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Mixed Solutions of Electrical Energy Storage

The paper presents electrical energy storage solutions using electric batteries and supercapacitors powered from photovoltaic solar modules, with possibilities of application in electric and hybrid vehicles. The future development of electric cars depends largely on electrical energy storage solutions that should provide a higher range of road and operating parameters comparable to those equipped with internal combustion engines, that eliminate pollution.

***Keywords**: supercapacitors, electric battery, photovoltaic modules, fuel cells*

1. Introduction

A current problem in the use of electricity is the difficulties faced in its storage, so as to be used when and where needed. Solutions are known on large scale, in the parable of the pumped storage hydropower plants in which electrical energy is stored by converting hydraulic energy potential or those represented by storing electricity in batteries, electric fuel cell or the use of supercapacitors [4].

Electric batteries are based on electrochemical conversion that is a process of direct conversion of chemical free energy, stored in some active materials, into electricity. Capacitor of last generations – supercapacitors, ar also an alternative of electrical storage, having high specific capacity and power.

The fuel cells convert directly the chemical energy into electric electricity. Those devices provide power as long they are supplied with fuel. As fuel, often consider is hydrogen and as oxidant, oxygen. The electricity production process through fuel cells, is exactly the reverse of electrolysis. The fuel two gaseous components of the fuel cells, hydrogen and oxygen, unite to form water and release electrons, which form the electric current. A fuel cell generates only a low voltage and therefore, to achieve a desired higher voltage, serial registration of more cells is necessary. Fuel cells operate in a similar way to electrical batteries, only instead of periodically recharged electric current source; they must be continuously supplied with hydrogen and oxygen gas [6].

One widespread fuel type is that with proton exchange membrane (PEFMC) - polymer electrolyte membrane fuel cell, which is efficient and uses as oxidizing gas, the atmospheric oxygen instead of pure oxygen. The electrolyte consists of a proton exchange membrane made of sulfated polymer. Hydrogen attracts the attention as a source for electricity generation and thus as fuel for electric vehicles.

2. Electric tandem battery - supercapacitor

The capacitor, in double layer structure, is the basis of building supercapacitors batteries. Figure 1 presents the structure of a double layer capacitor, comprising of: two electrodes on an activated charcoal placed in an organic electrolyte and electrically isolated by a separator membrane [3].

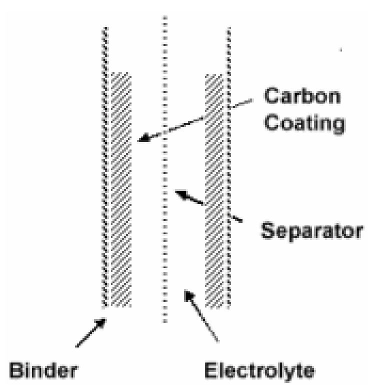

Figure 1. Structure of a supercapacitor

The distance between the regions with opposite electric charges being very little, a capacity of hundreds of Farazi can be realize. The electric model of the double layer capacitor is shown in Figure 2, where R is composed of inner resistance of the electrolyte, consist of the contact and the parallel resistance.

The problem of determining the maximum power stored in supercapacitor and that will be debited on the resistance R, imposes:

$$\frac{dP}{dR} = 0 \text{ and } P = Ri^2 = R\left(\frac{Uc}{R}\right)^2 \quad (1)$$

Therefore at r = R, the maximum power that the capacitor can give, will be:

$$P_{\max} = \frac{Uc^2}{4R} \quad (2)$$

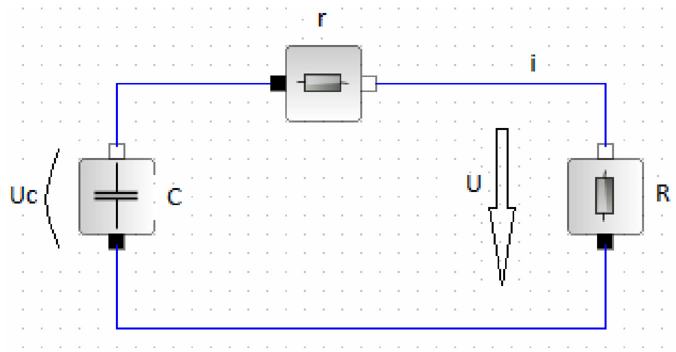

Figure 2. Electric model of the capacitor

The energy stored in capacitors with an capacity *C*, is:

$$E_0 = \frac{1}{2} C U_C = 2C \cdot R \cdot P \max \tag{3}$$

To the resistance R, the transferred energy results from:

$$\Delta E(t) = \frac{1}{2} C \left[U^2(t) - U_0^2 \right] \tag{4}$$

The initial energy depends on the square of the initial voltage U_0 from the capacitors terminals; the remained energy in the capacitor is:

$$E_c = \frac{1}{2} C U^2(t) \tag{5}$$

where U(t) is the voltage on the moment t.

