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Implementation of Power Optimization Technique for UAVs

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Abstract

Unmanned Aerial Vehicles (UAVs) are used in many civilian and commercial applications. The main challenge with UAVs is providing long run and light weight power source. This paper deals with the one of the important issues of providing power supply using super capacitor energy storage system for UAVs, which reduces the fluctuations and increases the flight time while it is flying. Super capacitors have less weight, fast charging as well as slow discharge which increases flight time when compared to Li-PO batteries. Hence the analysis, design and working of supercapacitor is considered in this paper. The simulation results of the Super Capacitor Energy Storage System (SCESS) show that supercapacitor is showing good performance.

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Keywords: DC-DC Converters; Li-PO batteries; Super capacitor energy storage system (SCESS); UAVs.

1. Introduction

Supercapacitor has the potential to allow major advances in the storage of energy which is a new technology. The fundamental equations of Super capacitors are same as conventional capacitors, but to achieve greater capacitance supercapacitor uses the electrodes with higher surface area and thinner dielectrics. This allows the energy and power densities greater than those of conventional capacitors and Li-Po batteries respectively. Due to this, it becomes attractive power solutions in nature and can be used in many applications, so it is one of the techniques used for Unmanned Aerial Vehicles (UAVs).For this type of Unmanned Aerial Vehicles (UAVs) applications the Li-PO battery discharges very fast at their run-time which depends on load. The power required by the load can be provided by supercapacitor in a static way which softens the requirements of load and improves the run-time.

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2. Li-Po batteries

Now a day's all are using Li-PO batteries in Unmanned Aerial Vehicles (UAVs), these batteries are slowly charged and fast discharged. The main disadvantage of these Li-PO batteries is, there is no possibility to operate at high level temperatures whereas super capacitors operate at high level temperatures. And its service life is also low comparing to Super capacitors. And also the charge rate based on various states: rate of charge, present State-of-Charge and ambient temperature [6, 7, 8].

- Battery efficiency: The process of discharging efficiency is defined by the well-known method known as peukert effect. [7] The peukert number N depends on below equation

$$C = I^N t$$

- State of charge: It can be determined based on four common methods. Those are
  - Measurement of specific gravity,
  - Measurement of open-voltage,
  - Measurement of terminal voltage,
  - Measurement of current (Amp-hour)

Offline methods are not applicable in battery systems which are specific gravity and open voltage methods and these are difficult to operate. If the battery is disconnected from the system then the measurement of State of Charge (SoC) can be achieved. The implement action of the terminal voltage and amp-hour methods is difficult because terminal voltage method depends on the current and gives inaccurate result [7]. So, the State of Charge can be achieved in the following equations.

$$SoC(t+\Delta t, I) = SoC(t) + \int \frac{I.p(I)}{C}.dt, discharge$$

$$SoC(t+\Delta t, I) = SoC(t) + \int \frac{I.\eta_{SoC(t)}}{C}.dt, charge$$

Block Diagram for the Whole Process of the System:

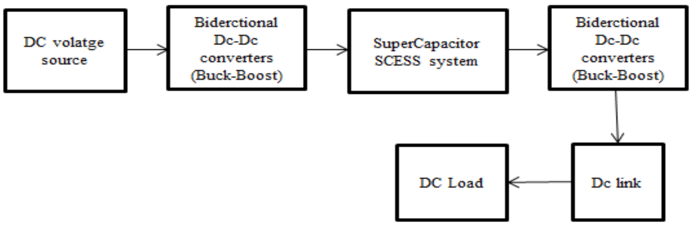

Fig. 1. System Block diagram

3. Supercapacitor

Supercapacitor energy can be stored by the polarisation of electrolyte solution. Using the dielectric interface the ions are separated in supercapacitor. The charged electrodes are on one layer and electrolyte ions are on another layer. The double-layer capacitance can be given by (1).

