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Battery Less Power Conditioner Using a Super Capacitor

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Abstract—Providing uninterruptible power to a critical load requires suitable energy storage device preferably an electro chemical battery. But the batteries are a great concern now- a -days since the lead used in most commercial batteries pollute the environment. The capability of providing instant high power, a very long life and very minimum maintenance makes a super-capacitor clearly advantageous than a battery This work proposes to develop a energy friendly ups system using super capacitors as energy storage device. A Matlab simulation model of an online UPS system is presented with the waveforms at various stages. The harmonic content of the super-capacitor based UPS is compared with battery based UPS. Simulation results are presented.

Index Term—Super -capacitor, battery, inverter, rectifier, boost converter, UPS.

1 INTRODUCTION

Many industries as well as the household require Uninterruptible power supply (UPS). UPS are used to provide backup power during the power failure from the supply. Generally, in industries, whenever the EB supply goes off, then immediately generator are used for supplying the power to the load [1]-[3]. But it takes 5mins to startup the generator manually. This starting time required for a generator can be reduced easily using Automatic main failure (AMF) panel. AMF panels are used for controlling DG START/STOP in accordance to the utility power supply. In general, generator set can be started in 3mins using AMF panel. So a back up system of providing short term energy is required in between the power outage and the starting of power back up facility like a diesel generator. For such short duration, a super capacitor is a good choice for energy storage in place of a battery power [4]. Thus by using super capacitor based ups It is possible to supply an uninterrupted power to the load especially the critical loads [5]-[6].

In a conventional ups system the power from the ac source is converted in to dc through a line commutated converter. The DC voltage thus obtained charges a battery as well as it is fed to the input of a PWM inverter. In case of a single phase UPS system, the rectifier and the inverter used are single phase devices in this work [7]. This work also

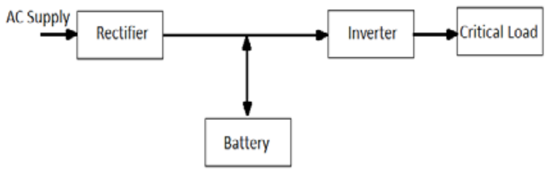

Fig. 1 Conventional On-line UPS System

This work also proposes an alternate storage method for a single phase UPS system. While the role of the inverter and the rectifier are maintained as in case of a conventional UPS shown in fig.1,the electrochemical battery is replaced with super capacitor also known as ultra capacitors in the proposed system shown in fig. 2.

Thus an environmental friendly UPS system is proposed, since the electrochemical batteries are a source of environmental pollution and poisoning of the ecology system of the planet Earth. The major drawback of using an ultra capacitor is that it is capable of providing energy at high density for a short duration of time, whereas the batteries discharge at a longer rate of time hence the ultra capacitors can be used only for short duration energy storage.

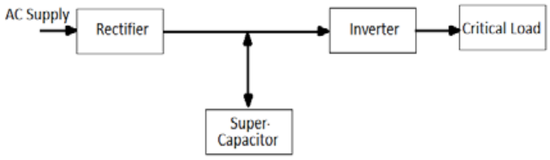

Fig. 2 Proposed Super-Capacitor based UPS

2 SUPERCAPACITOR

Super-capacitor is also known as Electric double-layer capacitors, electrochemical double layer capacitors (EDLCs)[8]. Ultracapacitors are electrochemical capacitors that have an unusually high energy density when compared to common capacitors, typically several orders of magnitude greater than a high-capacity electrolytic capacitor which are illustrated in fig.3.

EDLC share the same equivalent circuit as conventional capacitors as shown in fig.4. The first order model is represented by the circuit below. It

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is comprised of four ideal components. The series resistance Rs which is also referred to as the Equivalent Series Resistance (ESR). This is the main contributor to power loss during charging and discharging of the capacitor. It is also comprised ofa parallel resistance Rp which affects the self-discharge, a capacitance C and a series inductor Ls that is normally very small as a result of the cell construction.

