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# Wind Integrated Battery/Super Capacitor Combination in UPS

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***Abstract: - A new scheme for improving battery life with the use of supercapacitor is presented in this paper. In addition, wind energy is used to charge the battery and supercapacitor. The objective of the paper is to deliver a backup power output to the grid during a given time interval. Battery and Supercapacitor models have been modelled in Matlab/Simulink and evaluated. Supercapacitors are used to meet the transient load demands during outages.***

***Index Terms*—Battery, Supercapacitor, Wind, DC-DC converter, Inverter.**

## I. INTRODUCTION

Many industrial and residential applications require Uninterruptible Power Supply (UPS). They offer back up power during power shut down. Conventional UPS use lead-acid battery alone as the source. Batteries are efficient when they are used to supply low and steady loads. However batteries possess several disadvantages like low power density, limited charging and discharging cycles etc. Also pulsed or transient power cannot be extracted from the battery as it greatly reduce its run time and lifespan. A super capacitor on the other hand is a double-layer electrochemical capacitor which can store thousand times more energy than typical capacitors. It has the characteristics of batteries and conventional capacitors and also has an energy density about 20% of a battery. Super capacitors have great functionality, longer life and cycling capacity. Batteries can be used to provide backup power for about 10-15 minutes whereas super capacitor can deliver power only for 5-20 seconds. So it is better to combine the battery and SCs for higher power UPS application. The super capacitors and battery models are modelled using MATLAB/Simulink Software. Wind turbine is used to charge the battery and super capacitor whenever there is availability of wind.

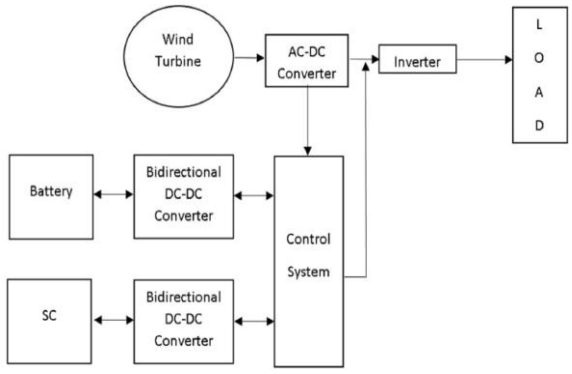


**Fig.1. Block Diagram of Wind integrated Battery/Super capacitor Combination in UPS**

The fig.1 shows the battery-super capacitor combination controlled using a control system. A wind turbine is used to charge the battery and super capacitor. A bidirectional DC-DC converter is being used to acquire the desired level during charging and discharging times.

## II. MODELLING OF WIND TURBINE

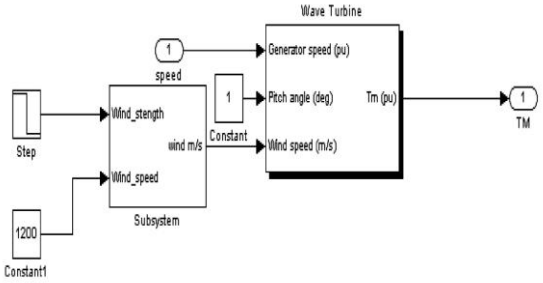


**Fig.2: Simulink Model of Wind Turbine**

The battery is modelled as a system of differential equations. Its input is the battery current $I_{BAT}$ and its outputs are the battery voltage $V_{BAT}$ (equal to the DC-bus voltage $V_{DC}$), temperature and the state of charge (SOC). It is introduced to the electric circuit of the DC-bus as a current controlled voltage source. The battery current $I_{BAT}$ is defined by the storage current $I_{ST}$ and the capacitor current $I_C$ as follows:

$I_{BAT}(t)=I_{ST}(t) - I_C(t)$

with $I_C(t)$ depending on the derivate of $V_{DC}$:

$$Ic(t)=C\frac{dVDC\,(t)}{dt}$$

Equation means that if the capacity C is very large, relatively slow changes in voltage lead to considerable Currents into or from the capacitor [2].