The capacitor discharges in time:

$$T_d = C(r + R) \tag{6}$$

The initial energy of the capacitor at maximum Power (r = R), is:

$$E_0 = \frac{1}{2} C U_0^2 \tag{7}$$

and the useful energy, on the resistance R, is:

$$E_R = \frac{E_0}{2} = \frac{1}{4} C U_0^2 \tag{8}$$

The capacitors efficiency is

$$\eta = \frac{E_R}{E_0} = 0.5 \tag{9}$$

Cause of global low energies, the super capacitors can be parallel connected with batteries, figure 3, each of them in series in a proper number.

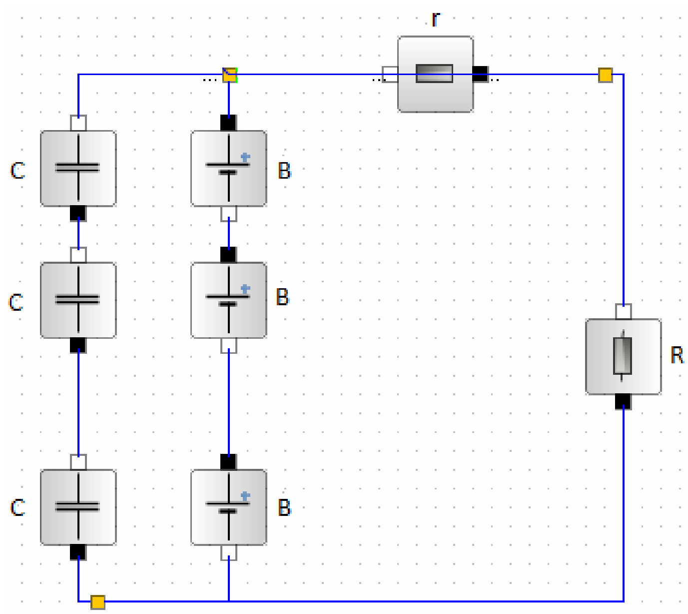

Figure 3. Systems of batteries - super capacitors

Usually, batteries and capacitors are loaded from the electric grid, 220 / 380V, 50 Hz, but in the last time it was proved as advantageous solutions with photo-voltaic modules.

3. Solar – photovoltaic systems for battery charging

The main problem consists in controlling the battery - super capacitor system, so that the operation takes place in the maximum power point (MPP). In this way the efficiency can be optimized and a minimum time in batteries charging. The automation system has to assure the functioning in the MPP, characterize through U_M, I_M, irrespective of the meteorological conditions, figure 4, [2].

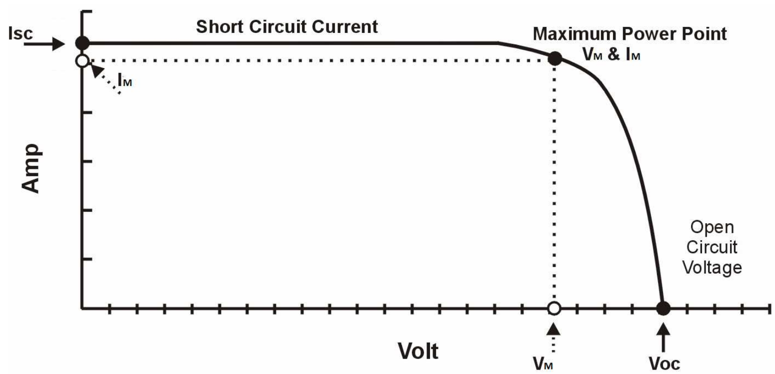

Figure 4. UI Characteristics of the PV module and MPP

The automation scheme that assures the MPP, is presented in figure 5, [5].

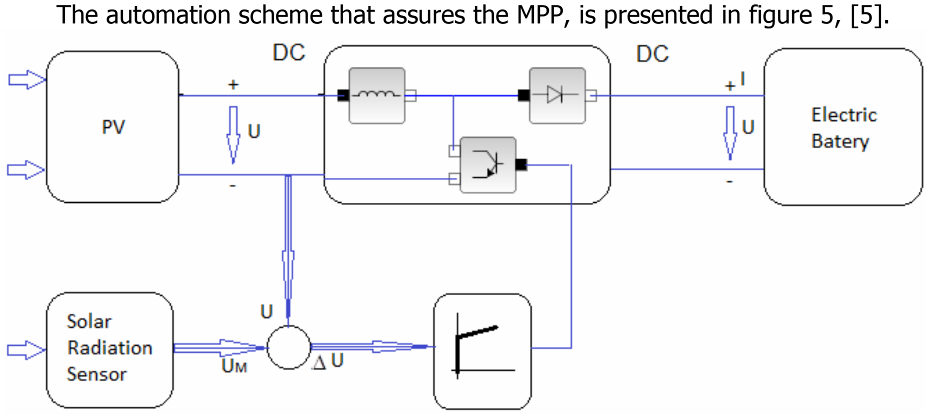

Figure 5. Control scheme in MPP

Through the solar radiation sensor, the voltage corresponding to the MPP is known. Comparing the prescribed voltage U_M with the momentary one U, the difference ΔU that enters in the PI controller and through the DC converter assures the functioning in MPP and loads, in the quickest time, the electric battery.