$$\frac{C}{A} = \frac{\varepsilon}{4\pi\delta} \quad \ldots\ldots\ldots (1)$$

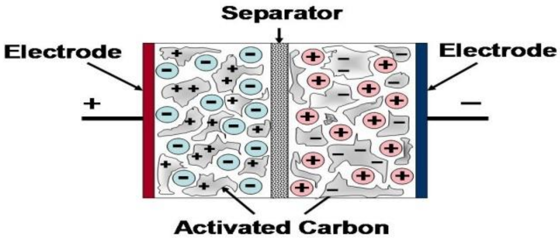

Fig. 2. Supercapacitor

Table 1.Comparision Between Li-Po Batteries And Supercapacitors

Parameter	Supercapacitors	Batteries (Li-Po)
Charging time	Fraction of a second to several minutes	Several hours
Self-discharging	Hours to days	Several minutes
Power density	>1000 W/kg	<500 W/kg
Density of power	<5 Wh/kg	10-100 Wh/kg
Charging/discharging efficiency	85-98%	70-85%
Cycle life	$10^6 - 10^8$	200-1000

Super capacitors are also known as electrochemical double layer capacitor which is having high capacitance, large surface area, their capacitance has higher value and also power rating is also high when compared to conventional capacitors because they can release energy faster [3]. The SCESS system having the super capacitor and the DC-DC converter which controls current flow [1, 2].
The equivalent circuit model of an ultra capacitor is shown below (figure 3).

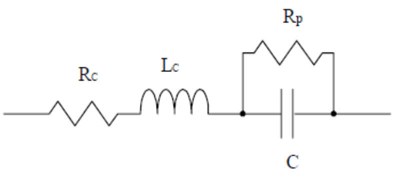

Fig. 3. Equivalent circuit of Supercapacitor

4. Algorithm for the management of power in supercapacitor

The proposed technique based on various states can be represented as state of charge of the supercapacitor. The energy of supercapacitor switches between states because it observes the conversion system power balance [11]. Initially the system is in “turnoff” state when supply is not available. It will automatically turns to “soft start” state when supply voltages are available from the sources. During this stage the super capacitor charges and it turns to “battery charge” state. If the supercapacitor in battery charge state charges very high automatically switches to “over power” and then it checks when the battery power is high or low. If it is high it remains in over power state otherwise it switches to “battery help” state. If the supercapacitor connected to load in battery charge state then the charge becomes very low then it turns to “turnoff “state and again the process repeats until it charges.

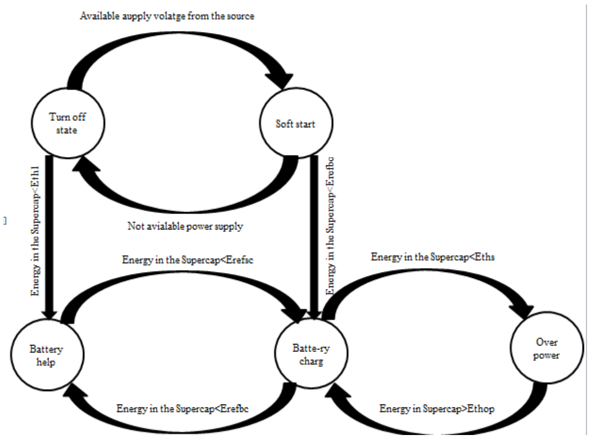

Fig. 4. State machine for the Management of power

[1, 2] The Supercapacitor energy storage system shown in Fig. 5 is used to select the parameters of the system. The fully charged and discharged voltages of the super capacitor are minimized to below 50% of the DC voltages. The minimized value provided by the inductor reduces the ripple current to 2% depends on eq(1).

$$\Delta I_L = \left(\frac{V_{SC}}{L}\right) dT \quad \ldots\ldots\ldots (2)$$

[1, 2]The recommended value for the DC link capacitor reduces the voltage to 2% in the boost mode depends on eq(2)

$$\Delta V_{dclink} = \left(\frac{PdT}{CV_{dclink}}\right) \quad \ldots\ldots\ldots (3)$$

The design of SCESS elements depends on eq(1) and eq(2).The SCESS system circuit can be shown below in Fig . (5).

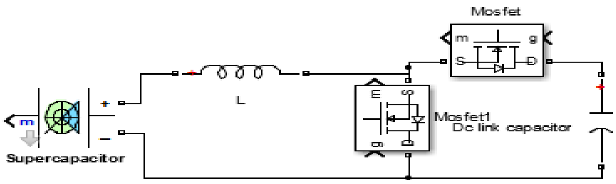

Fig. 5. The circuit of SCESS system

The functioning of MOSFET can be done in two modes. One is depletion mode and the other is enhancement mode. These are used in DC-DC converters to amplify the electronic signals.

