Super Capacitors Circuit Capabilities as an Upcoming Electrical Energy Storage Device

[1]P. Suresh Kumar
[1]Assistant Professor,
Department of Mechanical Engineering,
JCT College of Engineering and Technology, Coimbatore

[2]Dr. J. Niresh; [3]G. Tamilselvan; [4]B. G. Shri Varun; [5]Adharsh V Srinivasan,
[2]Assistant Professor, [3,4,5]Research Scholar
Department of Automobile Engineering, PSG College of Technology, Coimbatore

Abstract:- A battery, often known as an accumulator, is a type of electrical energy storage device. The battery's primary disadvantages are its long charging time, low lifespan, and lack of environmental friendliness. One of the challenges in the development of electric cars is this. A capacitor-based electrical energy storage medium has just been discovered. Capacitors work on the same principle as batteries, which can store electrical charges.Although the charging process of a capacitor is faster than that of a battery, the draining process is likewise quite quick. Capacitors have the advantages of not requiring a chemical process, little maintenance, and a longer lifespan than batteries. As a result, the scientist created super capacitor. The capacity of a super capacitor is greater than that of a standard capacitor. The goal of this research is to determine the charging and discharging performance of various super capacitor circuits.

Keywords:- *Battery, Capacitor, Accumulator, Electrical Energy, Charging.*

I. INTRODUCTION

Electrochemical capacitors and lithium-ion batteries are the most studied electrical energy storage systems [1]. Because capacitors are used to store and discharge electrical energy, their basic functions are similar to those of batteries. However, the functioning principle of a capacitor differs significantly from that of a battery [8]. The battery's disadvantage is the lengthy charging procedure. The trash generated during the chemical reaction used to charge and discharge the battery is extremely toxic to humans and ecologically unfriendly. The battery life is only two to three years.Another flaw in the battery is that the anticipated remaining energy is insufficient and requires periodic repair. This is one of the problems preventing the development of future vehicles that are ecologically beneficial, such as electric vehicles. Charging an electric vehicle, such as a bike or a car, takes a long time.The researcher created the super capacitor in response to the difficulty described above. Super capacitor is similar to a capacitor, except it is larger and has a greater capacity. The benefit of a super capacitor is that it charges quickly and has few chemical interactions throughout the process. The super capacitor has a long life of roughly 20 years, despite the fact that its power has dropped by 80%. The super capacitor is low-maintenance and has a high operating reliability [9]. The super capacitor voltage, on the other hand, is depleting quicker than the battery. The chemical reaction of the super capacitor requires a short period for charging but a very short time for discharging [8].

Fahad et al. [9] investigated whether supercapacitors might be used to store solar energy and replace batteries. Supercapacitors are easier to maintain, operate more reliably, and are more ecologically benign than batteries. The energy management circuit was used to create and develop the super capacitor. Control and monitoring devices for measuring capacitor voltage during charging and discharging processes were devised by Yifeng [10] and Hu et al. [11]. Their experiment successfully measured voltage and estimated state of charge (SOC).The previous study looked at using a capacitor to store modest amounts of energy. Capacitors are not used in high-energy systems like pumps, lamps, refrigerators, and washing machines. In the current study, the super capacitor is stacked in a series and is controlled by electronics during the charging and discharging process. The goal of this study is to figure out how to create and test super capacitors circuits. The characteristics of super capacitor circuit types will be established. The optimum circuit type may employ the primary component as a storage system for energy (ESS).The overall goal of this study is to determine the performance of a super capacitor while it is charged and discharged utilizing a control circuit. The precise goals are to (1) determine the optimal super capacitor circuit for energy savings, (2) design electronics control for charging and discharging, and (3) determine the super capacitor circuit's charging and discharging time.

II. RESEARCH METHOD

This study's method was divided into several steps: (1) selecting and procuring supercapacitors; (2) designing and assembling supercapacitors in series; (3) designing and assembling the charging and discharging balancer circuit; (4) assembling in series of supercapacitor, charging control, discharging (balancer), and lamp; and (5) retrieving data via video recoding to determine the performance of the supercapacitor circuit.

