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State of Charge Based Comparative Assessment of Energy Storage Systems

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ABSTRACT

The purpose of storing energy is to capture it and make it available for the future demand. The Energy storage system (ESS) is not the new thing but the hybridisation in the storage systems is the upcoming trend. For the hybrid vehicles, the hybrid energy storage systems are also configured. The ESS is the upcoming concept in transportation and here in this paper various potential ESS are discussed. The attributes of different ESS are required accordingly for different applications. Any specific Systems cannot be able to fulfil all the required demands of any Hybrid Electric Vehicle (HEV). There are some hybrid ESS are also available including combination of Battery and supercapacitor, Ultracapacitor and fuel cell etc. Some parameters like energy, power, demand etc are examined for different systems and their potential need is scrutinized. The working principle of many ESS is also explained in this paper so that it will be easier to find the potential systems. Finally, an overview of hybrid energy storage systems HESS is also given in this paper. HESS is the coupling of two or more energy storage technologies so that their operating characteristics can eb added and become helpful in better management of energy for HEV. There is a model used for finding the results of the analysis which is made by omitting the predefined relationship of ESS, in which its capacity is unpredicted.

Keywords: *ESS- Energy Storage Systems; Storage Method; HESS- Hybrid Energy Storage Systems; Battery; Ultracapacitor; Fuel Cell; Energy; Power.*

1.0 Introduction

The energy storage is the well known system and we are utilizing this property from early 1800 [1].Basically, the goal of energy storage is to collect it and provide it for use at a later time. The environmental effects of fossil fuels and various energy storage system solutions should be prioritized for the sustainable use of resources and the developing environmental concerns. Energy storage has been used to solve the intermittent nature of wind and solar power, which has the added benefit of lowering the demand for backup power plants [1][2]. The desire for a more dynamic and cleaner grid has greatly raised the demand for the development of new energy storage systems, which has caused the policy makers to enhance their view on considering updated solutions. If we examine how other resources, such as solar and wind, produce energy, it is evident that these are intermittent sources that depend on climatic variations and other environmental factors [3]. The ESS must be able to satisfy the power and energy requirement of drive cycles. The batteries and the ultracapacitors are the main ESS now – a days but they have their own pros and cons. Some

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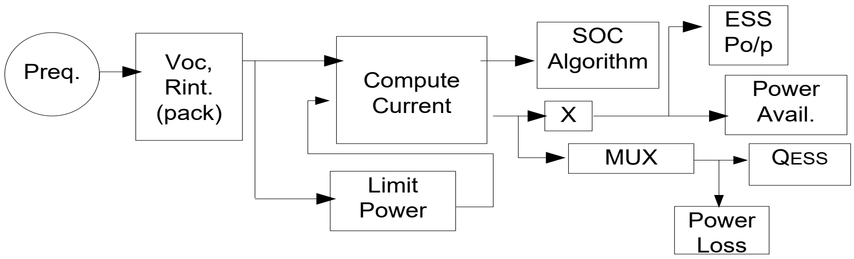
operating parameters like lifetime, charge cycle, state of charge, discharge cycle, current capacity, depth of charge, efficiency, operating temperature are taken into account for specifying the usage of Energy storage systems for the various applications.

2.0 System Configuration

The schematic diagram shows the configuration of the systems in which charge reservoir denotes the battery pack and the remaining charge is considered as the circuit parameter. The charge which ESS contains is considered as the constant value and the coulombic efficiency is the factor which affects battery replenishment [10]. The greatest amount of power that the equivalent circuit or the controller can tolerate under the conditions of the minimum voltage needs is the only amount that can be given by the battery.

Figure 1: Schematic Block Diagram of ESS Model



For the modelled vehicle, Energy Storage systems is denoted by ESS which have the onboard energy . During modelling, the charge is conserved, the configuration takes into account the circuit's properties, and the ESS is applied to the minimum voltage limit. With the requirement of SOC, the ESS is modelled in order to fullfill The output power requirements . R_{int} and V_{oc} are the OCV and Internal resistance denoting the SOC function which is linear [11].

The power available is max. and is concerned to parameters obtained as-

$$P = V_{bus} \times \frac{V_{oc} - V_{bus}}{R} \quad \ldots(4)$$

Where V_{bus} is $V_{OC}/2$

The KVL in the power expression is written as -

$$\frac{P}{I} = V_{OC} - (R \times I) \quad \ldots(5)$$

After multiplying I -

$$P = (V_{OC} \times I) - RI^2 \quad \ldots(6)$$

$$RI^2 - (V_{OC} \times I) + P = 0 \quad \ldots(7)$$

The lesser value of voltage is required and it is for equal amount of power. The current value is expressed by not exceeding voltage value-

$$I = \frac{V_{OC} - V_{max}}{R} \quad \ldots(8)$$

In advisor the SOC algorithm determines the residual capacity in Amp-hrs charge unit. The value is approximated by a series of steps, and during this estimation, the columbic efficiency and maximum capacity will remain functions of temperature [13][14]. Non-Zero value of rated current is used for starting value of SOC.

$$SOC = \frac{C\max - Ah}{C\max} \quad \dots (9)$$

The SOC is now calculated based on the power bus specifications, and the output has the available power. [15].

Calculating SOC for different instants of time-

$$SOC(t) = SOCi + \frac{1}{3600}\frac{\eta bat(i(t),T)}{Cap(T)}\int_{t0}^{t} i(t)dt \quad \dots (10)$$

3.0 Result and Discussion

Based on the model, the results of the analysis are presented and compared with the help of the below given table . The vehicle parameters taken for the analysis are also listed.

