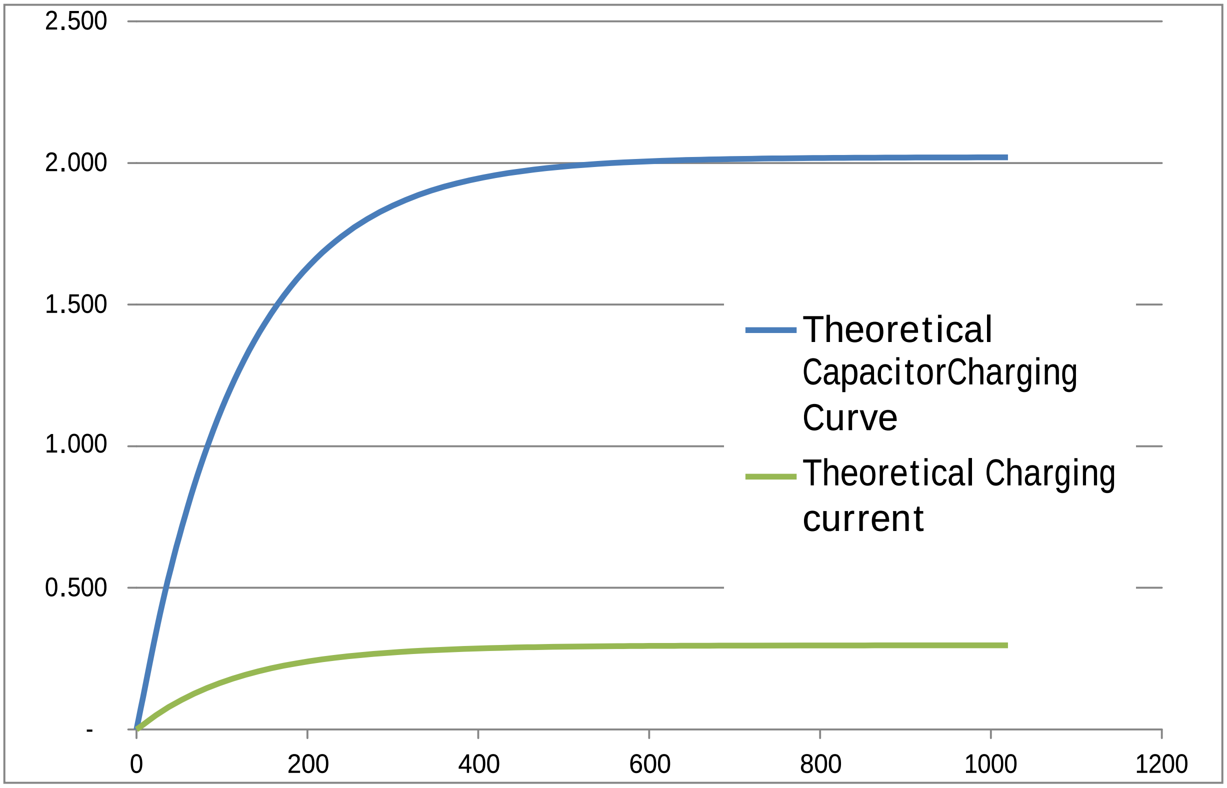

Fig 1.1 Showing theoretical charging characteristics of a supercapacitor

From the characteristics curve of the practical supercapacitor it charges exponentially in with respect to time, initially there was a steady rise in voltage before it finally became stable. It is the other way around in regards to the current, for initially there was a high current increase then over time it beings to reduce then it became constant when it got to the voltage of 2.01v. It can be observed that the practical capacitor had some amount of stored energy in it about 0.18v before charging. The ideal capacitor had zero voltage as compared to the practical supercapacitor. As it can be noticed, even when the capacitor had stored the energy it could store, the current did not go to zero. This is because of the resistors that were connected in across the voltage source.

That is why the current did not get to the zero mark. For even if the capacitor is full, current will still flow via the resistors. Outside the influence of the series resistors, this result is the same with available theoretical curves which demonstrates the charging characteristics of a super capacitor.