ISSN No:-2456-2165

A resistive load of an incandescent bulb was used to evaluate the supercapacitor's performance. To begin, obtain a supercapacitor that is more than 100F. If the supercapacitor voltage is less than 12 volts, the capacitors are connected in series until the voltage reaches 12 volts. Digital power supply, amperemeter, voltmeter, and video recorder are the test instruments used in this study. A voltage and current indication should be included in the digital power supply. To test the performance of the supercapacitor circuit, a 24V/50watt incandescent bulb was employed as the load. In the charging process, the digital power supply unit is employed to correctly give power to the supercapacitor circuit. In this study, the digital power supply unit is critical since it displays the voltage and current flowing to the load in real time. A video recorder was utilised to capture every aspect of the supercapacitor charging and discharging operation.

III. RESULT

120 Farad/2.7volt and 500 Farad/2.7volt super capacitors are accessible on the internet. Because each super capacitor has a voltage of 2.7 volts, while the output voltage from the solar panel is 18 volts, six super capacitors are connected in series. According to the calculations, the total voltage of six super capacitors is 2.7volt * 6 = 16.2volt. Figure 1 depicts the physical characteristics of six 120F super capacitors in series, as well as six 500F super capacitors in series.

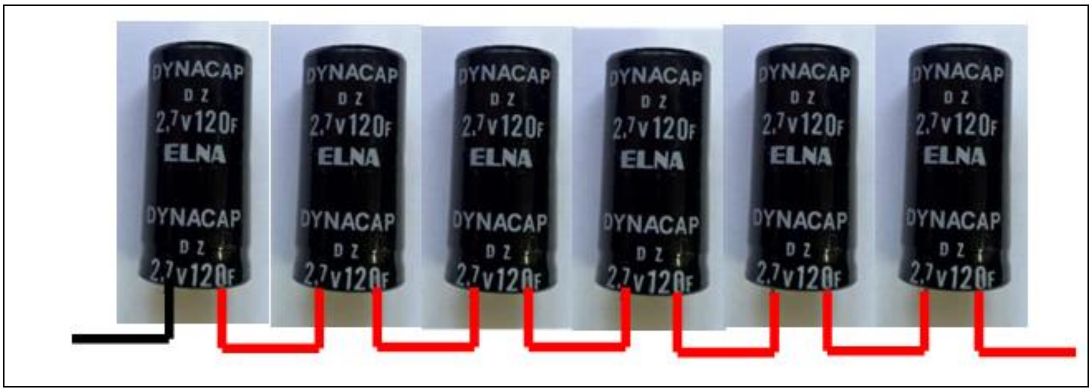

Fig. 1: Series arrangement of six supercapacitor 120F/2.7volt

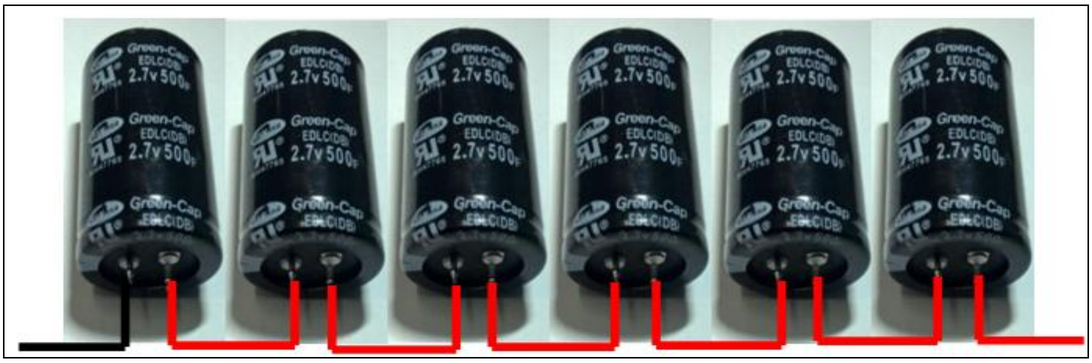

Fig. 2: Series arrangement of six supercapacitor 500F/2.7volt

We determined that every supercapacitor requires a balancing circuit after doing study, observation, and analysis on the output of series six supercapacitors. The main purpose of the balancer is to guarantee that each supercapacitor in series is charged in line with the voltage and current. The balancer based on the design is shown in Figure 3.