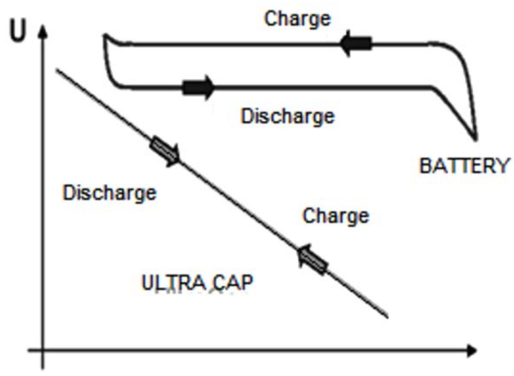

Fig:3 Ultracapacitor Discharge Curve

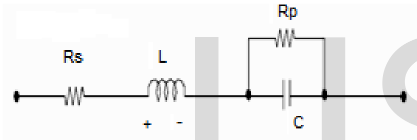

Fig:4 First Order Equivalent

Since Rp is always much larger than Rs it can be ignored. Similarly Ls is also ignored due to its small value.

The Ultracapacitors reside in between conventional batteries and conventional capacitors. They are typically used in applications where batteries have a short fall when it comes to high power and life, and conventional capacitors cannot be used because of a lack of energy. EDLCs offer a high power density along with adequate energy density for most short term high power applications [9]. Many users compare EDLCs with other energy storage devices including batteries and conventional capacitor technology. Each product has its own advantages and disadvantages compared to other technologies as can be seen in the table 1.

TABLE 1. COMPARATIVE CHART OF VARIOUS ENERGY STORAGE SYSTEMS

Available Performance	Lead Acid Battery	Ultracapacitor	Conventional Capacitor
Charge Time	1 to 5 hrs	0.3 to 30 s	10^{-3} to 10^{-6} s
Discharge Time	0.3 to 3 hrs	0.3 to 30 s	10^{-3} to 10^{-6} s
Energy (Wh/kg)	10 to 100	1 to 10	< 0.1
Cycle Life	1,000	>500,000	>500,000
Specific Power (W/kg)	<1000	<10,000	<100,000
Charge/discharge efficiency	0.7 to 0.85	0.85 to 0.98	>0.95
Operating Temperature	-20 to 100 C	-40 to 65 C	-20 to 65 C

3 METHODOLOGY

In this work simulation of an on line UPS system is done using MATLAB software, the conventional battery based UPS is not simulated but the working of the online UPS with super capacitor and without super capacitor is done and the simulation results are compared.

It is a known fact that batteries provide continuous power to load in an UPS system both during mains supply present as well as when it is absent or even during brownouts, blackouts cases. Thus an online UPS not only provides continuous power, it also ensures the quality of the power output to the load is as per the standard requirements.

In the following sections, where simulation circuits and results are discussed, it can be seen that the simulation work carried is simple and straight forward and is just to explain the concept of working of UPS system. Thus the simulation model is done with presence of a super capacitor in the circuit and in the absence of the super capacitor. The wave forms depicting the output of the rectifier, inverter and the critical load is presented.

The life expectance of a super capacitor is given by the equation 1

$$L2=L1*2X \qquad (1)$$

Where x = (Tm-Ta)/2

L1= Load life rating of the super capacitor.
L2= expected life at operating condition.
Tm= Maximum temperature rating of the supercapacitor.
Ta= Ambient temperature the super -capacitor is going to be exposed to in the application.

4 SIMULATION AND RESULTS

The power source to charge the super capacitor comprises of an ac power supply, a line commutated rectifier and a boost converter. A boost converter shown in fig 5 is a step up DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched – mode power supply (SMPS) contains at least storage element , a capacitor, inductor, or the two in combination. This switch used in this work is IGBT.

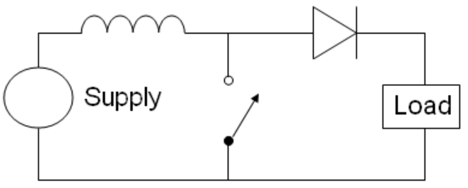

Fig:5 Schematic diagram of boost converter.

The simulation model of the rectifier and the boost converter to the ac source is shown in fig 6.

This combination is responsible for converting the ac to dc and also charging the super capacitor[10].

The equivalent model Super capacitor consists of two resistors (ESR,EPR) and one capacitor(C) in which capacitor(C) and resistor(EPR) are connected in parallel and in series with another resistor(ESR).This combination will forms a super capacitor and the values used are shown in table 2.

TABLE 2.