Table 1.1; Discharging Characteristics of a Supercapacitor

Time (S)	V (V)	I (A)
0.00	2.08	0.29
30.0	1.81	0.25
60.0	1.61	0.23
90.0	1.44	0.20
120	1.28	0.18
150	1.13	0.16
180	1.01	0.14
210	0.89	0.13
240	0.78	0.11
270	0.69	0.10
300	0.61	0.09
330	0.53	0.07
360	0.46	0.06
390	0.40	0.06
420	0.36	0.05
450	0.31	0.04
480	0.27	0.04
510	0.24	0.03
540	0.21	0.03
570	0.18	0.02
600	0.16	0.02
630	0.14	0.02
660	0.12	0.02
690	0.11	0.02
720	0.10	0.01
750	0.09	0.01
780	0.08	0.01
810	0.07	0.01
840	0.06	0.01
870	0.06	0.01
900	0.05	0.01
930	0.05	0.01
960	0.04	0.01
990	0.04	0.00

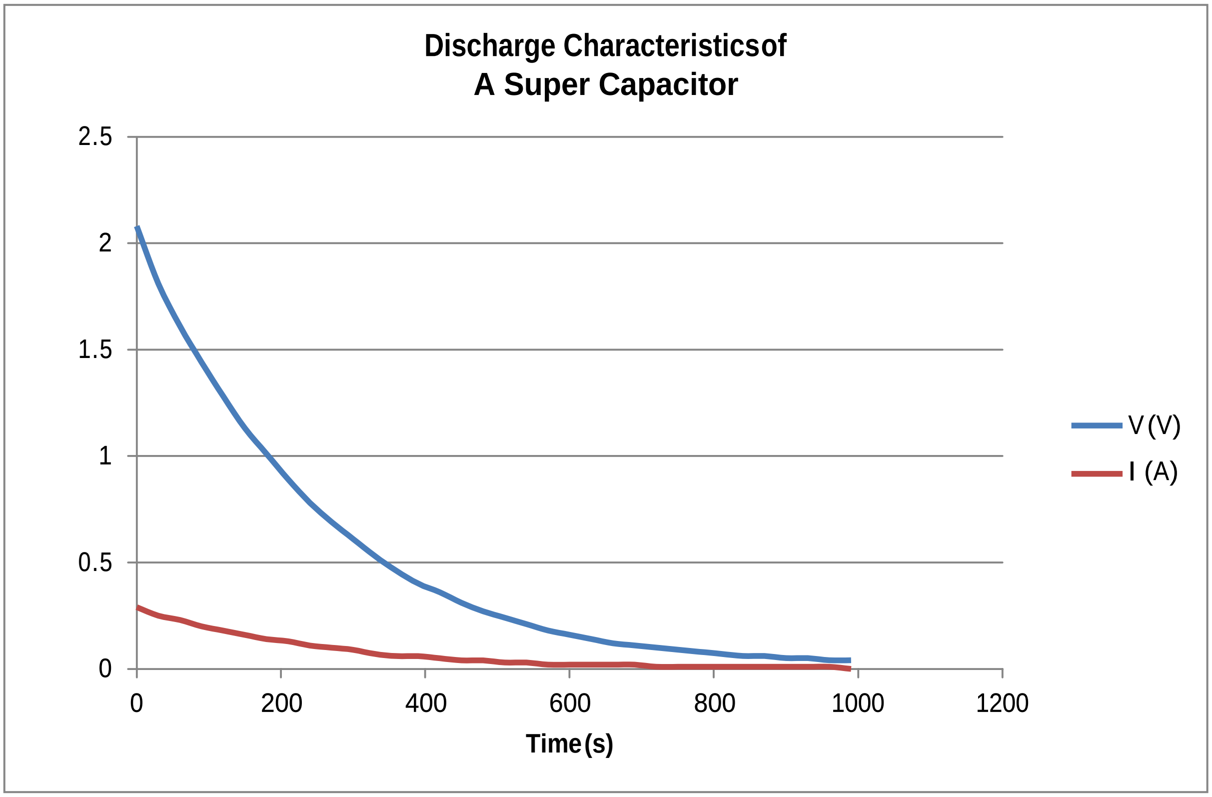

Fig 1.2 Discharging Characteristics of a practical Super Capacitor

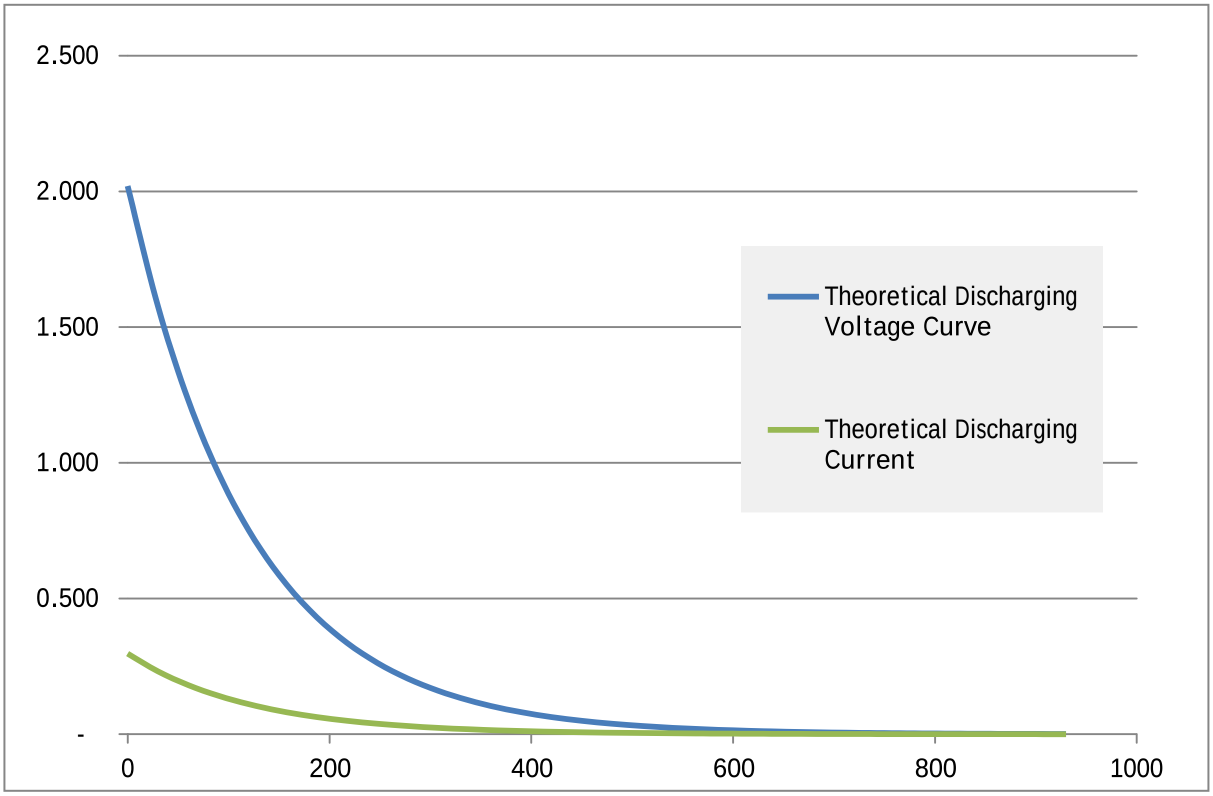

Fig 1.3 Discharging characteristics of a theoretical capacitor.

The only difference spotted from the theoretical graph is the rate at which the voltage was dropping was similar to the practical capacitor but the difference is that it took longer time from the practical capacitor to drop to zero due to internal resistance. It could hardly be spotted here because in this application it is very small. Outside that, it is perfectly the same with theoretical curves.

The total amount of energy in the capacitor before discharge (initially);

Using the formula= $^{1}CV^{2}$

2

= 1⁄2 × 30 × 2.08^{2} = 64.9J

Energy supplied to the load; Energy = PT = IVT = $I^{2}RT$

But I= ½Cdv/dt

Therefore, using the formula; Energy = (^{1} C^{dv})^{2} x R x T

2

dt

The graph below shows energy supplied over time;