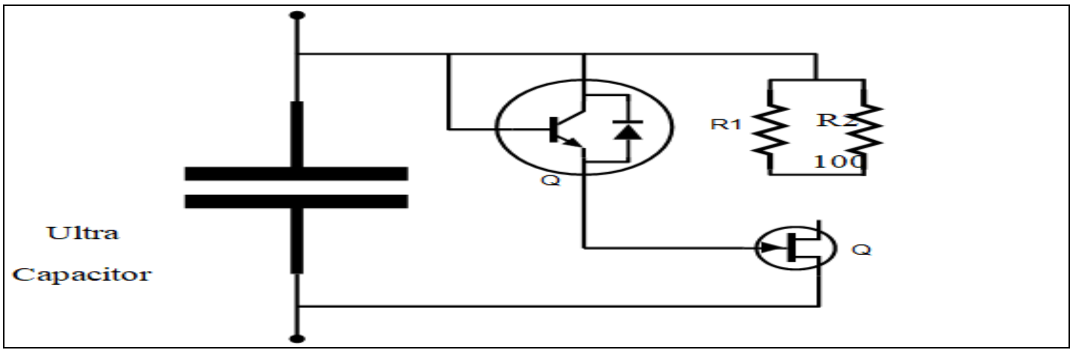

Fig. 3: Balancer circuit for super capacitor

The number of super capacitors is the same as the number of balancer circuits. The supercapacitor and balancer are assembled in Figure 4. The circuit is then loaded with a 24volt/25watt incandescent light for testing. The output voltage of the supercapacitor charging process was set using a digital variable power source. Voltage and current statistics show rapid changes in voltage and current levels. From the time the light was turned on until it was turned off, the video recorder recorded voltage and current values. The video data is then studied until the supercapacitor's performance is determined.

The supercapacitor is a typical capacitor with a large size and capacity (in order hundred farad). The charging behaviour studied is identical to that of a standard capacitor. The voltage of the capacitor in t seconds was calculated using equation (1).

Fig. 4: Six arrangement of supercapacitor and balancer

$$V_c(t) = V_{in} + \left\{ \{V_c(0) - V_{in}\} e^{-t/RC} \right\} \quad (1)$$

where V_{in} : input voltage from the source, $V_C(0)$: initial voltage of capacitor, R: resistor arrangement series with capacitor for set filling time constant, and t: filling time from 0 secon.

If the initial time, there is zerro voltage, $V_C(0) = 0$ volt, so the equation (1) to be equation(2).

$$V_c(t) = V_{in} \left\{ 1 - e^{-t/RC} \right\} \quad (2)$$

The charging current in after t secon shown in equation (3).

$$i_c(t) = \left(\frac{V_{in}}{R} \right) e^{-t/RC} \quad (3)$$

Based on equation (2) and (3) the graph relationship between voltage and current of capacitor charging can be obtained, see Figure 5.

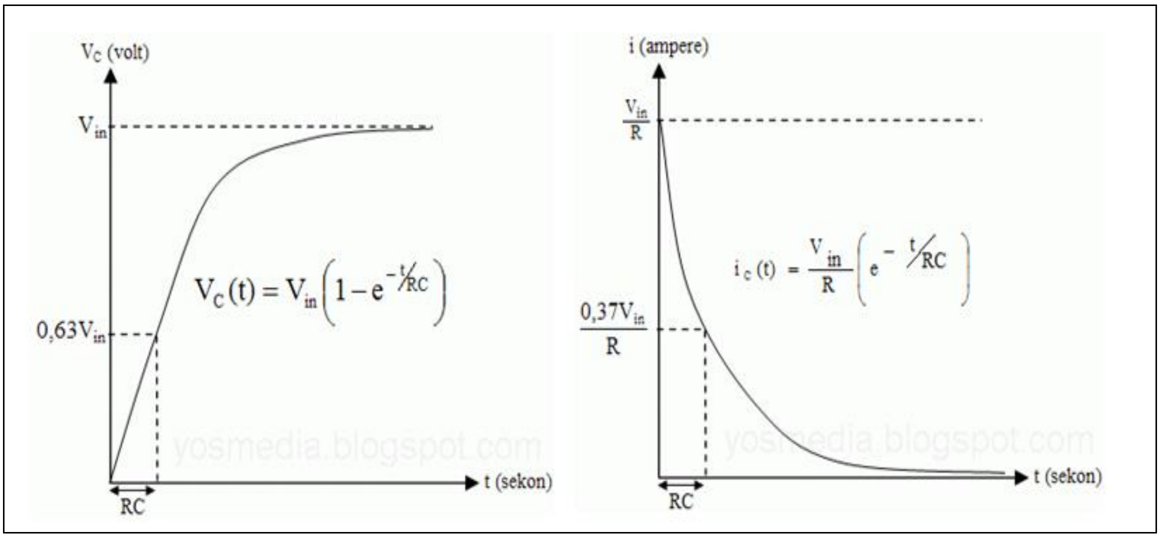

Fig. 5: Graph of the characteristic voltage and current of supercapasitor charging

