CONTRIBUTION IN A REGULATION METHOD OF BATTERY CURRENT IN ELECTRIC VEHICLES. APPLICATION IN A RACING SAIL SHIP.

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Abstract

In the most automatic systems, the regulation loop constitutes the primeval element of a good system stability and accuracy with which its output is supplied. Forcing a physical parameter to some sort of value requires a good control algorithm, which must be convergent and accurate at the same time.

In the case of electric vehicles, where it is advisable to have a constant current of charge, an adequate current control method has been developed. The algorithm is established in a microcontroller. The control system has been then utilized in laboratory in a test bench simulating fast charge and discharge cycles of a nickel cadmium battery. Experimental results obtained are exposed. The regulation system has been employed in a racing ship to control the charge current in automatic and equalization states of the duty battery. In both cases, it has demonstrated that it is well adapted to those kinds of applications.

Introduction

In the racing ship, the electric system is formed by energy generators (generally constituted by alternators, wind engines and solar generators), battery of accumulators and consumers [1]. The main reason for the battery existence in the electric system is that it is the only way to moderate the intermittent character of working generators. An economical use of the battery is possible if the treatment thereof is proper [1,2,3].

The algorithm chosen for this case employs a constant current for the equalization and automatic charge states which is, in fact, very suitable with this kind of application. To have a precise constant current, an adaptable algorithm of current control seems to be necessary.

Current control with digressive steps

The excitation command of the alternator is a variable which has a positive value applied to a digital to analog converter (DAC). It is declared as a signed integer in the program because the compiler can not perform division with non signed integers. This command must be coded in only 12 bits, from 0 to 4095, corresponding to a positive output voltage of the DAC, situating between 0 and 2.5 V. The particularity of this command is to be always positive, even if the regulation chain can change sign. Only the sign of the command variation (Δ(DAC)) can change with the error sign.

The measuring amplifier, which follows the DAC, applies to the MOS transistor constituting the excitation command a potential difference between his gate and his source (Vgs) varying between 3 V and 3 V + 2.5 V dispatched in differential mode between the output voltage (Vout) and the reference voltage (Vref) of the amplifier. This offset of 3 V permits to center the variation range of the command signal sent to the DAC between the useful scale of Vgs, and to improve the resolution of this voltage. The transistor input present a threshold of 3.2 V. Under this voltage, the drain current is approximately equal to zero.

The command gamut of the alternator excitation current is estimated between 0 and 4A, which corresponds to a gate voltage variation of 1 V (Vgs from 3.5 V to 4.5 V). This implies that the DAC command range is from 819 to 2457 which corresponds to a variation scale of 1638 corrected, in this project, to 1500 to simplify calculus. With a step corresponding to a current value of 0.1A, we stir alternator with a current varying between 0 and 150 A.

To stabilize the regulation loop, we choose a command with variable step rather than a command working with dichotomy method. In fact, the latter has the advantage of speed, but this is probably what we must avoid to have a stable loop. The command with variable steps permits easily to introduce a time constant. With an interruption period of 100 ms, the 1500 steps of the command zone are achieved on 150 s, which, probably, cover all author time constants of the loop.

However it is a very long time. Therefore, it is recommended to work with steps rather than unity to reduce this time length.

Table 1 and figure 1 gives variations of the equivalent current and the total command time with the step.

Step	Equivalent current of one step (A)	Total command time (s)	Annotations
200	20	0.75	very fast
100	10	1.5	fast but can be suitable
50	5	3	appropriate
20	2	7.5	slow
10	1	15	very slow
1	0.1	150	useless

Table 1 : Variations of the total command time with the step value.