## III. BIDIRECTIONAL DC-DC CONVERTER

A bidirectional four port converter is used here [2]. The boost-type input port can limit the current ripple and this characteristic is helpful to increase the lifetime of Batteries, but the diode connected in series with each MOSFETs makes reversible power flow impossible. To overcome this drawback, two current-fed dual-input bidirectional converters are used.

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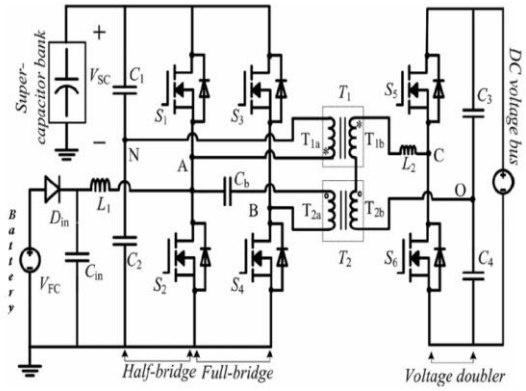


**Fig.3: Bidirectional DC-DC Converter**

As shown in Fig.3, a battery bank as the main input power source is connected to the BHB circuit which can limit the input current ripple; an SC bank as the auxiliary power source can deliver power to the load through the full-bridge circuit. The proposed converter can draw power from these two different dc sources individually and simultaneously.

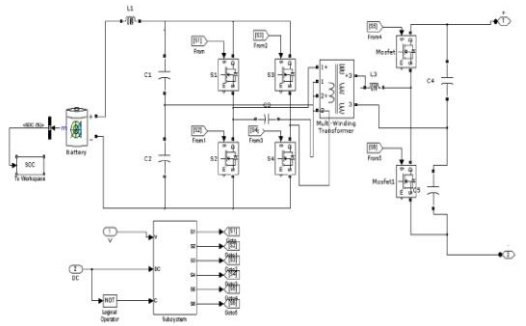

**Fig.4: Simulation model of Battery and DC-DC Converter**

## IV. SIMULATION AND RESULTS

MATLAB/Simulink model of Battery, SC, Bidirectional DC-DC Converter and Wind Turbine was designed. The Simulation model and various output waveforms are shown below.

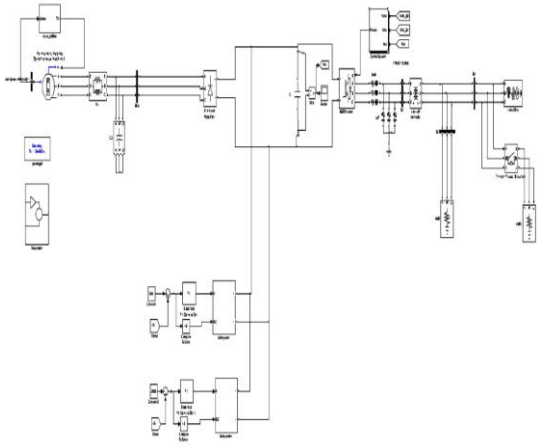

**Fig.5: MATLAB/Simulink Model of Wind Integrated Battery Super capacitor Combination**

The Fig.5 shows the Simulink model of the proposed paper. The output from the battery/SC is inverted using an IGBT Inverter. The output is then fed to a three-phase load.

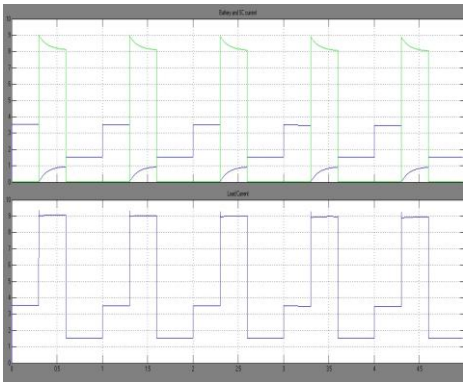

**Fig.6: Battery-Super capacitor without recharge for R load**

The Fig.6 shows the output from battery/SC for R load without any recharge from the wind turbine. The load is simply met by Battery/SC Combination.