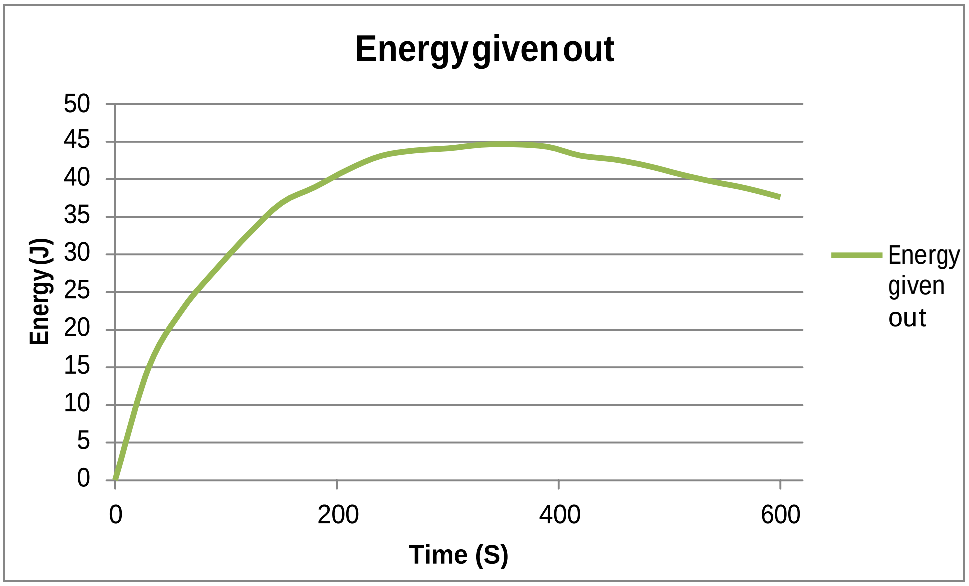

Fig 1.4 Energy output to a 6.8Ω Load against Time

As noticed from the graph, the maximum energy output was at time 330s which was 44.6J. As time increased, the energy calculated began to reduce below its previous value.

This insinuates that 44.6J was the maximum the capacitor could give out at a resistive load of 6.8Ω. Beyond the 330s point, the other values read (voltage, current) will not be able to do any meaningful work or could be seen as noise in the system; since it is not possible that the total energy supplied, will over time begin to reduce.

44.6J is below its calculated initial potential energy which is 64.9J which is about 68.7%. Therefore it could only supply about 68% of its stored energy.

Calculating its capacitance;

Using the value within the first 1 minute

I =Cdv/dt

Where;

I = 0.29+ .023 = 0.26amps

2

dv = 2.08 – 1.61 = 0.47V

$I = Cdv/dt$ = 0.26 × 60⁄ 0.47 = 33.19F

Since the capacitor has a -20% - +40% tolerances, therefore the value above is within limit and in line with the manufacturers' datasheet.

Calculating its internal resistance;

= *Voltage before loading−Voltage after loading*

Current

= 2.10−2.08 = 0.07Ω

0.29

As illustrated on the graph, as current is drawn from the capacitor the voltage also reduces. This is one of the major problems of a super capacitor which do make it a very strong contender with the battery. To overcome this short fall, a DC-to-DC converter will need to be used which adds up to the overall complexity and cost of the system.