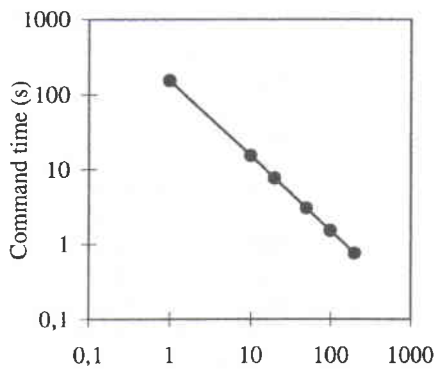

Figure 1 : Command time variation with the step value of the DAC

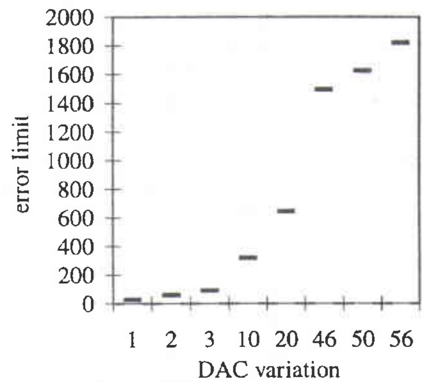

Figure 2 : Low and High error limit variation with the DAC error. a = 49, b = 1450, c = 1597.

A command step of a DAC corresponds approximately to 1 or 2 steps of an analog to digital converter (ADC) measurement step. Thus, if we send the two steps to the DAC, the loop can't be stable because the gain of the closed loop becomes equal to 2 in this level. It is so necessary to divide measurement variations by 2, which can be done with the loop error.

Stability must be then tested experimentally by diversifying the division factor.

The step variation is chosen linearly between the two extreme points of regulation with non-signed values which are easier to treat.

Low point :

$\Delta(DAC) = 1$ ($\Delta i = 0.1$ A to 0.2 A) for error = 3. (1)

High point :

$\Delta(DAC) = 50$ ($\Delta i = 6$ A) for $error_{max} = 1600$ (2)

We have to resolve an equation of a straight line which passes from the two points described above. We obtain :

$$\frac{\Delta(DAC)-1}{error-3}=\frac{50-1}{1600-3} \quad (3)$$

Consequently

$$\Delta(DAC)=\frac{(49*error)+1450}{1597} \quad (4)$$

Generally

$$\Delta(DAC)=\frac{(a*error)+b}{c} \quad (5)$$

Where a, b, and c are three coefficients which are stocked in a non-volatile memory to modify them easily with any control of monitor.

Inversely we calculate the error function of the variations.

$$error=\frac{(c*\Delta(DAC))-b}{a} \quad (6)$$

Table 2 and Figure 2 describe error variations with Δ(DAC).

Δ(DAC)	error	Commentary
0 0 0	0 1 (0.1 A) 2 (0.2 A)	not one command of DAC between 0 and 0.2 A
1 1	3 (0.3 A) 35 (3.5 A)	step of +- 0.1 A low limit step of +- 0.1 A high limit
2 2	36 (3.6 A) 67 (6.7 A)	step of +- 0.2 A low limit step of +- 0.2 A high limit
3 3	68 (6.8 A) 100 (10,0 A)	step of +- 0.3 A low limit high limit
10	296(29.6 A)	low limit
20	622(62.2 A)	low limit
46 46	1469 (146.9 A) 1501 (150.1 A)	low limit high limit
50 50	1600 (160 A) 1632 (163.2 A)	low limit high limit
56	1800 (180.0 A).	low limit

Table 2 : regulation zone variation with the command variation and the resulting error, a = 49, b = 1450, and c = 1597.

The finely regulation with ± 0.1 A is carried out in the interval situated between 0.3 A and 3.5 A. The non-regulation zone is of ± 0.2 A which is a small value.

Author hypothesis considers that the lower limit of error corresponding to Δ(DAC) = 1 is of 10 (= 1.0 A) and the error is equal to 1600 (= 160 A) for the higher point corresponding to Δ(DAC) = 50. This implies :

$$\Delta(DAC) = \frac{(49 * \text{error}) + 1100}{1590} \qquad (7)$$

$$\text{error} = \frac{(1590 * \Delta(DAC)) - 1100}{49} \qquad (8)$$

Comparing with general equations (5) and (6) we have a = 49, b = 1100, and c = 1590.

