EFFICIENT ENERGY MANAGEMENT SYSTEM FOR HYBRID ELECTRIC VEHICLE USING SUPERCAPACITOR SIZING METHOD

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Abstract: This paper presents an efficient energy management method that uses hybrid energy storage element for electric vehicle application. When conventional supercapacitor voltage controller (SCVC) is employed it is a challenging task to calculate the size of supercapacitor and filter parameter due to the presence of non linearities. This problem can be overcome by using the method based on supercapacitor energy controller (SCEC). The electric power source is composed of single phase grid as main source and hybrid energy source i.e. battery and supercapacitor as auxiliary source. This method is suitable to calculate the value of supercapacitor and the filter parameter. The proposed control system allocates the high frequency power variation to supercapacitor resulting in increasing the lifetime and the efficiency of the battery. It also maintains the operation of battery and supercapacitor with a state of charge limit. It will provide the efficient operation of hybrid energy storage system (HESS).

***Index Terms* – Energy Management, Hybrid Energy Storage System (HESS), Battery, Supercapacitor, Sizing, State of Charge, Electric Vehicle.**

I. INTRODUCTION

Since the population is increasing the uses of vehicle got increased which in turn increases the consumption of fossil fuels. Nowadays, as the non renewable energy sources are getting depleted there is a shortage of fuel such as petrol, diesel that is used to run the vehicle. The cost of fuel is getting gradually increasing day by day. Thus there is a need for alternative energy source to reduce the consumption of fuel and to improve the energy saving and to protect environmental aspects the hybrid electric vehicle is proposed.

The major disadvantage in the electric vehicle is the availability of energy which is stored in the battery. The stored energy in the battery will not entirely meet the required energy demand of electric vehicles power consumption. The best solution for this problem is to couple battery in combination with supercapacitor which results in high rate capability and good cyclability[1]. The main purpose of using supercapacitor is to improve the battery lifetime by minimizing the greater frequency battery current variation. The variation of high frequency power is diverged to supercapacitor to provide smooth power output [2]. It also provides more energy required than that of battery which fails to do. Hence the supercapacitor can fulfill the extra energy spurt for acceleration of vehicles. Supercapacitors have low resistance hence it offers high power output in a very short time.

Hybrid energy source has two energy sources in which battery is used as first source and supercapacitor is used as second source in order to supply the electric vehicle. The main purpose of hybrid energy storage system is the sizing of energy storage system with the battery in combination with supercapacitor to improve the system power capability in electric vehicle or grid connection [5]. The supercapacitors are used to reduce the energy consumption from grid during peak time. The energy stored in the supercapacitor is used to start and stop the vehicle and energy stored in the battery is used to run the vehicle.

In hybrid energy storage system (HESS), the voltage of supercapacitor tends to vary in a wide range. Thus supercapacitor state of charge (SoC) controller is used to limit the chance of supercapacitor overcharging and over discharging. SoC controller will set the reference amount of power is to be transmitted [3]. SoC plays a vital role in increasing the smoothing capacity of energy storage system. The required amount of energy is delivered by the system to the grid when the state of charge has low value.

Based on the concept of supercapacitor state of charge (SoC) control, The Supercapacitor voltage controllers (SCVC) were employed in filter based HESS. The impact of SCVC on HESS power allocation will not have proper solution because of the presence of nonlinearities [5]. Due to the nonlinearities it is very difficult to formulate the solution of energy storage power component. Hence it is very difficult to analyse the effect of SCVC on HESS and moreover it is a challenging task to calculate the value of supercapacitor and filter parameter.

To overcome the problem of nonlinearities, the supercapacitor energy control (SCEC) is proposed for a high pass filter based HESS. The SCEC parameters have a great impact on power allocation frequency[5]. Thus the effect of SCEC on HESS can be analyzed and it is possible to calculate the value of capacitance and filter parameter.

