On Pulse Charging of Lead-Acid Batteries

1. Introduction

There are claims that pulse charging of lead-acid batteries from the bemf of certain magnetic motors is an overunity process, the batteries can be charged while the motor is doing useful mechanical work and the net energy gained (mechanical work plus stored energy in the battery) is in excess of that supplied to the motor. The overunity is usually ascribed to the magnetic motor, but this paper examines the possibility that the overunity comes from the pulse charging process. If this proves to be the case there is the potential for developing batteries that contain solid-state self-powered pulse generators that keep the battery topped up while actually delivering power to a load.

2. Battery Electro-Chemistry

2.1. Discharge Process

The positive electrode is lead-oxide PbO_2 and the negative electrode Pb while the electrolyte is dilute sulphuric acid H_2SO_4 plus H_2O. At the positive electrode the discharge process is

$$PbO_2 + 3H^+ + HSO_4^- + 2e \rightarrow PbSO_4 + 2H_2O. \qquad (1)$$

The process consumes two electrons supplied by the external current flow, three H^+ ions and one HSO_4^- ion taken from the sulphuric acid, to convert one PbO_2 molecule into one $PbSO_4$ molecule and two water molecules. At the negative electrode the chemical equation is

$$Pb + HSO_4^- \rightarrow PbSO_4 + H^+ + 2e \qquad (2)$$

Here one $HSO4^-$ ion supplied from the sulphuric acid is consumed to convert one Pb molecule into one $PbSO_4$ molecule releasing one H^+ ion and two electrons that are passed to the external circuit. These processes are illustrated in figure 1.

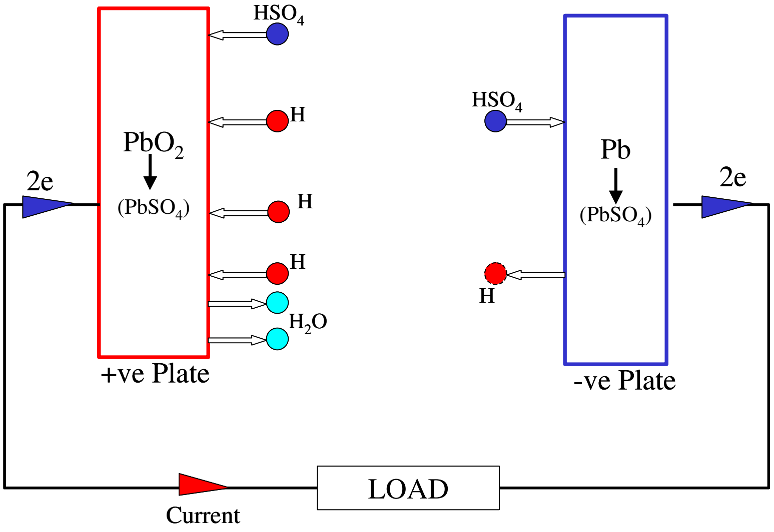

Figure 1. Molecular Discharge Process

Adding the internal ion flow yield the situation as shown in figure 2.

