Journal of the University of Chemical Technology and Metallurgy, 42, 3, 2007, 321-324

NON - DISTURBANCE PULSE WIDTH MODULATION CONTROL OF HEATERS

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Received 05 May 2007
Accepted 12 August 2007

ABSTRACT

An algorithm for power control of a great number of electrical consumers by pulse width modulation (PWM) is offered, which is unaffected by the disturbances, typical of the frequent commutation of electrical loads. This is achieved through an appropriate displacement of the pulses and the pauses for each consumer in such a way, that each turn off of a consumer is combined with a turn on of other consumers with the same power. The total consumed power will be constant in each moment and the behavior of the total ensemble of consumers is the same as that of a constant load. The power, supplied to each consumer, is controlled through the pulse / pause relation and can be changed by the operator at every moment. The algorithm, set in the software, causes a displacement of the total sequence of the moments of switching over after each change of the set powers, in order to keep the load constant.

Keywords: pulse width modulation (PWM), commutation disturbances.

INTRODUCTION

The pulse width modulation (PWM) is related to a periodical switch of electrical consumers, most often by semiconductor devices. The modern technical designs use the so-called "zero crossing technique" (switching when the voltage crosses the zero value), by which the high frequency disturbances generated and transmitted in the power net will be practically zero. Nevertheless, the switching on and off of consumers causes other negative phenomena in the power supply system and is sanctioned in most countries by limiting the switch frequency or by higher price of the electrical energy under such working conditions.

In many cases, especially in the processing of polymer materials, a great number of unified electrical heaters with the same power are controlled by the PWM mode. The sequence period of the pulses is within the limits from 0,5 to 2 seconds (a longer period can cause undesirable temperature fluctuations), which makes these consumers liable to sanctions.

In the existing technical developments a palliative solution of this problem is offered, by associating the consumers in small groups, which are switching on or off simultaneously, but in a moment, differing from those for the other groups. [1].

The aim of this paper is to find a way and develop an algorithm for the control of a great number of consumers, which leads to the establishment of a constant electrical load, or a load with minimal variation.

ANALYSES

The concept of this control is each switching off of an electrical load to be followed by a switching on of electrical load with the same power. Since the switching on and off occurs at zero crossing of the voltage, i.e. practically at the same moment, it is equal to a permanent connected consumer. This will be possible through a suitable dislocation in time of the pulses and pauses of all consumers, keeping the same ratios between them. The exchange of the connected consumers resembles a relay-race, which allows this method to be named a “relay method”.

The next analyses are based on the assumption, that the pulse width / pause width ratio depends on the power required for each consumer and is determined by technological considerations. The repetition period depends on the permissible temperature fluctuations and the thermal inertia and is also set in advance.

The effect of this control will depend on the average value of the power of the total ensemble of heaters. If it is proportional to the power of a single consumer, the effect will be100 %, because the same number of consumers will operate at every moment and will alternate as a relay-race. If the average value is not proportional to the single power, the total power will show a small variation in the frame of a cycle, that is equal to the power of a single consumer. In order to evaluate the minimum of this variation, we will refer to an example of a vacuum forming installation for plastic packages, which contains ca. 100 – 160 heaters. Hence, the power variation will be below 1 %.

In the digital systems the power rate of the consumers varies from zero (pause without pulse) to a maximum value (pulse without pause), while within these limits the rate can take only discrete values, corresponding to discrete values of the pulse width at a constant period (pulse plus pause). If the number of discrete values is D, and the period is T, the time interval, separating two adjacent values will be T / (D-1), because D-1 steps exist between D levels. The pulse width will be fixed by the number of steps (intervals), during which the consumer is turned on for a period T. Most often D=101 is used, which defines power levels from 0 to 100 % of the maximal power with an 1 % step.

Initially, we suppose, that all N consumers have the same power P_0. If the average value of the power is P_A, the number:

$$K = P_A / P_0$$

will be the number of the simultaneously operating consumers. In the optimal case, K can be an integer, whereupon the total power will be constant and no disturbance will appear. In the general case, one of the consumers must be switched on or off once during the period, which, for a large number N, is a minimal disturbance.