To determine the performance of supercapacitors, two types of testing are used: charging and discharging process characteristics. Figure 6 depicts the charging process' characteristics. Figure 6's voltage and current graphs are identical to the theoretical supercapacitor charging characteristics in Figure 5. In series with the supercapacitor, the electrical resistance (R) from the cable, solder connection, and connections is 1 ohm. So, for supercapacitor 20F, the time constant value is RC = 1ohm x 20F=20, and for supercapacitor 83F, the time constant value is RC = 1ohm x 83F=83.

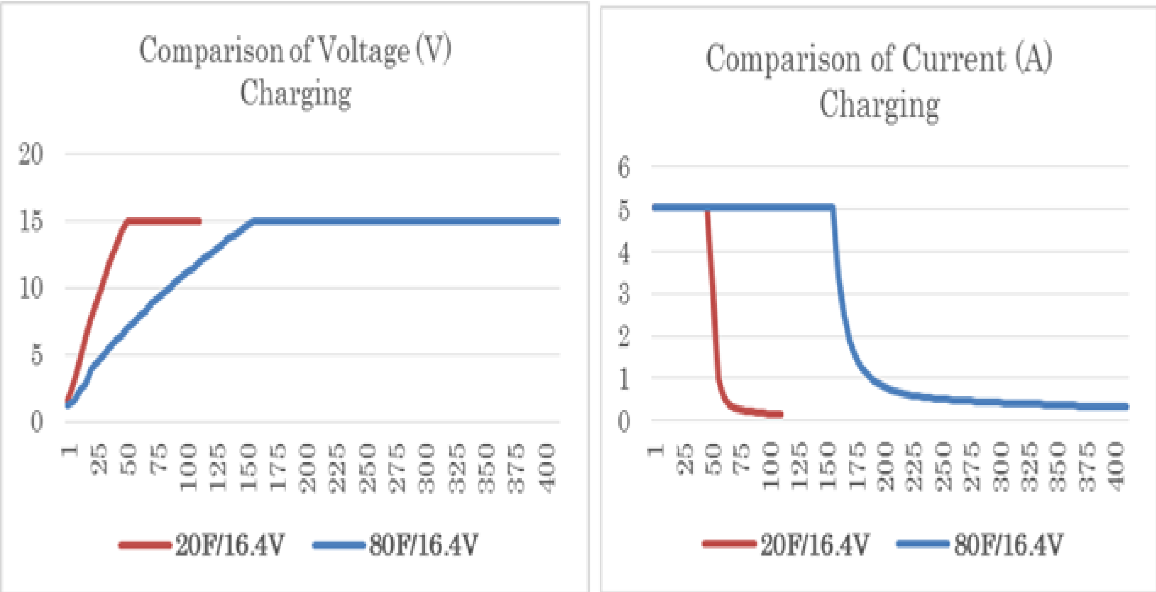

Fig. 6: Characteristic graph for charging supercapacitor

Table 1: Relationship between Charging Time and Prosentage of Capacitors Voltage

t	Vc		t	Vc
0	0		2 RC	86.5%
0.7 RC	50%		3 RC	95%
RC	63%		5 RC	99%

The link between charging time and capacitor voltage is seen in Table 2. The charging time for a full supercapacitor voltage of 99 percent of the super capacitor 20F/16.2V is 5RC. 5RC stands for 5 x 20 = 100 seconds. Time required for supercapacitor 83F/16.2V is 5 x 80 = 400 seconds. There is a high concordance between research and calculation results based on research and theoretical calculations.