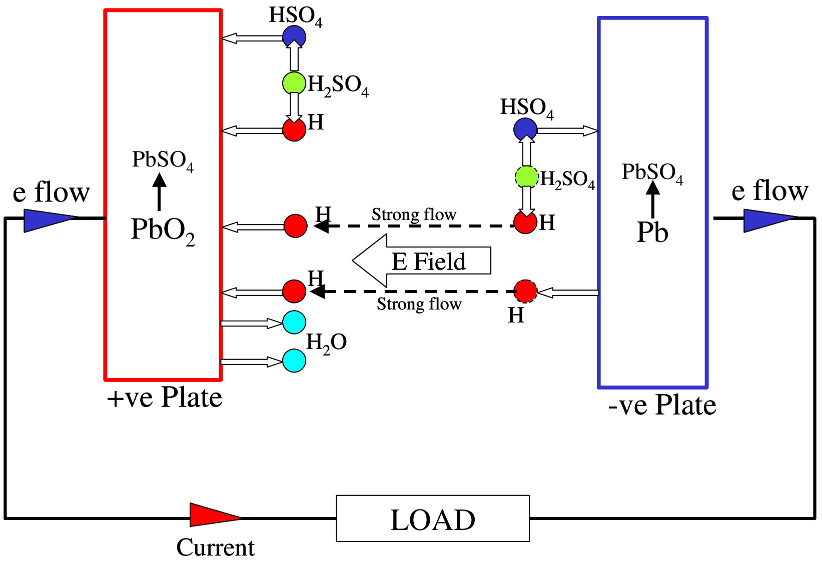

Figure 2. Continuous Discharge Process

The absorption of a HSO_4^- ion at the surface of the negative electrode leaves a free H^+ ion that, along with the other H^+ ion released, gets dragged by the electric field towards the other plate. There we see those H+ ions being absorbed and converted to water. The net result is a dilution of the acid as the acid molecules get converted to water.

2.2. Charging Process

Here both the positive and the negative electrode are lead sulphate $PbSO_4$ and the charging process is simply the reverse of (1) and (2). At the positive plate

$$PbSO_4 + 2H_2O \rightarrow PbO_2 + 3H^+ + HSO_4^- + 2e \qquad (3)$$

and at the negative plate

$$PbSO_4 + H^+ + 2e \rightarrow Pb + HSO_4^- \qquad (4)$$

as illustrated in figure 3.

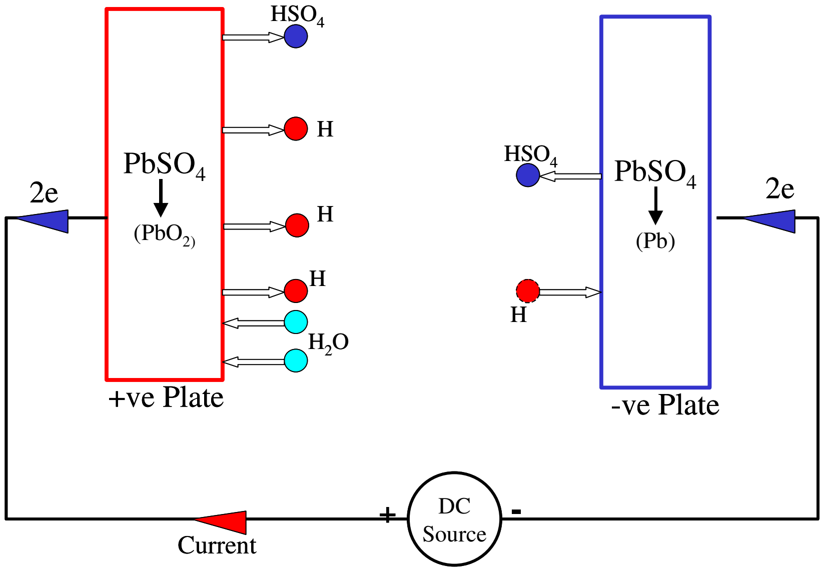

Figure 3. Molecular Charge Process

Adding the ion flow to figure 3 gives the picture shown in figure 4.

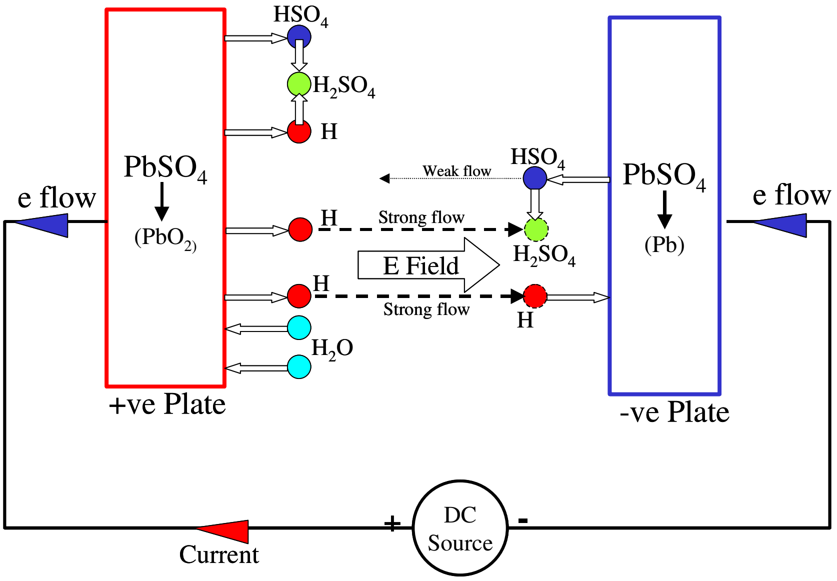

Figure 4. Continuous Charge Process

Here we see water molecules absorbed at the positive plate while sulphuric acid is created at both the positive and negative plates.