EQUIVALENT CIRCUIT VALUES OF SUPER CAPACITOR

Slno	Component	Range
1	Equivalent Series Resistor(ESR)	0.0001 Ohms
2	Equivalent Parallel Resistor(EPR)	10 Ohms
3	Capacitor(C)	5 milli Farad

The simulation output of this module is shown in fig 7 and fig 8, which depicts the output of the rectifier and the output after the super capacitor section respectively.

5. INVERTER SECTION

Single phase inverter is an electronic component which converts DC to AC. The inverter used in this work is a single phase PWM inverter with four Mosfet switches in H-Bridge configuration[11]. The simulation model of the inverter section is shown in fig 9. In this model, Input to the inverter is given from super-capacitor block. The need for a PWM inverter is to reduce the effect of harmonic content and also for controlling the output voltage.

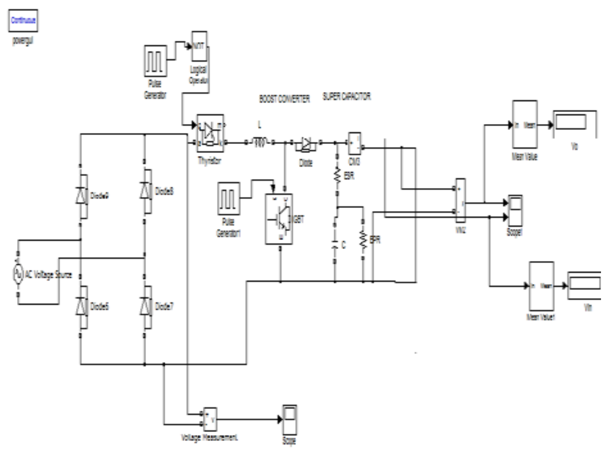

Fig:6 simulation model of rectifier and boost converter

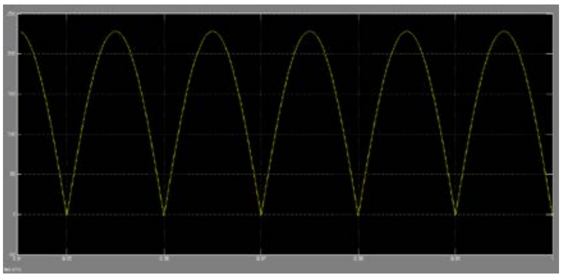

Fig 7. Output of the line commutated converter

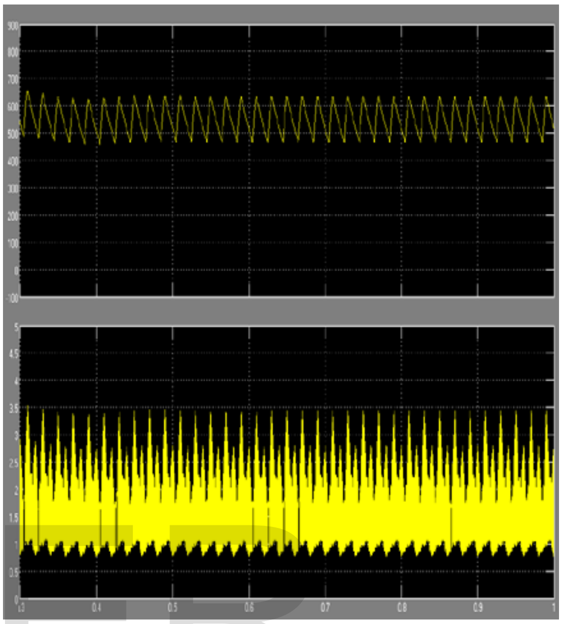

Fig 8 output after super capacitor block

In Fig. 10 the output of the inverter is shown when the super capacitor is connected and ac supply voltage (mains Voltage) is interrupted periodically. It can be seen that the output of the inverter is continuous even though the power supply is interrupted, this provides that the super capacitor acts to supply the load continuously with the energy stored in it to ensure the continued power supply.

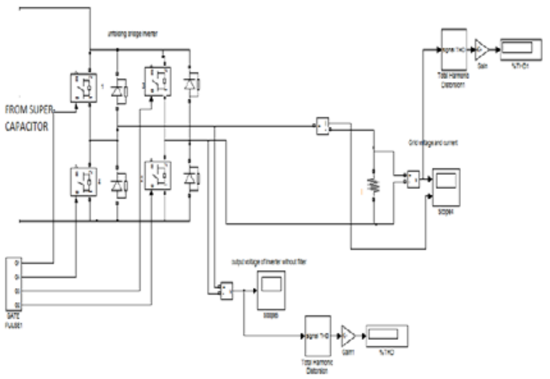

Fig: 9 simulation model of inverter

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The interruptions can be extended to minutes through the increase of value of super capacitor similar to that of increasing the rating of battery in a conventional UPS system.