II. PROBLEM FORMULATION

In this paper, a supercapacitor sizing method and a HESS power allocation parameter selection method are to be studied for a supercapacitor SoC controlled filter based battery-Supercapacitor HESS. First the operation of the filter-based HESS with conventional supercapacitor voltage controller (SCVC) is analyzed and the challenges posed by the SCVC on the supercapacitor sizing and HESS parameter selection are presented. Then, a supercapacitor energy controller (SCEC) is proposed for a high-pass filter based HESS in order to reduce the issues related to the nonlinearity of the SCVC. Effect of the SCEC on the filter-based

HESS power allocation strategy is extensively analyzed. It is shown that the SCEC parameters have a significant effect on the power allocation frequency. A method to calculate the required high-pass filter and SCEC parameters along with the required supercapacitor size to meet specific HESS requirements is to be presented.

III. PROPOSED METHODOLOGY

The proposed system consists of two double-loop controllers which are used to control the left-hand-side and right-hand-side boost converter legs as shown in Figure 1. Each double-loop controller consists of an outer voltage control loop and two inner current control loops. One for the battery connected boost converter leg and another one for the supercapacitor connected boost converter leg.

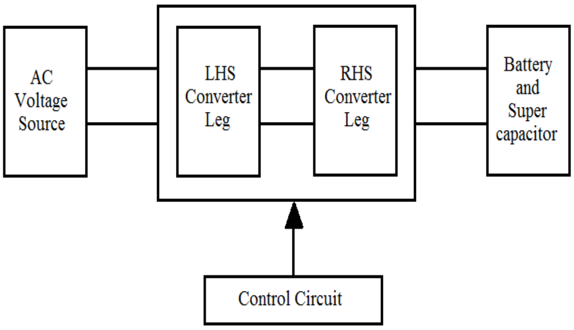

Figure 1: Block diagram of double-loop controller

The modified outer voltage control loop for the left-hand side boost converter legs with the SCEC is shown in Figure 2.

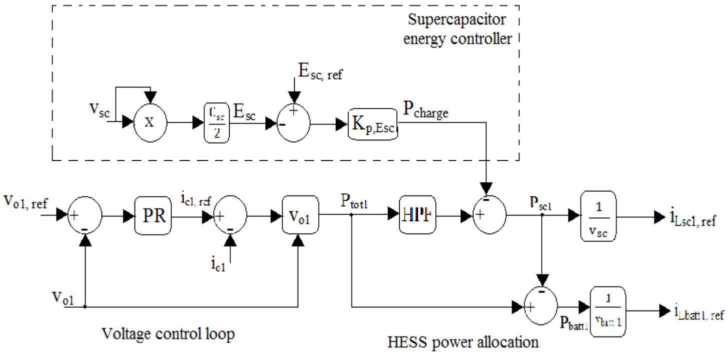

Figure 2: Control loop of SCEC method

Instead of controlling the supercapacitor voltage Vsc, the energy stored in the supercapacitor Esc is controlled around a reference energy level Esc,r. The stored energy in the supercapacitor Esc is calculated as [5]

$$E_{SC} = \frac{1}{2} C_{SC}\, v^2_{SC} \quad (1)$$

The transfer function between the supercapacitor energy change dEsc(s) and the HESS output power $P_{HESS}(s)$ can be found as

$$H_{dEsc} = \frac{d_{Esc}(s)}{P_{HESS}(s)} = \frac{as}{as^2+(1+2aK_{P,Esc})s+2K_{P,Esc}}\,\frac{1}{\eta} \quad (2)$$