The non-regulation zone can be extended from 0 to 0.9 A, which is better, and the finely regulation zone with Δ(DAC) = 1 can be extended from 1 A to 4.2 A which is very suitable to our application.

Practical experience

This method is implemented in an automatic test system of fast charge and discharge cycles of a nickel cadmium battery in laboratory. The convergence error limit (CEL) is determined experimentally.

The regulation is achieved around an hysterics loop situated between I_m - CEL and I_m + CEL where I_m is the mean current of charge or discharge. A good stability and an acceptable convergence time are observed with this method.

Figure 3 describes the test bench mounted in laboratory. The figures 4-(a) 4-(b) and 4-(c) illustrate shapes of charge and discharge currents obtained in this test bench with this method.

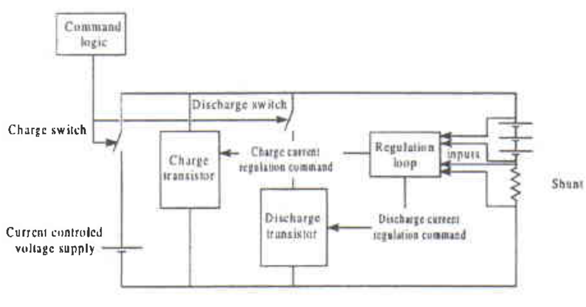

Figure 3 : Synoptic of the test bench mounted in laboratory.

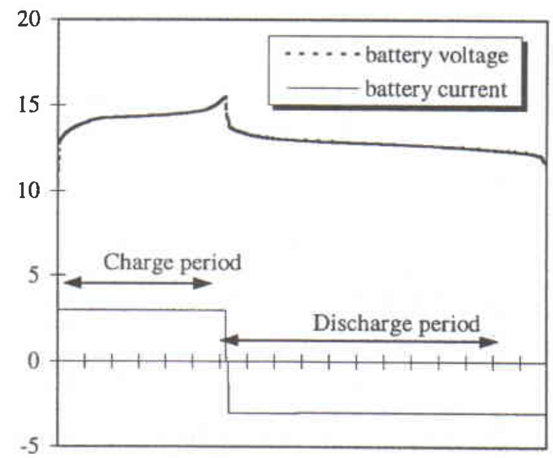

Figure 4-(a) : Battery current and voltage obtained during charge and discharge periods

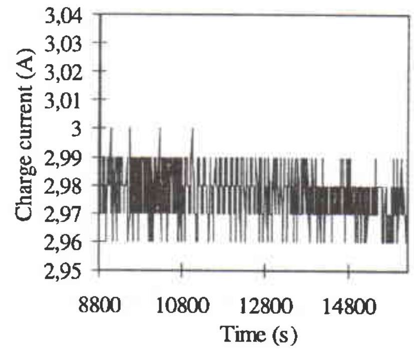

Figure 4-(b) : Detailed shape of charge current

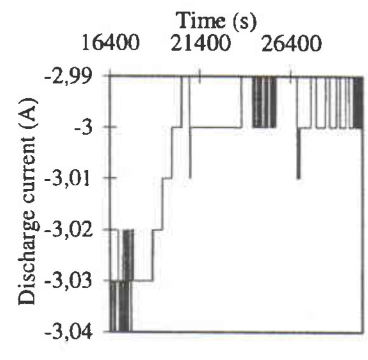

Figure 4-(c) : Detailed shape of discharge current

Conclusion

The control method with digressive steps has been implemented in a racing ship which has undertaken the world round course in four months. The deduction of charge current values has proved that the method converges very well and consequently the global system is very stable.

With a method, defining the absolute error values as inputs, we hope to bring a faster convergence to the system, which is very important in such applications.

References

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