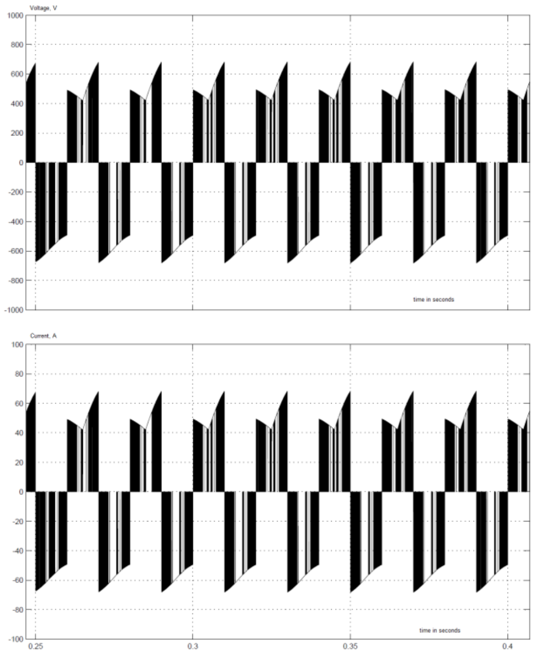

Fig.10 output of inverter when super capacitor is connected and supply interrupted

Fig 11.Shows the output of the inverter, where the inverter is supplied with the absence of the super capacitor in the power supply block. Thus it can be seen there is a discontinuity in the output of the inverter whenever the ac power supply is interrupted. Since the output of the inverter is not continuous, the load is not supplied with continuous power hence critical loads fail with this configuration.

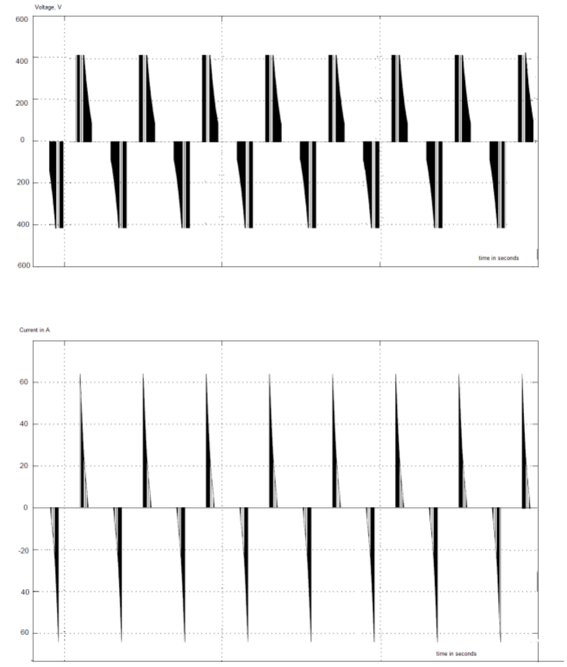

Fig 11. Output of the inverter in absence of super capacitor and interruption in mains

The simulation shown in Fig.6 and Fig 9 when integrated forms the entire proposed system with rectifier section, super capacitor block, inverter section and critical load. The entire circuit was simulated for both the condition when the power supply is disrupted with energy storage element is present and also when the same is absent.

Thus fig 11 depicts both Voltage and current fed to the load when the energy storage element is absent and with the power supply disruptions present. It can be seen that the output is not continuous hence the critical load fails. From the preceding sections it can be proved that the super capacitor acts as a energy storage element as an alternative to the battery and provides a critical load continuous power supply,

6 Conclusion

In this work an on line UPS system using a super capacitor as an energy storing element was successfully simulated for both power on and power interruptions mode. It can be seen from preceding sections, that the working of the ups with super capacitor results in continued output irrespective of power interruptions, to that of an ups without super capacitor. Since the output is continuous with a super capacitor, the load gets unaffected by supply interruptions, similar to that of what happens in an UPS using an electro chemical battery. Hence it can be concluded that the super capacitor works similar to that of battery

hence it is a suitable energy storing element for an UPS system

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