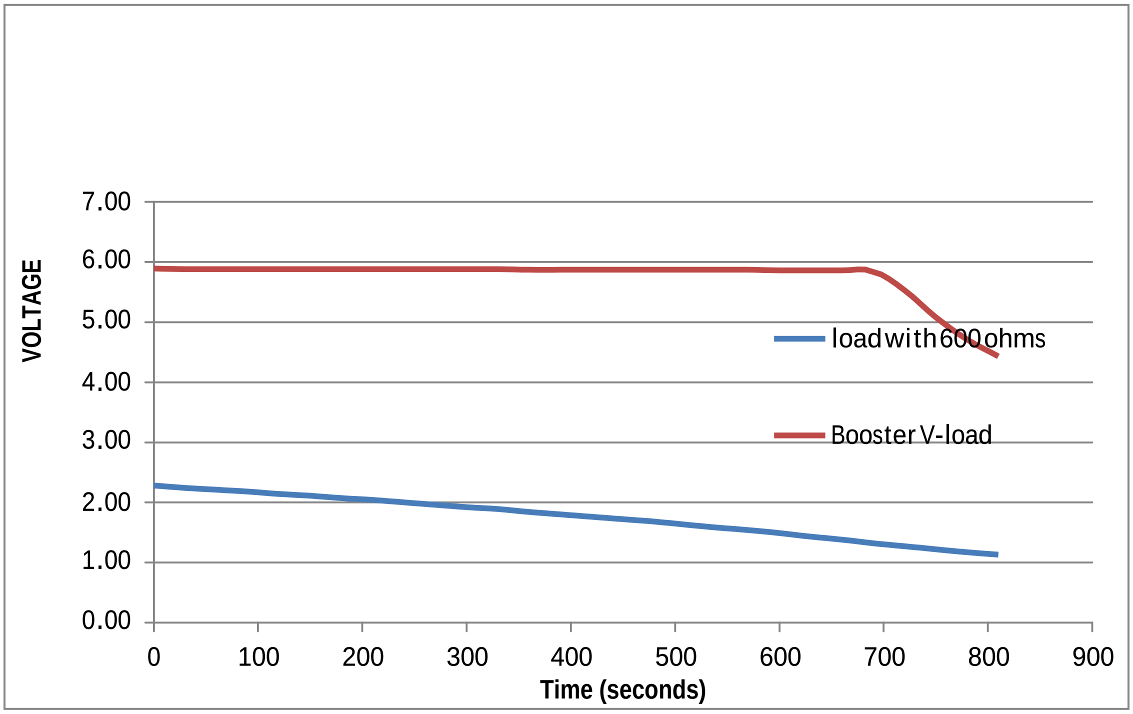

Fig 1.5 Discharge of capacitor with DC-DC

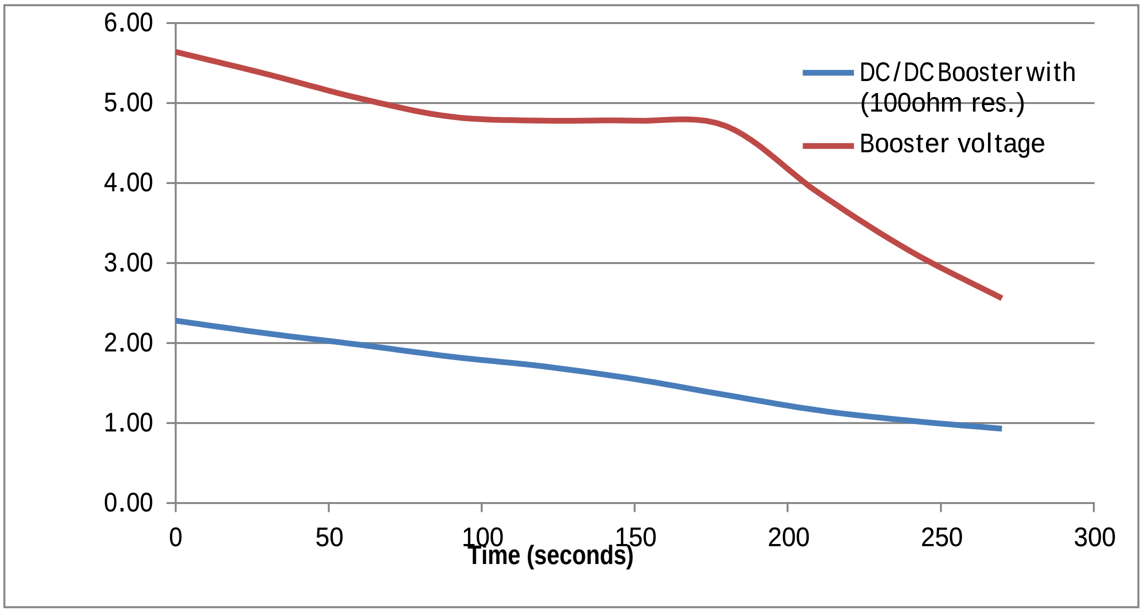

Fig1.6 Discharge characteristics of supercapacitor when a load of 100ohms was connected with dc-d

IV. CONCLUSION

The experiment was performed taking care of some errors that might occur from equipment limitation which might affect the expected result. From the result of the experiment with the super capacitor without the DC/DC converter from the fig1.0, it was observed that the super capacitor curve followed the same curve with that of the theoretical result. As can be seen the practical capacitor charges at the same rate with the reference theoretical capacitor until at a voltage of 2.08 before it continued at that constant rate which is the maximum and the current has little deviation from the theory because the capacitor which was used for this experiment contained some charges in it because practically the capacitor supposed to have started from zero. In fig1.1 of the discharge curve, it would be observed that the capacitor discharges correspondingly with the theoretical characteristics. Both these results confirmed that the theory is the same as the practical computation from the laboratory. From fig 1.6, when the load of 100ohms was connected with capacitor and with the dc-dc converter it was observed that the dc-dc converter continued to boost the voltage level and the time of discharge was found to have extended more than the actual rate without dc-dc. And when a load of 600ohms was connected across the output terminal it was found that the voltage was more constant and the discharge rate was increased this showed that as the load was increased the discharge the more stable the voltage. It can be concluded that power retaining capacity of a supercapacitor can be increased using a DC/DC converter.

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