3. Discussion

It is clear from the chemical formulae that in the charging process the rate of electrode "manufacture" (molecules per second) is directly related to the current (electrons per second). Hence the battery charge is directly proportional to the time integral of the current. Since that current is associated with the nominal cell voltage V_{cell} it is clear that the energy W_{stored} stored by the charge process is given by

$$W_{stored} = V_{cell} \int i.dt \qquad (5)$$

That equation runs in reverse for the discharge yielding the current×time product available from the stored energy, hence the usual expression in terms of ampere-hours. If no charging current flows then no stored energy is created, so the possibility of pulse charging by placing a voltage across the battery while virtually zero current flows (hence zero power) due to ion inertia is not feasible. In fact it can be shown that current will flow even though ions have not travelled from plate to plate, see figure 5.

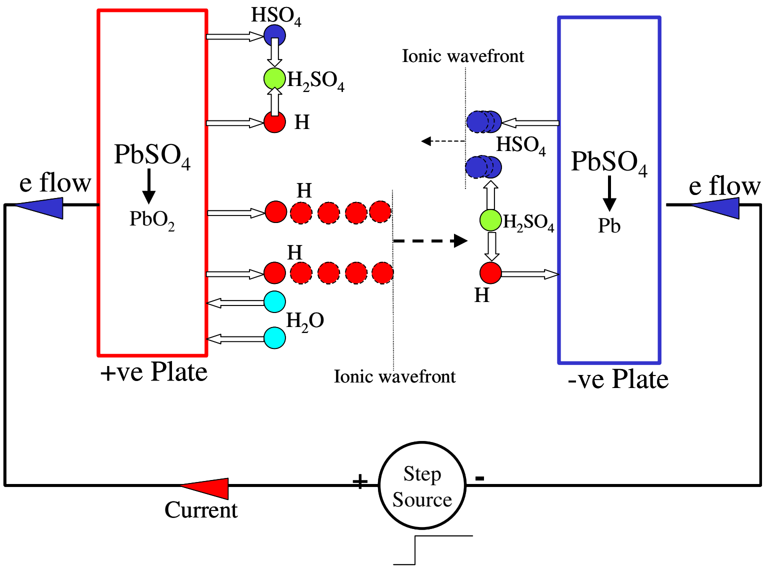

Figure 5. Application of a Step Waveform

This shows a time shortly after the initial step of a step charging waveform. H^+ ions from the positive electrode have not yet reached the opposite side, but because of their relative low mobility they have travelled a further distance than the HSO_4^- ions leaving the negative electrode. During this time current is continually flowing from the charging circuit to supply the ions in this ionic delay line.

If we are to look for an overunity charging process we need, not volts with zero current but current with zero volts. That realization leads to the possibility described in the next section, using the capacitance *C* of the electrodes and supplying current that obeys

$$\int i.dt = C \cdot V_{pulse} \qquad (6)$$

where V_{pulse} is the change in voltage across *C*.

4. A Possible Overunity Charging Scheme

The electrical capacitance *C* between the electrodes although small is not negligible. The very design of the electrodes (which maximises electrode area while minimising the separation) also maximises capacitance, and the liquid dielectric has a high relative permittivity *K* (e.g. water has *K*=80). So the possibility exists to supply a fast rise-time pulse where the capacitance gets charged during that initial rise, but the time scale is too short for any chemical reaction to take place. This could be done by transformer coupling, applying the voltage step in series with the load circuit, as shown in figure 6.