The two graphs in Figure 6 are very noteworthy. First, an exponential curve, which means it takes roughly 400 seconds to charge the 83F/16.2V supercapacitor from a voltage near 0 volt to 16,2 volt. Second, the duration of the charging period is related to the supercapacitor's capacity. The higher the supercapacitor's capacity, the longer the charging time. If you increase the capacity of a supercapacitor by building more and more parallel supercapacitors, the charging time will be n times longer than before. Third, the duration of charging time is determined by the capacity and physical resistance of the supercapacitor rather than the amount of the capacitor voltage.

Supercapacitor discharge test using discharge supercapacitor mechanism and formula. The load on the resistor R is 24V/25W incandescent bulbs in ohm. The Qo is the super-initial capacitor's charge at both 20F and 83F. The starting voltage of the supercapacitor is Vo. The voltage of supercapacitors in the discharging process at time t may be described using the fundamental theory of electricity (4).

$$Vc(t)=(Vs)\{e^{-t/RC}\} \quad (4)$$

The current of discharging at time t can describe in equation (5).

$$i_c(t) = [Vs/R]e^{-t/RC} \quad (5)$$

V_S is initial voltage of supercapacitor. Both equation of discharging voltage and current are exponential equation, so the graph of the equation is exponential too. Based on equation (4) and (5) can be made graph Figure 7. Based on the Figure 7 can be derived the relationship between discharging time and percentage of supercapacitor voltage, see Table 2.

ISSN No:-2456-2165

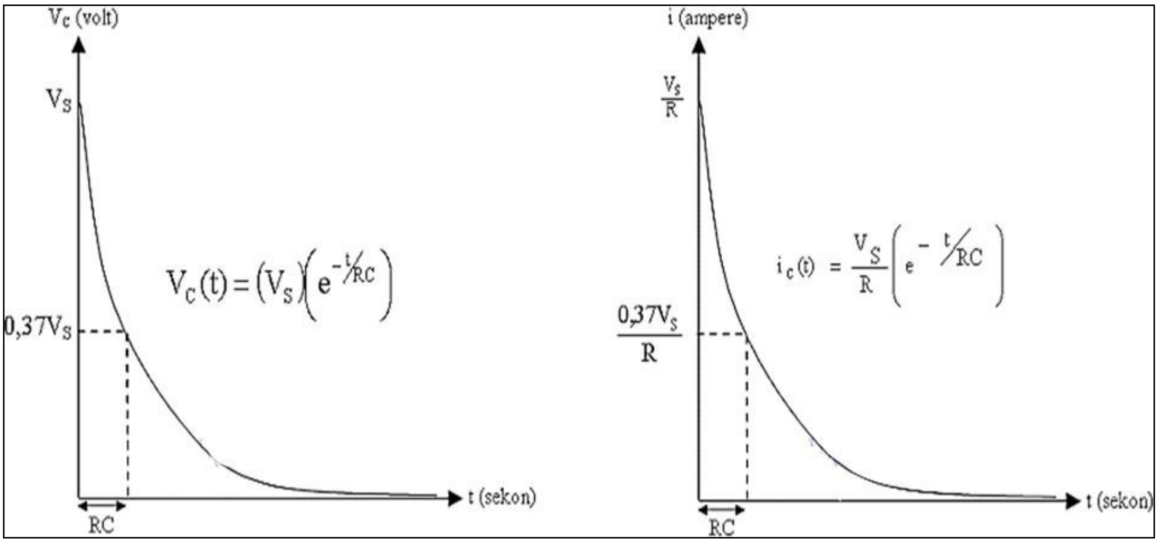

Fig. 7: Relationship between voltage or current and time in discharging process

Table 2: Relationship between discharging time and supercapacitor voltage

t	*Vc*		*t*	*Vc*
0	99%		3RC	5%
RC	37%		4RC	2%
2RC	14%		5RC	1%

To calculate the time constant of discharge τ = R.C, must be known first load R. Here, the load from incandescent lamps, measured directly using digital. The load of incandescent lamps are Rd=1.1 ohm, so R=2.1 ohm. The time constant of discharge (τ) of both supercapacitor can be obtained. Supercapacitor 20F: τ =R.C= 2.1 ohm * 20F = 42 and supercapacitor 83F: τ = R.C = 2.1 ohm * 83F =174.Discharging time until 0.16 volt (1%) using Tabel 2 above. Supercapacitor 20F need discharging time t = 5RC = 5*2.1*20 = 210 sec, while supercapacitor 83F need discharging time t=5RC=5*174= 871 sec.