A mode of “relay” alternation of the consumers is illustrated in Fig. 1. The time and the period T are shown on the x-axis. On the y-axis are placed simultaneously operating rows of relay switchings. Their number is (K)+1, where (K) is the integer of K. Their vertical position is of no account. One of the rows (here shown as the top one) is not full, because, in the general case, K is not an integer.

The arrows in Fig. 1 are related to the algorithm of the pulse arrangement. The moments of switching on and off of each consumer should be stored in the memory. More precisely, for each discrete moment the consumers, which should be switched on or off should be recorded and identified. If the commutation is made by an address mode, their addresses should be recorded and stored.

The most rational mode for a fast execution of the commutations is to have the addresses, arranged in 2N consecutive cells of the memory in the sequence of their commutation. This number is determined by the fact, that each consumer is present two times– for switching on and off. An additional bit, or another mode for determination of the type of commutation is necessary. The sequence of the simultaneously commutated consumers is not important.

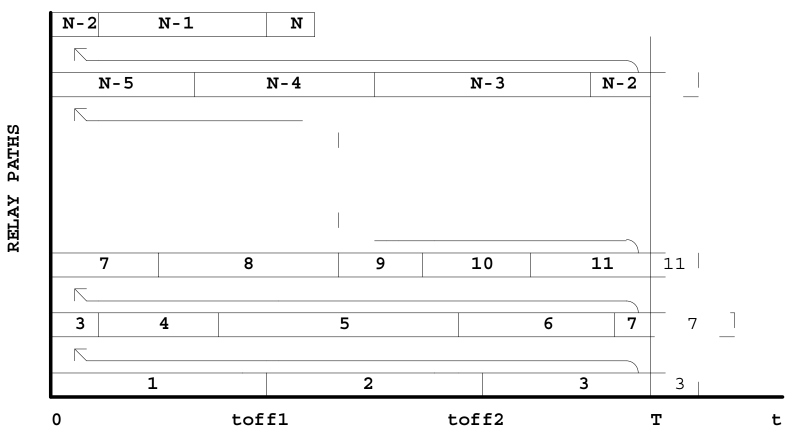

Fig. 1. A mode of “relay” alternation of the consumers.

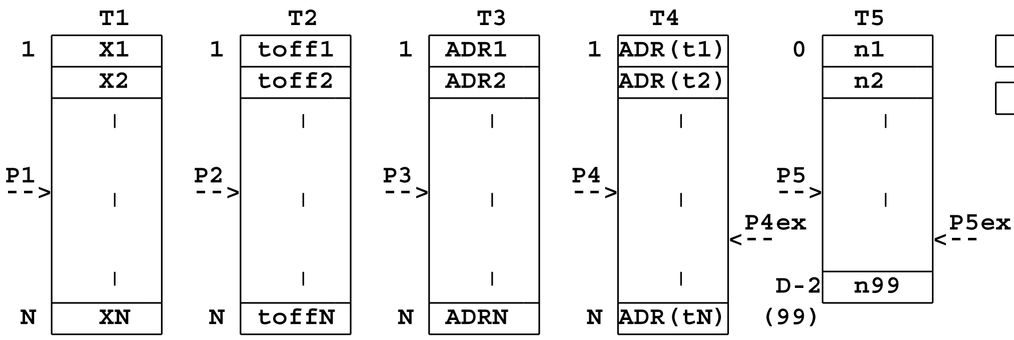

Fig. 2. The rows of cells for the realization of the method.

A second sequence of D cells should contain the number of commutations for each discrete moment. At the execution at each discrete moment (initiated, e.g. by an interruption) the processor should read the necessary number of commutations and would execute the consecutive switching of the respective number of addresses from the first sequence.

