The Review of Hybrid Energy Storage Topologies for Power Systems Application

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Abstract

The paper discusses typical hybrid energy storage applications in power systems, Such as frequency and voltage regulation, demand management, load shaving and energy arbitrage. The review has provided the state of the art in the field of battery super capacitor hybrid energy storage topologies for power systems application . A comparison of advantages and disadvantages of the passive, the semi-active and the active dc and ac schemes has been made. The parallel active hybridization scheme has been chosen as the most appropriate solution for power system application. The review has proven relevancy of the research in the field. The steps for the future research have been identified.

Keywords: Transformer, Inverter, Semiconductor Hybrid energy storage system

I. Introduction

1.1 Background

Modern batteries (e.g.Li-ion batteries) provide high discharge efficiency, but the rate capacity effect in these batteries drastically decreases the discharge efficiency as the load current increases, Electric double layer capacitors, or simply super capacitors, have extremely low internal resistance, and a battery-super capacitor hybrid may mitigate the rate capacity effect for high pulsed discharging current. However, a hybrid architecture comprising a simple parallel connection does not perform well when the super capacitor capacity is small, which is a typical situation because of the low energy density and high cost of super capacitors. This project presents a new battery-super capacitor hybrid system that employs a constant-current charger. The constant-current charger isolates the battery from super capacitor to improve the end-to-end efficiency. Ultra capacitors (UCs) are the options with higher power densities in comparison with batteries. Super capacitors, also known as Electric double-layer capacitors, electrochemical double layer capacitors (EDLCs) or ultra capacitiors, are capacitors with an unusually high energy density when compared to common capacitors.

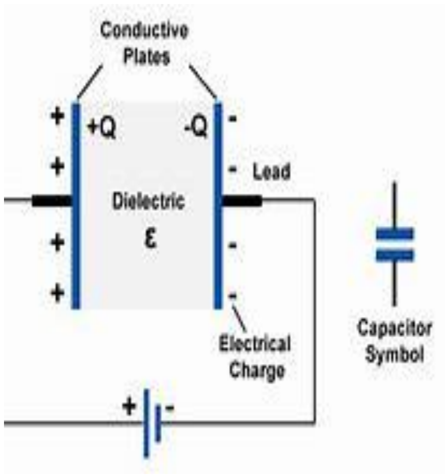
1.2 Motivation

Energy storages introduce many advantages such as balancing generation and demand, power quality improvement, smoothing the renewable resource's intermittency, and enabling ancillary services like frequency and voltage regulation in microgrid (MG) operation. Hybrid energy storage systems (HESSs) characterized by coupling of two or more energy storage technologies are emerged as a solution to achieve the desired performance by combining the appropriate features of different technologies. A single ESS technology cannot fulfill the desired operation due to its limited capability and potency in terms of lifespan, cost, energy and power density, and dynamic response. Hence, different configurations of HESSs considering storage type, interface, control method, and the provided service have been proposed in the literature.

II. Methodology and Components

2.1 Capacitor

Capacitor or condenser is a passive two – terminal electrical component used to store energy electro statically in an electric field.



Energy of Capacitor –

Energy of capacitor is equal to the work done to charge it. Consider a capacitor of capacitance C, holdin a charge +Q on one plate and –Q on the other. Moving a small element of charge dq from one plate to the other against the potential difference V=q/c requires the work dw.

$$dW = {}^{q}/C \quad dq$$

$$dW = \frac{q}{C}\,dq$$

$$W = \int_0^Q V\,dq = \int_0^Q \frac{q}{C}\,dq = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ$$

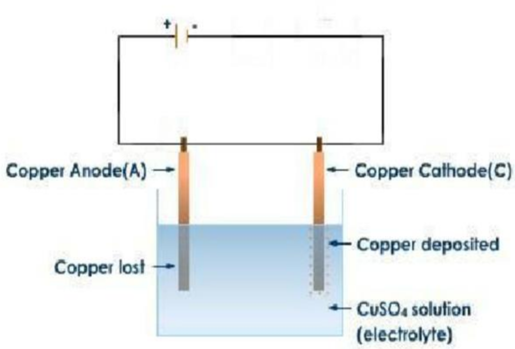
2.2 Battery

Principal -

In battery a simple chemistry takes place, as we know every chemical elements want to pair with other element to complete the eight atoms in their last shell. Due to this chemical reaction between elements takes place and chemical formation takes place.