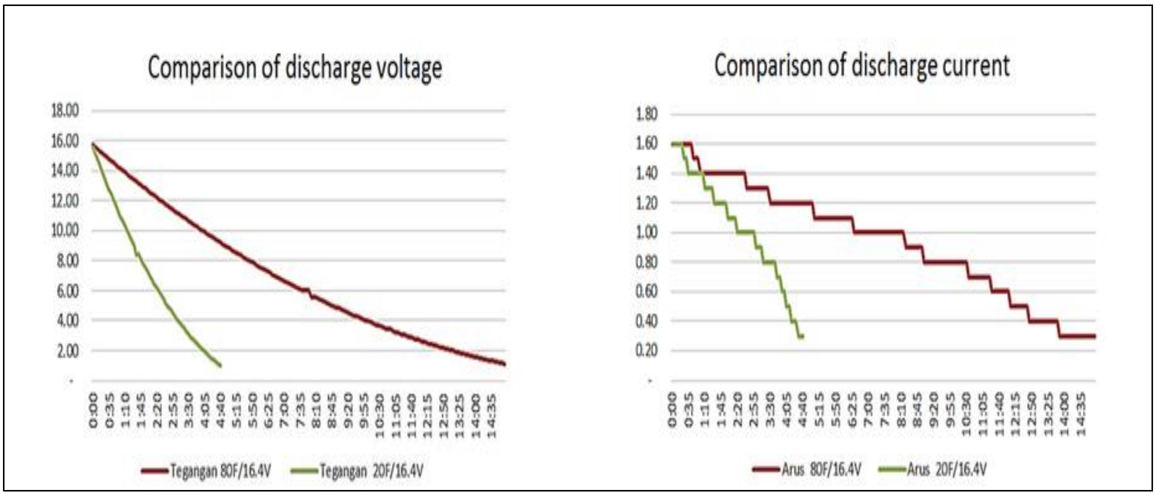

Fig. 8: The characteristic of supercapacitor discharging

The graph of supercapacitor voltage 20F/16.2V and 83F/16.2V vs discharging time is shown in Figure 8 (a). This supercapacitor's load is 24 volts/25 watts. The supercapacitor voltage measured in the initial test when the bulb was attached was 16V. The 20 F supercapacitor voltage was 12-13 volt after 35 seconds, while the 80F supercapacitor voltage was 15 volt. The 20 F supercapacitor voltage was 10 volt after 35 seconds, while the 80F supercapacitor voltage was 14 volt. The difference between the 20F and 80F supercapacitor voltages at t seconds tends to rise with time until the lamp turns off. After 4 minutes 40 seconds for supercapacitor 20F and 14 minutes 35 seconds for supercapacitor 83F, the lamp turns off when the capacitor voltage reaches 1 volt.Figure 8 shows a graph of supercapacitor current at 20F/16.2V and 83F/16.2V. (b). V = I.R, where R stands for electrical resistance, governs DC current and voltage. Because the resistance is constant, the current decreases as the voltage decreases. Figure 7 demonstrates that supercapacitor capacity is proportional to voltage and current (see equation) (6).

ISSN No:-2456-2165

$$C=Q/V \quad (6)$$

where: C is capacity of super-capacitor (F), V is capacitors voltage (V) and Q = capacitors charge (Coulomb). The capacity of capacitor is not depend on V and Q but influence of V andQ. The capacity depends on size and form of super capacitor. From equation (6) shows if there are two capacitor having $C_1=4xC_2$ and having same voltage, so the capacitor voltage is $Q_1= 4\ C_2$. Its mean that capacitors voltage Q_1 is four times Q_4 Mean.From the basic theory of electricity, electricity current (I) in ampere is shown in equation (7).

$$I=Q/T \quad (7)$$

Where t is time in sec

From the equation (7) shows that the electric charge increase in super capacitor so the electric current will increase. If the ability of the load to absorb electricity in constant, so the higher Q is need longer time for discharging process.

IV. CONCLUSION

We can draw the following conclusions based on the conversation and study findings.