In the considered boost-inverter-based HESS, Vsc,min is determined by the maximum possible gain of the converter while Vsc,max has to satisfy

$$v_{sc,max} \le V_{dc} - \frac{V_0}{2} \quad (3)$$

Then, the required supercapacitor value can be obtained as

$$0.5E_{sc,\,u} = \max(|dE_{sc}|) \quad (4)$$

$$C_{sc} = \frac{4\max(|dEsc|)}{v^2_{sc,max} - v^2_{sc,min}} \quad (5)$$

IV. SIMULATION RESULTS AND DISCUSSION

A. Simulink Model

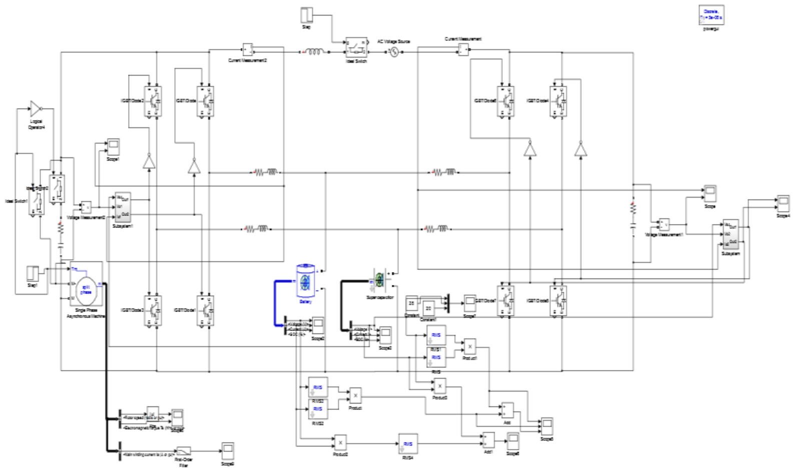

Figure 3 : Simulink model of SCEC

The simulink model of Supercapacitor energy controller (SCEC) is as shown in Figure 3. Initially, the switch1 is in on position and switch 2 is in off position. When the switch 1 is in the on position then the grid is connected to the circuit. Switch 2 in off position implies that the electric vehicle is at rest. The energy from the grid is used to charge the battery and supercapacitor till the time of 0.5sec.

After 0.5sec the switch 1 is in off position and switch 2 is in on position. Since the switch 1 is in off position the grid will get disconnected from the circuit. Switch 2 in on position implies that the electric vehicle is connected to the circuit which in turn implies that the vehicle starts moving.

The behavior of battery and supercapacitor when the hybrid electric vehicle is connected is as shown in the below simulation results.

B. Simulation Results of Battery

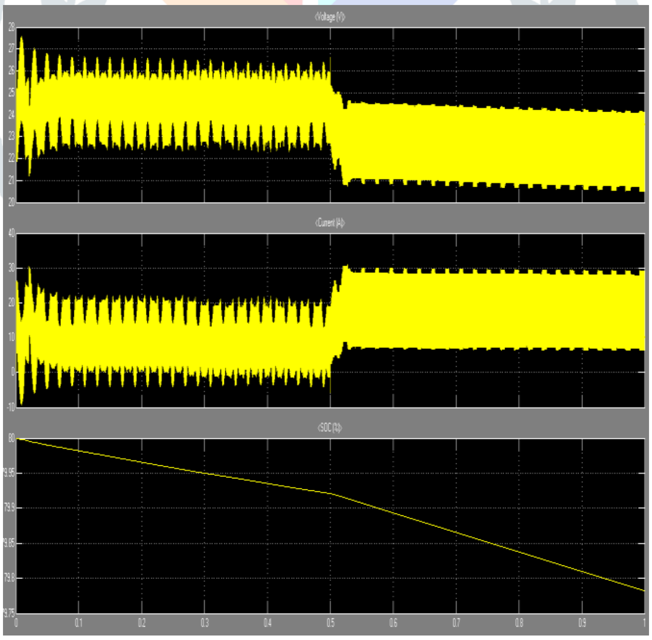

Figure 4: Voltage, Current and SoC of battery

The battery is charged by using single phase grid till t = 0.5sec. During this time the vehicle is disconnected from the circuit i.e., the vehicle is said to be at rest. After 0.5sec the vehicle starts moving. From the Figure 4 it can be see that the voltage starts decreasing and the current starts increasing to a positive value.