Table 1: Vehicle Parameters for the analysis

Component	Parameter	Value
Vehicle	Veh_Cargo mass	136 kg
	Veh_Glider mass	592 kg
ESS	Li-ion	260
	VRLA	310
	Ultra-cap	40
	Ni-Mh	330
	Ni-Cad	162
	Ni-Zn	305

The following figures shows the different ESS characteristics having their SOC variation with the internal resistance. The four different technologies including Li-ion, Lead Acid , Nickel Metal Hydride and Nickel Cadmium are shown for their SOC(State of Charge)variation in the figures 2(a) to 2(d) respectively.

Figure 2.a

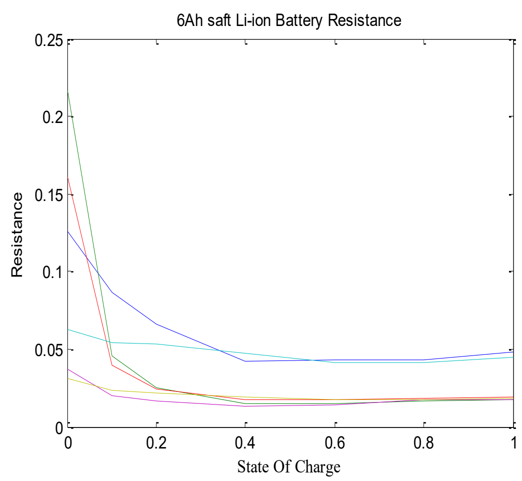


Figure 2.b

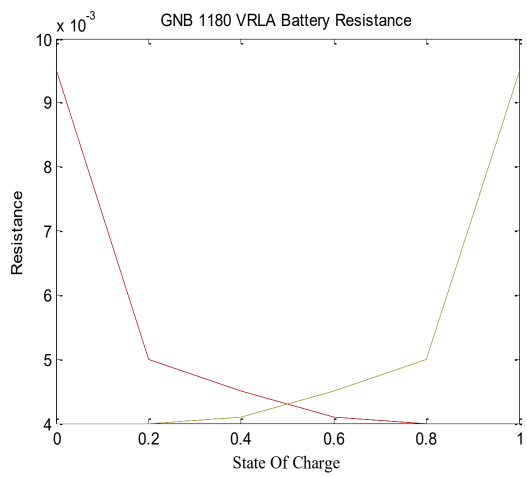


Figure 2.c

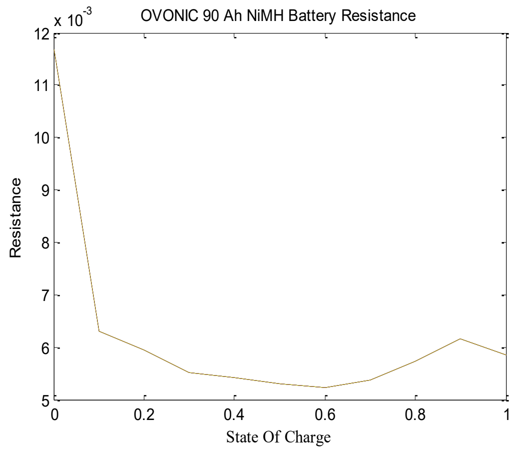
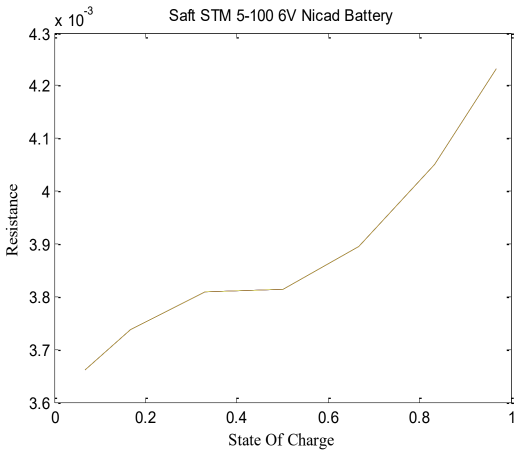


Figure 2.d



In these figures it is shown that for nickel-based batteries, larger changes have been noticed. The Ni-Mh battery shows the inverse relationship of SOC and internal resistance. It Infers that higher performance of battery cannot be achieved just after the full charge. For nickel cadmium, there is lower value of internal resistance and for Ni-Mh it is higher. For better understanding a table having specifications listed in the table are shown below-

Table 2: ESS Specifications

Parameters/ESS	VRLA	Li-ion	Ni-MH	NiCad	Ni-Zn
Voltage (Max)	16	12	15.65	7	14.2
Voltage (Min)	10	6.2	9.15	5.88	6.63
Capacitive module	665	796	832	772	1178
Effective res(off)	0.642	7.84	1.60	0.842	3.210
Effective res(on)	0.365	1.14	0.52	0.35	0.40

The Nickel based batteries are more complex for charging as compared to Lithium or lead acid batteries . During a round trip , Li-ion battery lost approx. 5 % of energy i.e giving around 95 % efficiency .

4.0 Conclusion

HESS technology is very interesting as well as promising and it is helpful in short- or long-term fluctuations. The vehicle is dependent on energy storage systems thus it is very crucial to select best ESS according to the required application. The conventional lead acid battery is proved for the highly efficient and reliable storage system with minimal maintenance requirement. The lithium-ion battery has higher storage capacity as well as high horse power demand. High rate of charging is the requirement of Ni cadmium battery and it also have lower internal resistance with higher discharge cycle . But the longer life time is the advantageous feature in this system. The Li-ion battery has very popular attributes like it have longer lifetime, weight effective , faster recharging process etc which makes it best choice . But after analyzing all other ESS we can say that if one ESS is better in some way then other have some additional features. Hence any ESS can not replace other one completely which makes the HESS as the effective and better way for the effective automotive technology.

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