- Six 120F/2.7V super capacitors in series (total 20F/16.2V) require around 100 seconds of charging time, whereas supercapacitors 500F/2.7V (total 80F/16.2V) require approximately 400 seconds of charging time.
- The charging time of supercapacitors is proportional to their capacity. Longer charging times are required for larger capacities. When the capacity of a supercapacitor is increased by n times, the charging time increases by n times.
- An electronic balancer might be built to ensure that the voltage of each supercapacitor remains constant throughout the charging process.
- Super capacitor 20F/16.2V discharging time for load 24V/25W is around 200 seconds, whereas supercapacitor 83F/16.2V discharging time is roughly 400 seconds.
- The capacity of a supercapacitor is exactly proportional to its discharge time for the same load. The higher the capacity, the longer the discharge time.When the capacity of a supercapacitor is increased by n times, the charging time increases by n times.

REFERENCES

[1]. S Anuphappharadorn, S Sukchai, C Sirisamphanwong and N Ketjoy 2014 Comparison the Economic Anallysis of the Battery between Lithium-ion and Lead- acid in PV Stand-alone Application (Energy Procedia) pp352-358

[2]. W T F Fok, T K Cheng, P W T Pong, C CNgan and R Ho 2011 Local Weather Effect on the Town Island PV System (Energy Procedia) 12 pp480-487

[3]. T Kameya, J Uddin, H Kazuka, G Suzuki and H Katsuma 2014 Demonstration Experiment for Energy Storage and Rapid Charge System for the Solar Light Rail (Energy Procedia) 57 pp906-915

[4]. Anonymous, OlahPotensi 112.000 GWp with Fotovoltaik

[5]. M Fathi, A Chikouche and M Abderrazak 2011 Design and Realization of LED Driver for Solar Street Lighting Appications (Energy Procedia) pp 160 –165

[6]. Ministry of Energy Energi Surya danPengembangannya di Indonesia (ESDM: Indonesia)

[7]. Anonymous, Indonesia Solar Power Mapping Study using Secondary Data (Energy Indonesia)

[8]. Anonymous, The Kidwind Project: Using Mini-Super capacitors to Store Energy

[9]. A Fahad, T Soyata, T Wang, G Sharma, W Heinzelman and KSShen 2012

[10]. SOLARCAP: Super Capacitor Buffering of Solar Energy for Self-Sustainable Field System (SOC Conference (SOCC)) (IEEE International) Pp 236-241

[11]. G Yifeng 2011 Analysis and Design of the Super Capacitor Monitoring System of Hybrid Electric Vehicles (ProcediaEngieneering) 15 pp 90-94

[12]. J Hu, Y Fan and Q Feng 2012 Running Control of the Super Capacitor Energy-Storage System (Energy Procedia) pp 1029-1034

[13]. M Matsumura 2009 Utilization of Solar Cell (Lecture Notes Research Center for Solar Energy Chemistry Osaka University)

[14]. G P Smestad 2002 Optoelectronics of Solar Cells (SPIE Press)Washington

[15]. K West, 2003 Solar Cell Beyond Silicon (Riso International Energy Conference)

[16]. S Pan, Z Zhang, W Weng, H Lin, Z Yang and Peng., H., Miniature Wire-shaped Solar Cells Electrochemical Capacitors and Lithium-ion Batteries (Materials Today)Vol 17 No 6 (2014) pp 276-284

[17]. S Y Tseng, C Y Hsu 2013 Interleaved Step-up Converter with a Single-capacitor Snubber for PV Energy Conversion Applications (Electrical Power and Energy System) 53 pp909-922

[18]. W Sutopo, D I Maryanie, A Purwanto and M Nizam 2014 A Comparative Value Chains Analysis of Solar Electricity for Energy (Proceeding of the International Multi Conference of Engineers and Computer Scientists) Vol 2

[19]. Y. Gunardi and A AWibowo 2010 Perancang and an PembuatanSistemSoalar Cell PenjejakMatahari 4 Arahuntuk Lampu Penerang Jalan(Prosiding Seminar

[20]. Nasional Teknoin 2010 Bidang TeknikElektro)

[21]. Pusat Listrik Tenaga Surya https://tenagamatahari.wordpress.com/beranda/sejarah-solar-cell/.

[22]. B. Yuliarto Solar Cell Sumber Energi Terbarukan Masa Depanhttp://esdm.go.id/berita/56-artikel/4034-solar-cell-sumber-energi-terbarukan-masa-depan-.html.