The state of charge (SoC) of battery gradually increases when the vehicle is at rest and it rapidly starts decreasing when the vehicle starts moving.

C. Simulation Results of Supercapacitor

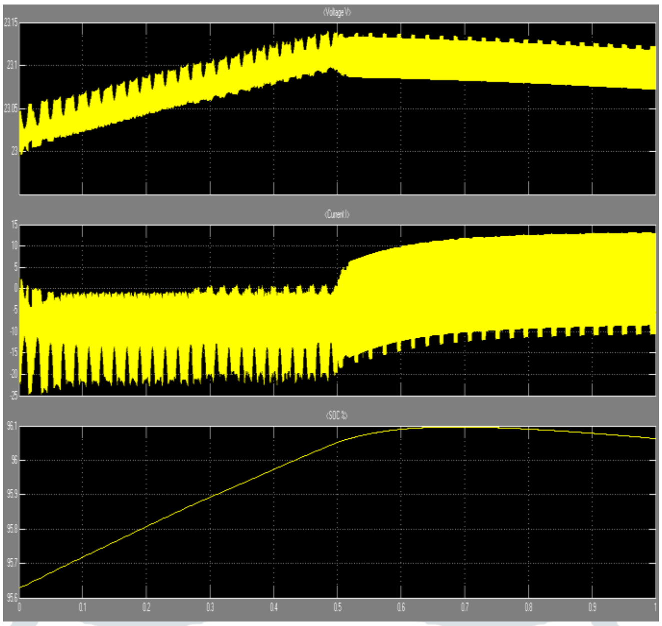

Figure 5: Voltage, Current and SoC of supercapacitor

As the vehicle starts to move at 0.5 sec the voltage of supercapacitor decreases slowly compare to the battery voltage. The supercapacitor current slightly starts to increase above the initial value.

The state of charge of Supercapacitor holds the charge so that it will not allow the charges to go suddenly to zero. From this discussion we can say that the energy stored in supercapacitor will not decrease fastly as compare to the state of charge of battery.

D. Simulation Results of P_{HESS}

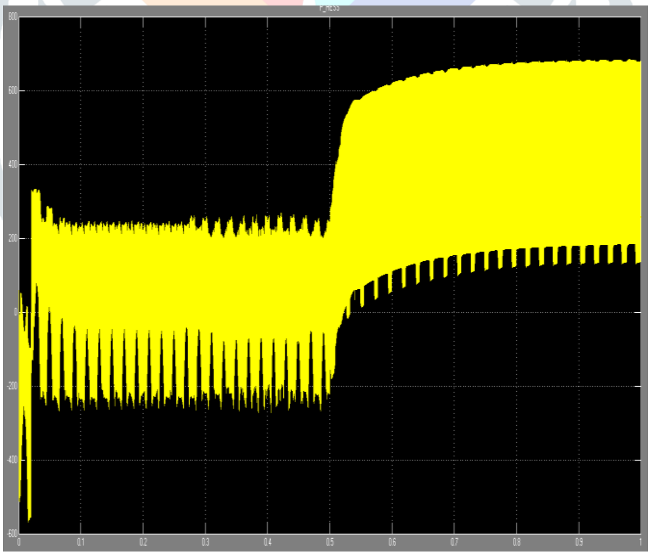

Figure 6: Power of hybrid energy storage system

Electric vehicle with only battery cannot meet the energy requirement in require of high power demand. To overcome this issue electric vehicle is combined with supercapacitor HESS. This improves the performance of working condition of battery which is connected to hybrid electric vehicle. The results are as shown in the Figure 6

