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Intend of Battery-Super Capacitors Arrangement in UPS

[1]B. NAGARJUNA REDDY, [2] SHAIK. MABHU JANI
[1]M.Tech Research Scholar, Priyadarshini Institute of Technology & Management
[2]Assistant Professor, Priyadarshini Institute of Technology & Management

Abstract: This paper presents a study of the reduction in battery stresses by using Super capacitors (SCs) in UPS. We aim at investigating the optimal Super capacitors-battery combination versus the SCs cost. This investigation is threefold; first, super capacitors and battery models developed using MATLAB/ Simulink are presented and validated. Second, the architecture and the simulation of the designed system that combines the SCs and the battery are shown. The Super capacitors are used as high-power storage devices to smooth the peak power applied to the battery during backup time and to deliver full power during short grid outages. By charging the SCs through the battery at a suitable rate, all impulse power demands would be satisfied by the Super capacitors. Third, extensive simulations are carried out to determine the gain in battery RMS current, the gain in energy losses, the energy efficiency and the elimination rate of surge load power. These four performance parameters are determined by simulation and then analyzed.

Keywords: Capacitors, Simulink, power, storage, energy, supply, energy loss

1. INTRODUCTION

In many industrial sectors, high reliability power supply is required for critical loads. Uninterruptible power supplies (UPS) are used to improve power quality and guarantee the reliability of backup power. During voltage sags or complete interruptions of the power supply, the energy has to be supplied by local energy storage systems (ESS).Conventional ESS for UPS is basically relying on the choice of good lead-acid batteries. However, there are many disadvantages associated with batteries such as low-power density and limited charge/discharge cycles. Moreover, extracting pulsed power instead of average power from the battery can decrease its lifespan. First, the current variations cause voltage transients that can be interpreted by the low voltage detection circuit as a discharged battery creating a premature shutdown. Second, the pulsed currents have a higher RMS value, which might cause increasing battery losses. Third, pulsating currents also reduce greatly the battery runtime. A super capacitor is a double-layer electrochemical capacitor that can store thousand times more energy than a typical capacitor. It shares the characteristics of both batteries and conventional capacitors and has an energy density about 20% of a battery. Moreover, they have almost negligible losses and long lifespan. They can process a large number of charge and discharge cycles (several hundred thousand cycles) compared to only a few thousand cycles for lead-acid batteries, and can supply much higher currents than batteries. Batteries are mostly efficient when used to supply low, reasonably steady power levels. Super capacitors are very effective in storing charge for later use. Their leakage rate and series resistance is quite small. We present a power-sharing method between the super capacitors and the lead-acid battery in 500-kVA rated UPS.Combining super capacitors with battery-based UPS system gives the best of high energy and high-power configurations.

The super capacitors ensure the power impulses and reduce high power demands away from the battery during the 10-min backup time. They also deliver the whole load power during outages lasting less than 10 s. The lifetime of the batteries could then be extended. We focus then our study of the reduction in battery stresses by the use of SCs. We aim at investigating the optimal SCs/battery combination with respect to the cost price of super capacitors. This investigation is threefold; first, super capacitors and battery models are developed then validated using MATLAB/Simulink software.

2. PRESENTATION OF THE STUDIED UPS

2.1 UPS Specification

Its topology is an Online/Double-Conversion system [2]. Before adding the super capacitors (without the dotted part), in the case of interruption of the power grid room Input1," the battery supplies immediately the full power to the inverter during short and long outages. The period of backup time is 10 min and it is the required time for the generator to start up and to reach its rated operation. Referring to Standard EN 50160 [3], grid failures requirements are as follows:

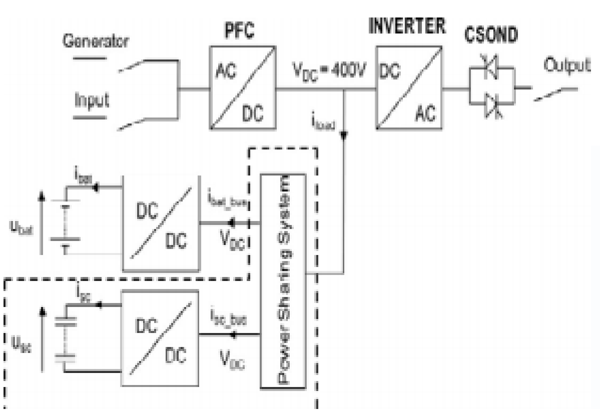


Fig1. Topology of the 500-kVA UPS

1) Short interruptions of voltage supply: (up to 3 min), few tens–few hundred/year, duration 70% of them <1 s;

2) Long interruptions of voltage supply: (longer than 3 min),<10–50/year. We mention that in practice, these requirements are not particularly rigorous for the supplier. On the other hand, the consumer regards the limits given in EN 50160 as requirements that must be guaranteed by the supplier [3].