5. DC-DC Converter

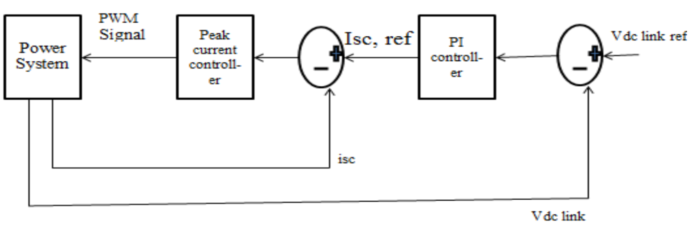

Fig. 6. Boost mode of SCESS

In boost mode, the outer loop consists of discharge current and inner loop consists of DC link voltage. Fig. 4 is block diagram of the boost mode [1].

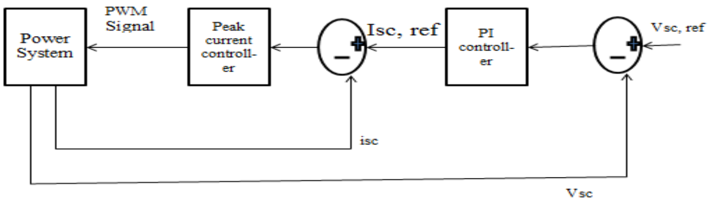

Fig. 7. Buck mode of SCESS

In buck mode, the outer loop consists of charging current and inner loop consists of voltage of Super Capacitor. Fig. 5 is the block diagram of buck mode [1].

6. Simulink Design Of Buck And Boost Converter

The buck and boost convertors are used to provide lower and higher dc voltages respectively and also to generate an output voltage which may or may not equals to the input voltage. Buck/Boost convertor, which converts unregulated DC voltage to regulated DC output voltage [1, 2, 5].