We may consider a proportional controller, described by the equation:

$$\Delta\alpha = K \cdot \Delta U = K(U_M - U) \tag{10}$$

where U_M is the prescribed size and U the adjustable size.

The controller with a PI controlling law, is described by the expression:

$$\Delta\alpha = K_P \cdot \Delta U + K_I \int_0^{\zeta} \Delta U dt \tag{11}$$

For each element of control scheme in figure 5, a model for the components is developed. The photovoltaic system, considering an simplified linear mode, we will have:

$$U = U_0 + \frac{(U_M - U)}{I_M} I \qquad (12)$$

where U_0 is the no-load voltage of the solar modules; U – momentary voltage, current value; I – cutting current of the solar module, current value; U_M, I_M – corresponding values to the MPP point estimated by the solar radiation sensor.

The DC-DC converter through which the prescribed voltage U_M is obtained, making the transitions from the voltage U to the battery voltage U_A, a linear dependence between the input size U of the DC-DC converter and his output size U_A is considered, as:

$$U = K_{CC} U_A \qquad (13)$$

The output power of the solar will be stored in the electric battery, as equal:

$$U \cdot I = U_A \cdot I_A \qquad (14)$$

A generally battery U – I characteristics is described in figure 6, [2].

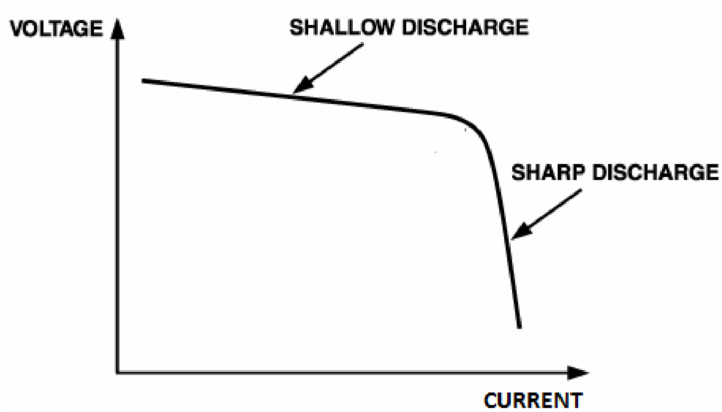

Figure 6. U – I characteristics of the batteries

$U_A = U_M$ – constant can be considered in the normal functioning area of the batteries.

To achieve the mentioned desiderates it is important to use solar modules with sun tracking systems, because the captured energy is higher than o fix positioned solar module, and the necessary time of battery charging is reduced. Figure 7 presents comparative a fix positioned solar module and a mobile one that follows the sun [1].

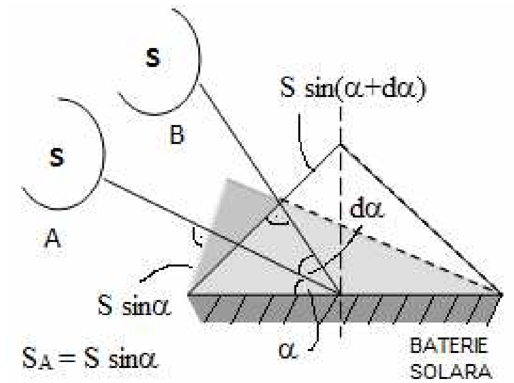

Figure 7. Comparison between fix and mobile solar module

The perpendicular surface on the sunlight has the value, in case A, $S_A = S\cos\alpha$. In case B, accordingly to the angle *α+dα*, the surface is $S_B = S\sin(\alpha + d\alpha) = S(\sin\alpha + d\alpha\cos\alpha)$.

Considering the apparent movement of the sun in the time interval T, we can write $\omega T = \pi$ and so $d\alpha = \omega dt = \frac{\pi}{T}dt$.

The captured energy in the time interval *dt*, at the angle α, will be:

$$dW_1 = K_S S_A dt \cong K_S S\sin\alpha dt\ , \tag{15}$$

where KS is the solar constant (1kW/m^2).

The total energy:

$$W_1 = 2\int_o^{T/2} K_S S\sin\alpha dt = 0.63 K_S ST \tag{16}$$

For an solar module with tracking system, the total energy is: $W_2 = K_S ST$, meaning with 37% more captured energy with an mobile system than a fix one, being so favorably for the accumulators loading applications.

3. Conclusion

Considering the specific energy, expressed in Wh/kg, as an essential comparison criterion, especially in the applications where the accumulators mass and volume are important (electric transport), Li – Ion batteries, having the highest specific energy (approximately 8 time higher then acid with Pb batteries), are required. But nevertheless, systems with PbO(H_2SO_4)Pb have a sufficiently high voltage and the experience in their use, makes them widely used in present too [5]. The charging time of supercapacitors is very low but also, the specific energy is small. Tandem systems using batteries - supercapacitors have a lower mass and gauge, than if the two systems were used separately. The battery and supercapacitor loading process using solar modules is favorable especially in regions with high solar potential.

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