2.2 Super capacitors Pack Sizing and Modeling

We have chosen that the super capacitors, added as high-power storage devices, must supply the full power Pload= PN during Δt= 10 s, the delivered energy is then estimated to be around 4.8 MJ. The energy Esc stored at the voltage Uscof the SCs pack voltage can be expressed as follows:

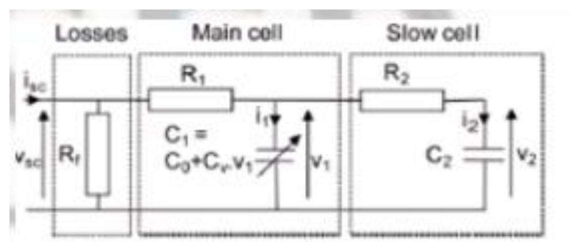
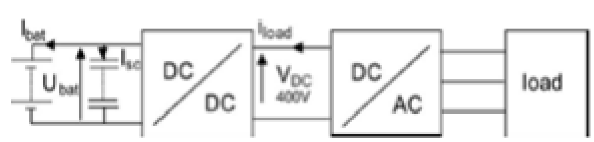


Figure 2: Super-Capacitor simplified circuit: two branches model

3. DESIGN OF BATTERY - SUPER CAPACITORS COMBINATION

3.1 Combination without Control System

First, the battery and the super capacitors have been combined in parallel without control system as shown in Fig.6the dc/dc and the ac/dc converters are supposed to be ideal without losses. The dc-bus voltage VDC is equal to 400 V. The super capacitors are configured as such to have approximately the same total number calculated in the previous section (672 cells) and to



ensure initial voltage

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Figure 3: Parallel combination between SCs and battery

3.2 Controlled SCs-Battery Combination

The control system presented in this section is designed to benefit the fast charge and discharge capability of the super capacitors in order to reduce the battery stresses due to instantaneous power demands. The purpose of the combination between SCs and the battery is to make the SCs supply the power transients and to smooth the high-power demands applied to the battery during autonomous operation [8]. Fig 4 shows the new UPS topology counting the control system for power sharing between SCs and the battery.

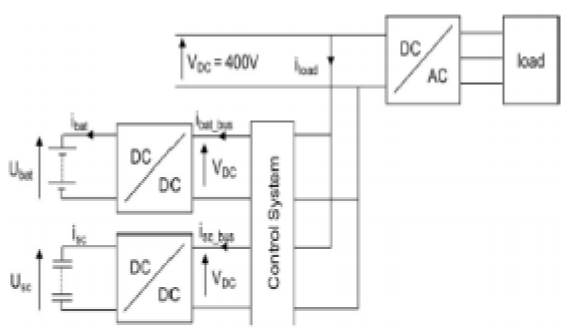

Figure 4: Topology of the controlled SCs/battery Combination

The dc/dc converters are supposed to be without losses and modeled as dc ideal bidirectional transformers. The input currents of the converters associated with the battery and the SCs pack, respectively ibat bus and isc bus are controlled by the power-sharing system. This control system performs according to the SoC of the SCs pack and to the shape of the load power. The load current iload and the load power Pload are distributed to the battery and the SCs according to the principle represented in Fig.6.

4. SYSTEM STUDY

Existing System:

Uninterruptible power supplies (UPS) are used to improve power quality and guarantee the reliability of backup power. During voltage sags or complete interruptions of the power supply, the energy has to be supplied by local energy storage systems (ESS).Conventional ESS for UPS is basically relying on the choice of good lead-acid batteries. However, there are many disadvantages associated with batteries such as low-power density and limited charge/discharge cycles. Moreover, extracting pulsed power instead of average power from the battery can decrease its lifespan.

Proposed System:

Explanation: Super capacitors are a double-layer electrochemical capacitor that can store thousand times more energy than a typical capacitor. It shares the characteristics of both batteries and conventional capacitors and has an energy density about 20% of a battery. Moreover, they have almost negligible losses and long lifespan. They can process a large number of charge and discharge cycles (several hundred thousand cycles) compared to only a few thousand cycles for lead-acid batteries and can supply much higher currents than batteries. Batteries are mostly efficient when used to supply low, reasonably steady power levels. Super capacitors are very effective in storing charge for later use.

5. CONCLUSION

In this paper, the design of a control system that optimizes the battery-super capacitors combination in a 500-kVA rated UPS has been presented. The advantage of having a hybrid energy source for the UPS has been shown. The importance of super capacitors in peak-power smoothing has been elaborated on. The SCs pack and the battery are modeled using MATLAB/Simulink software and then validated. The reduction in battery stresses has been discussed. The super capacitors overcome the power surges and reduce high-power demands away from the battery during the backup time. They also ensure the whole load power during outages lasting less than 10 s. The study of some performance parameters with respect to the cost of the SCs pack has also been presented and an optimal configuration has been found for a filter constant Tau = 2 s, a number of SCs parallel branches Np sc=8, and battery recharge current Ibat charge =400 A. The cost of this system is higher today than pure battery system, however, it should be pointed out that super capacitors undergo intensive development and become more and more available in small size and low price. At the current state, the SCs pack cost is almost triple of the battery pack cost. The system we conceived would be efficient if the battery lifetime is enhanced at least four times. We are undertaking accelerated tests on lead-acid batteries to observe the effect of pulsed loads and smoothed loads on battery wear out process and reliability. Some extensions of this study are undertaken and experimental bench has been set up to carry accelerated tests on lead-acid batteries. We aim to observe the effect of pulsed loads and smoothed loads on battery wear out process and reliability in order to quantify the efficiency of the designed system.

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