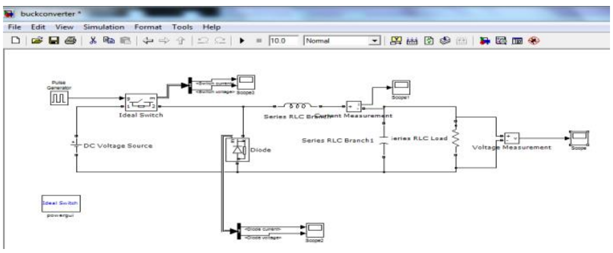

Fig. 8. Buck converter in matlab simulink model

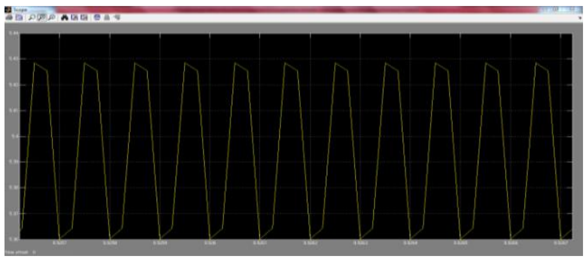

Fig. 9. Simulation result of buck converter model voltage vs. time

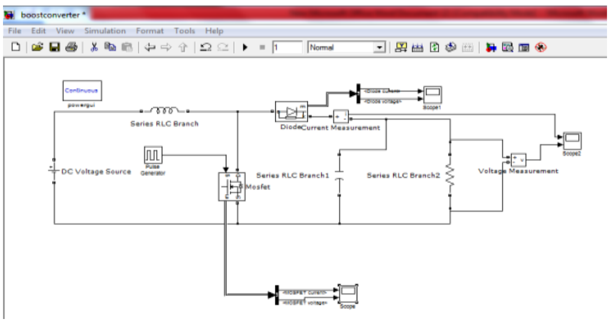

Fig. 10. Boost converter in matlab simulink model

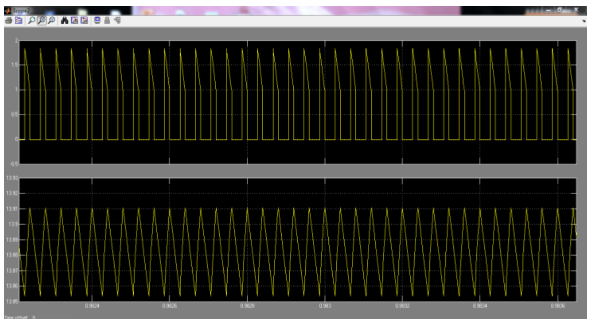

Fig. 11. Simulation result of boost converter model voltage (v) vs. time

The Fig. 11 can be described about the boost converter which increases the voltage up to the load operating voltage as well as buck decreases the voltage as shown in Fig. 10.

7. Simulation of supercapacitor energy storage system

A model of SCESS was designed in the Matlab simulink software [9, 10] which has power and control circuits.

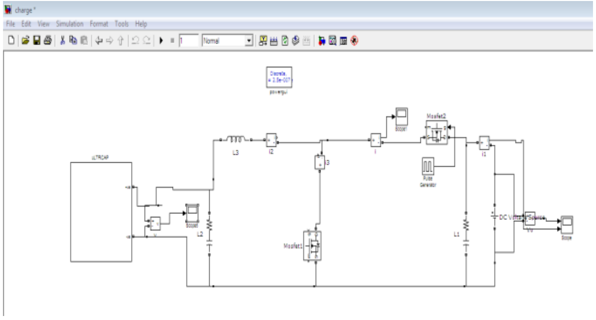

Fig. 12. Charging modelof SCESS in matlab simulink

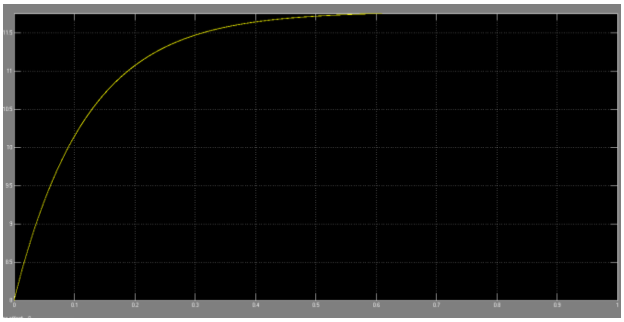

Fig. 13. Simulation of SCESS charging voltage vs time

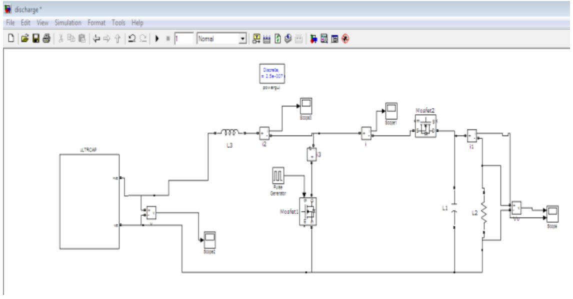

Fig. 14. Discharging model of SCESS in matlab simulink

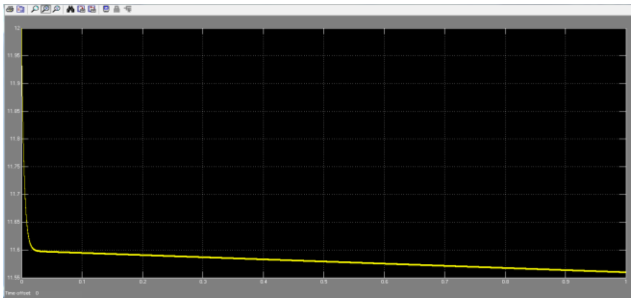

Fig. 15. SCESS discharging voltage (v) vs. time(seconds)

In Fig. 13 the supercapacitor is quickly charging and slowly discharging as shown in Fig. 15 in SCESS model when compared to Li-Po batteries [9].

8. Conclusion

In this paper simulink models are developed for the SCESS to show that the supercapacitor in SCESS model can quickly charged and slowly discharged when compared to Li-Po batteries. Supercapacitor and li-Po batteries are used in UAVs. To increase the flight time of the vehicle we have used supercapacitor and SCESS technology improves power system stability. This research can be improved to a hardware technique of the implemented system for Unmanned Aerial Vehicles.

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