This requires a filter following the transformer as shown so as to prevent the pulses from reaching the load. Then the voltage pulse of amplitude V_{pulse} sits on top of the cell voltage V_{cell} and during the rise time of the pulse we obtain the current impulse (5) into the cell. That supplies energy of value

$$W = 0 \cdot 5C(V_{pulse})^2 \qquad (7)$$

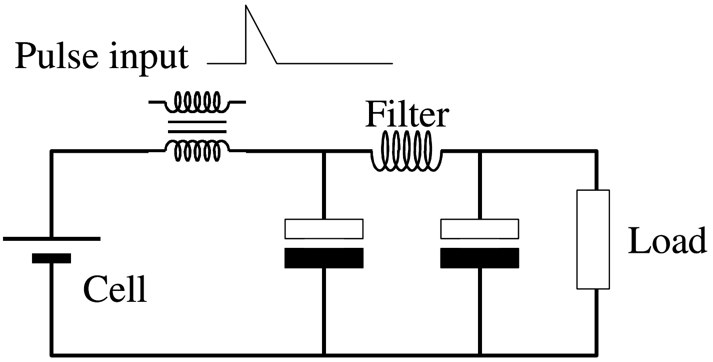

Figure 6. Pulse Charging Circuit

We then have the situation shown in figure 7 where the charge is on the surface of the electrodes but no chemical reaction has yet taken place.

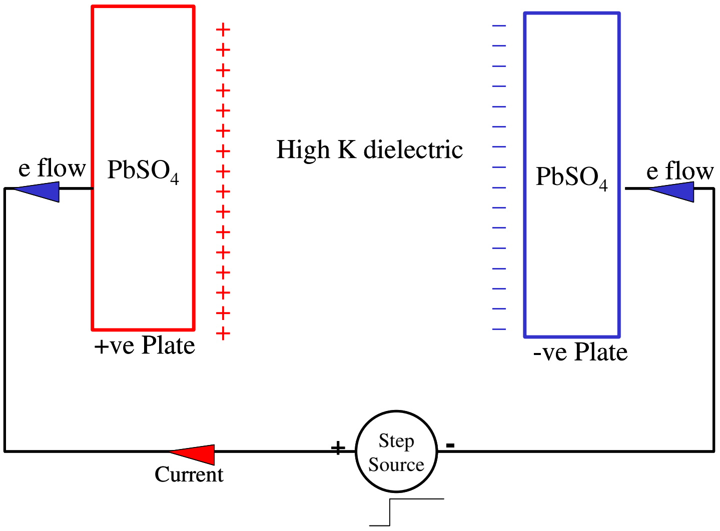

Figure 7. Cell Capacitance Charged

Those surface charges will now allow the slower reactions to take place, converting the surface charge into ions and also converting the electrode molecules into “charged” versions. If we terminate the pulse at the point where that conversion is complete, we can stop the otherwise conventional charging process where the pulse is supplying the ionic current. Thus the pulse must meet two conditions

(a) rise time faster than the chemical reaction time and
(b) pulse width no greater than that reaction time.

We now have the situation where the input pulse energy is given by (7) while increase in stored energy of the electrodes is given by (5). From (5) and (6) we obtain for that increase in stored energy

$$W_{stored} = C \cdot V_{pulse} \cdot V_{cell} \qquad (8)$$

which is greater than (7), thus indicating overunity. Taking the ratio of (8) to (7) we obtain the COP as

$$COP = 2\frac{V_{cell}}{V_{pulse}} \qquad (9)$$

This can be a significant value so it is worth exploring this possibility. However we should be cognisant of the fact that when the pulse is terminated the reducing voltage creates a reverse current thus extracting energy from the cell. The hope is that since this voltage reduction can occur while the initial electronic charge is being converted into chemical energy, the inherent change of cell impedance during that conversion will automatically reduce the voltage so the reverse effect will be minimised.

5. Conclusion

There exists the possibility of overunity charging of the lead-acid battery by having charging pulses that exhibit a fast rise time and an optimum pulse width. Current flows into the battery during the voltage rise to charge the inter-electrode capacitance, that time being too short for any chemical reactions to take place. That value of stored electronic charge is then converted into chemical energy and the pulse is slowly terminated during this process. The stored chemical energy appears to be greater than the electrical energy supplied. It is recommended that this possibility be researched.