It is clear (Fig. 1), that the relay rows can be filled by a random sequence of the heaters; an unfinished pulse at the end of the period can be transferred to another row, which means that it will continue during the next period. This chopping does not mean more commutations. The random sequence means that we can choose a sequence equal to that in the memory. This will simplify the procedure, because the switching off of a consumer will be succeeded by the switching on of the next one, based in the next cell. An additional bit will not be necessary and the first sequence can contain only N cells.

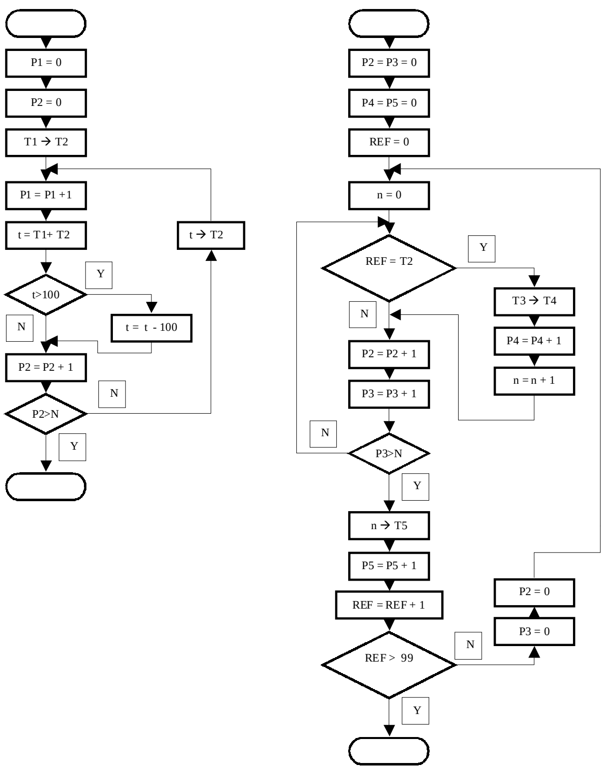

Fig. 3. An example of the processing algorithm.

Fig. 2 shows the rows of cells, necessary for the realization of the method. In the first table T1 the powers are recorded as percents of the maximal powers. In the second table T2, the moments t_{off} are entered in the same sequence, as a number of discrete steps from the beginning of the period. In the third T3, the addresses of the consumers are recorded in the same sequence. In T4, the same addresses are entered, but in the sequence of their switching off. In T5, consisting of D cells, each corresponding to a discrete moment of the period, the numbers of switching off "n" for the respective moment are stored. These numbers can vary from 0 to N. A pointer P_X is associated to each table. Two subsidiary cells are used: n – for the number of commutations in the fixed moment and REF – for the switch moment.

The content of the first table T1 is set by the operator or in another way. If a separate processor is responsible for the relay control, the content will be received through the interface channel. The content of the third table is set in the program memory. The other tables are filled up through a processing procedure, which should be performed at every change in the content of the first table. Fig. 3 is an example of the processing algorithm. The first algorithm fills up table T2, the second – the tables T4 and T5. For the execution of the commutations, another software segment uses tables T4 and T5 with other pointers - P4ex and P5ex.

The case when a part of the consumers consists of single consumers connected parallel is more complicate, because they will be presented simultaneously in many relay rows, as is the number of the single connected consumers. Their displacement in the separate rows is inpossible. Without entering into details, which is not the object of the present work, we can define that a relay control with a minimum disturbances is possible by observing of the conditions:

$$\sum n_k . P_0 . t_k < P_M \quad \text{and} \quad n_{max} < K ,$$

where $n_k = 2, 3, \ldots n_{max}$ is the number of parallel connected consumers, t_k is the time of the "on" state for the period T. The first condition suggests that in the relay rows there is a place for single consumers, which will form a minimal residue. The second condition means that no composite consumer can have a greater power than the average value, since in the opposite case an unavoidable power pulsation will occur.

CONCLUSIONS

A way for reducing to almost zero of the electrical disturbances arising at the PWM control is given and an algorithm for microcomputer control of the pulses and pauses for each consumer is developed. This work is the first step in this direction and will be the basis for solving more complicated cases.

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