For example, $Cu^{+} + SO_4 = CuSO_4$

When this chemical is diluted with water the bond between them become weaker, and we can separate both ions by the help of electrical charge method. When this liquid and two electrodes present in the utensils as shown in figure, is the basic arrangement of battery.

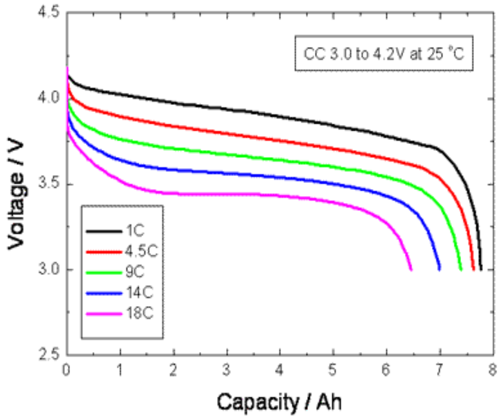


Classification of Batteries -

1) Batteries are basically of two types-
2) Un- rechargeable battery or primary battery.
3) Re-chargeable battery or secondary batter.

Battery discharging process-

The battery curve describes the nature of discharging of battery with respect to time in reference with discharging current.



2.3 Inverter

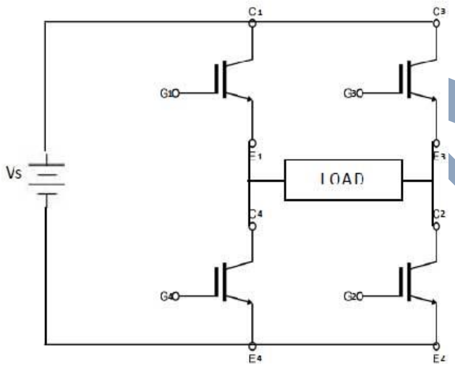


Fig. 1: Single Phase Inverter

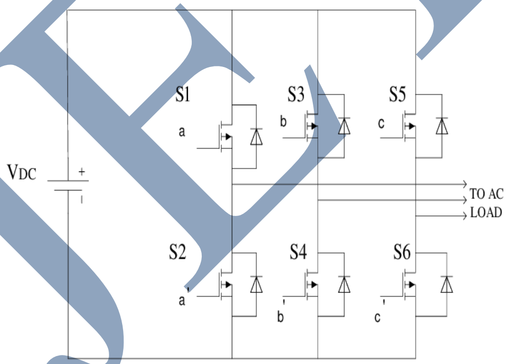


Fig. 2: Three Phase Inverter

III. CALCULATIONS

For Discharging time –
13.5V, 10F super capacitor

$E= \frac{1}{2} cv * v$

$E= \frac{1}{2} 10 * 13.5 * 13.5$

E=911.25 joules
1Joule = 1 watt sec
911.25 = watt sec
Here, we are using 60 w household fan
So,

$$\text{Time} = \frac{911.25}{60}$$

Time = 15.187 sec
This is theoretical value, but in measurement the actual value of time of discharging capacitor is 6 sec

Percentage error is $= \frac{15.187 - 6}{15.187} = 60.24\%$

Inverter response with the battery -

We have 5AH, 12V battery which is comfortable with the inverter.

Discharging of battery –

E = V * I * t

E = 12*3 watt hour

E = 36 watt hour

E = 36 watt hour

For 60 watt house hold fan

Time $= \frac{36}{60}$ hour

Time = 0.6 hour

This is theoretical value, in the practical actual value comes is 6 minute

Percentage error is $= \frac{40 - 06}{40} = \frac{34}{40} * 100 = 85.33\%$

This error comes due to the harmonic present in the transient period of load when feeding through the battery.

IV. Conclusion and Future Work

The paper has been successfully designed and was a gradual process from gathering of material to testing of component. It is to be noted that the loading capacity of this project depends on the power rating of battery and super capacitor connected to the input and on the total power of load connected to the output. Thus the hybrid system employing inverter circuit, battery and super capacitor could deliver constant power for a calculated number of hour efficiently. In view of inconsistence and unreliable harmonic distortion in the battery reduces the battery life span and overall system efficiency is reduced, but the working of super capacitor in parallel with battery prolonged the life span of battery and hence make the system efficient and successful.

Although the objective of this project has been achieved, but for more improvement on this project, further research can include:

1. Increasing the power rating of inverter by increasing the number of power switching devices and current rating of transformer.
2. Use of microcontroller to implement PWM in inverter circuit.
3. Use of microcontroller to make the charging system of battery and super capacitor more accurately and automatic.

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