E. Supercapacitor Charging and Discharge Limit

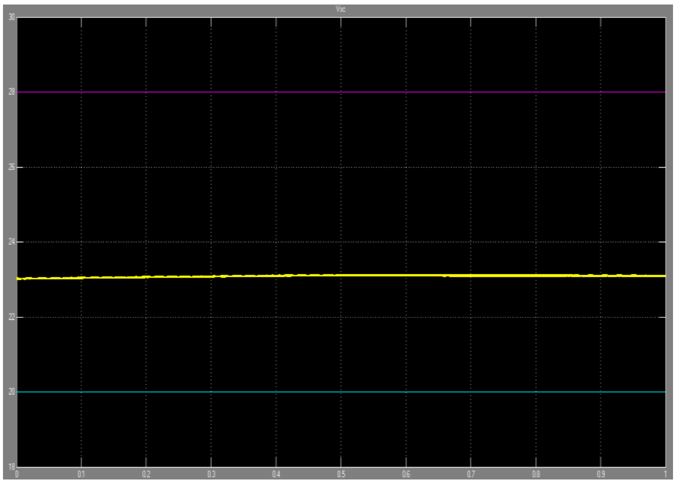

Figure 7: Supercapacitor charging and discharging Voltage limit

The maximum and minimum voltage considered to be are 28V and 20V respectively.

From Figure 7 we can say that the supercapacitor is charging and discharging within a given voltage limits. Thus there are no chances of overcharging and over discharging.

F. Power of Supercapacitor, Battery and The Total Power

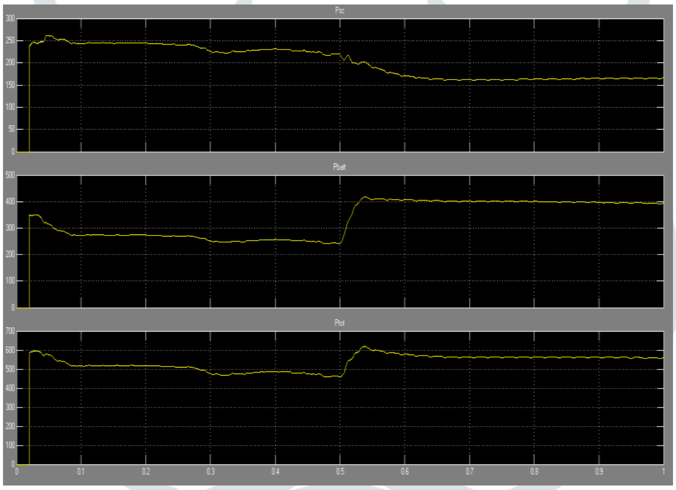

Figure 8: Supercapacitor power, battery power and total power

When the vehicle start moving the power of supercapacitor decreases and the battery power increases. Which means the energy of supercapacitor is used and this lead to the increase in the battery lifetime. Thus the total power is maintained which is as shown in Figure 8.

V. CONCLUSIONS

The paper represent the operation of SCEC on the filter based HESS analysis which helps to overcome the challenges of SCVC. In hybrid electric vehicle the operation of battery storage system is coordinated with a supercapacitor to improve the performance of battery. Battery in combination with supercapacitor will overcome the disadvantages of single battery technology. In coming era the hybrid electric vehicle plays an important role has it is practically more efficient, low pollution vehicle. This will contribute the reduction in consumption of fuel and green house effect. We can conclude that the greater efficiency and the conservation rate are very much on the anvil today's energy deficit world.

REFERENCES

[1]Damith Buddika Wickramasinghe Abeywardana, BranislavHredzak, Vassilios G. Agelidis, and Georgios D. Demetriades, "Supercapacitor Sizing Method for EnergyControlled Filter-Based Hybrid Energy Storage Systems"

[2]J. Cao and A. Emadi,"A new battery/ultracapacitor hybrid energy storage system for electric, hybrid, and plug-in hybrid electric vehicles," IEEE Trans. Power Electron., vol. 27, no. 1, pp. 122–132, Jan. 2012.