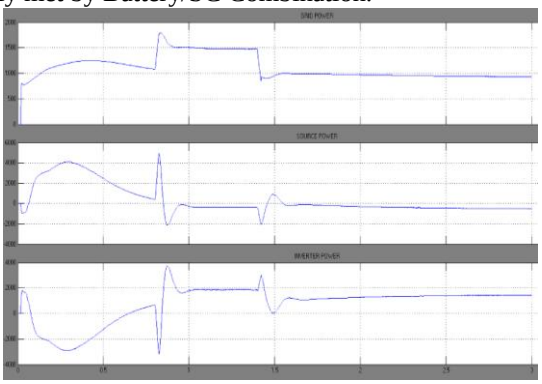

**Fig.7: Simulation Output Waveform**

The Fig. 7 shows the output waveforms of the simulation model designed. The grid power requirement is met by the Battery/SC combination and also with necessary recharging from the wind turbine.

## V. CONCLUSION

In this paper, the design of a control system that optimizes the battery-super capacitors combination in 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. 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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## REFERENCES

[1] Amine Lahyani, Pascal Venet, Abdessattar Guermazi, and Alaeddine Troudi, "Battery/Super capacitors Combination in Uninterruptible Power Supply (UPS)", IEEE Transactions on Power Electronics, Vol. 28, No. 4, April 2013.

[2] Z. Zhang, Z. Ouyang, O. C. Thomsen, and M. A. E. Andersen, "Analysis and design of a bidirectional isolated DC–DC converter for fuel cells and supercapacitors hybrid system," IEEE Trans. Power Electron., vol. 27, no. 2, pp. 848–859, Feb. 2012.

[3] R. A. Dougal, S. Liu, and R. E. White, "Power and life extension of battery–ultra capacitor hybrids," IEEE Trans. Compon. Packag. vol. 25, no. 1, pp. 120–131, Mar. 2002.

[4] A. Rufer and P. Barrade, "A supercapacitor-based energy-storage system for elevators with soft commutated interface," IEEE Trans. Ind. Appl., vol. 38, no. 5, pp. 1151–1159, Sep./Oct. 2002.

[5] J. Chiasson and B. Vairamohan, "Estimating the state of charge of a battery," IEEE Trans. Control Syst. Technol., vol. 13, no. 3, pp. 465–470, May 2005.

[6] B. S. Bhangu, P. Bentley, D. A. Stone, and C. M. Bingham, "Nonlinear observers for predicting state-of-charge and state-of-health of lead-acid batteries for hybrid-electric vehicles," IEEE Trans. Veh. Technol., vol. 54, no. 3, pp. 783–794, May 2005.

[7] D. Rakhmatov, S. Vrudhula, and D. A. Wallach, "A model for battery lifetime analysis for organizing applications on a pocket computer," IEEE Trans. Very Large Scale Integr. (VLSI) Syst., vol. 11, no. 6, pp. 1019–1030, Jun. 2003.

[8] L. Zubieta and R. Bonert, "Characterization of double-layer capacitors for power electronics applications," IEEE Trans. Ind. Appl., vol. 36, no. 1, pp. 199–205, Jan./Feb. 2000.

[9] Sioe Yao Kan, Martin Verwaal and Herman Broekhuizen, Faculty of Industrial Design Engineering, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, the Netherlands, "Battery – Capacitor combinations in photovoltaic powered products", Journal of Power Sources.

[10] S. Pay and Y. Baghzouz, "Effectiveness of Battery-Supercapacitor Combination in Electric Vehicles", 2003 IEEE Bologna Power Tech Conference, June 23th-26th, Bologna, Italy.

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