[3]B. Hredzak, V. G. Agelidis, and G. D. Demetriades, "A low complexity control system for a hybrid DC power source based on ultracapacitor-lead acid battery configuration," IEEE Trans. Power Electron., vol. 29, no. 6, pp. 2882–2891, Jun. 2014.

[4]D. B. W. Abeywardana, B. Hredzak, and V. G. Agelidis, "Single-phase grid-connected LiFePO4 battery/supercapacitor hybrid energy storage system with interleaved boost inverter," IEEE Trans. Power Electron., vol. 30, no. 10, pp. 5591–5604, Oct. 2015.

[5]N. Mendis, K. M. Muttaqi, and S. Perera, "Management of low- and high-frequency power components in demand-generation fluctuations of a DFIG-based wind-dominated RAPS system using hybrid energy storage," IEEE Trans. Ind. Appl., vol. 50, no. 3, pp. 2258–2268, May/Jun. 2014.

[6]S. S. G. Jayasinghe, D. M. Vilathgamuwa, and U. K. Madawala, "Diode- clamped threelevel inverter-based battery/supercapacitor direct integration scheme for renewable energy systems, "IEEE Trans. Power Electron., vol. 26, no. 12, pp. 3720–3729, Dec. 2011.

[7]B. Hredzak, V. G. Agelidis, and J. Minsoo, "A model predictive control system for a hybrid battery-ultracapacitor power source," IEEE Trans. Power Electron., vol. 29, no. 3, pp. 1469–1479, Mar. 2014.

[8]O. Laldin, M. Moshirvaziri, and O. Trescases, "Predictive algorithm for optimizing power flow in hybrid ultracapacitor/battery storage systems for light electric vehicles," IEEE Trans. Power Electron., vol. 28, no. 8, pp. 3882–3895, Aug. 2013.

[9] J. Moreno, M.E. Ortuzar and J.W. Dixon,"Energy management system for a hybrid electric vehicle, using ultracapacitors and neutral network", IEEE Trans. Ind. Electron, Vol.53, no. 2, Apr.2006.

[10]M. Zandi, A. Payman, J. P. Martin, S. Pierfederici, B. Davat, and F. Meibody Tabar, "Energy management of fuel cell/supercapacitor/battery power source for electric vehicular application," IEEE Trans. Feb 2011.

[11] J. Shen, S. Dusmez, and A. Khaligh," Optimization of sizing and battery cycle life in battery/ultracapacitor hybrid energy storage system for electric vehicle application," IEEE Trans. Nov 2014.

[12] R. Esteves Araujo, R. De Castro, C. Pinto, P. Melo and D. Freitas," Combined sizing and energy management in EVs with batteries and supercapacitor," IEEE Trans. Sep 2014.

[13]M. A. Tankari, M. B. Camara, B. Dakyo, and G. Lefebvre, "Use of ultracapacitors and batteries for efficient energy management in wind diesel hybrid system," IEEE Trans. Apr. 2013

[14]R. Esteves Araujo,R. DeCastro, C.Pinto, P.Melo, and D.Freitas,"Combined sizing and energy management in EVs with batteries and supercapacitors," IEEE Trans. Sep. 2014.

[15]F. Ongaro, S. Saggini, and P. Mattavelli, "Li-ion battery–supercapacitor hybrid storage system for a long lifetime, photovoltaic-based wireless sensor network," IEEE Trans. Sep. 2012.

[16]E. Schaltz, A. Khaligh, and P. O. Rasmussen, "Influence of battery/ ultracapacitor energy storage sizing on battery life time in a fuel cell hybrid electric vehicle,"IEEE Trans. Veh. Technol., Oct. 2009.

[17]A. Kuperman, M. Mellincovsky, C. Lerman, I. Aharon, N. Reichbach, G.Geula etal.,"Supercapacitor sizing based on desired power and energy performance," IEEE Trans. Power Electron, 2014.