THE EXTREME CONTROL SYSTEM OF ELECTRICAL PROPULSION ENGINE MODULE ON THE BASIS OF SPT-100

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ABSTRACT

On the basis of experimental dependence of amplitude of a discharge current oscillations and average value of a discharge current from an electromagnet current for the Stationary Plasma Thruster SPT-100, which have extreme character, the extreme system of automatic control is offered. The system contains the Stationary Plasma Thruster SPT-100, as object of control, the controlled power supply of an electromagnet current and the analogy regulator. The regulator provides the measurement output variable of SPT - the discharge current, the formation of a criterion of quality and determination of controlled signals ensuring the minimisation of a criterion of a system quality. The criterion of quality consists of a number components with weight factors. As components are used: amplitude of oscillations and average value of a discharge current and square of value of an electromagnet current. Two variants of a regulator, based on the following methods of extreme search are offered: a method of synchronous detecting and method with memorizing of extreme. Results of digital modelling of offered system are presented. On the basis of these results the parameters of offered variants of regulators were determined, including structure and parameters of criterion of quality are determined.

1. CHOICE OF QUALITY CRITERION ON THE BASIS OF THE ANALYSIS OF EXPERIMENTAL DATA.

During experimental researches of the thruster SPT-100 the presence of extreme dependence of an average discharge current and amplitude of discharge current oscillations from a level of an electromagnet current are determined [Ref. 1]. Thus a minimum of an average discharge current and minimum of amplitude of discharge current oscillations or practically coincide or are rather close. The qualitative kind of these dependence is kept at change in a wide range of a discharge voltage and a mass flow rate of working substance.

The presence of physical extreme dependencies between variables of the SPT allows to create automatic control extreme system with various types of criterion of quality:

1) Sum of weighed values of an average discharge current I_d and square of an electromagnet current I_m^2, taking into account expenses on control;

2) Sum of weighed values of an average amplitude of the discharge current oscillations I_p and square of an electromagnet current I_m^2;

3) Sum of weighed values of an average amplitude of discharge current oscillations I_p, an average value of the discharge current I_d and square of an electromagnet current I_m^2.

The numerical values of weight factors were selected by practical consideration, proceeding from the requirements to separated components of criterion of quality and maximum speed of convergence of process of extremum search.

In result of the analysis of various variants of criterion of quality of extreme automatic control system of an electrical propulsion engine module on the basis of the Stationary Plasma Thruster SPT-100 criterion of quality was chosen. This criterion provides the compromise between the minimum size of the discharge current oscillations I_p and minimum level of an average value of the discharge current I_d at change of values of a discharge voltage V_d and mass flow rate of working substance $\dot{m}$.

2. CHOICE OF STRUCTURE OF AN EXTREME REGULATOR.

The choice of the block diagram of a regulator is determined by criterion of quality and algorithm of extremum search. Two variants of an extreme regulator were investigated:

1) Extreme system with synchronous detecting;
2) System with the memorising of extremum.

The block diagram of extreme system with synchronous detecting is presented on Figure1 and contains a standard set of elements: SPT as object of control, generator of a search signal, block of calculation of the criterion value, passband filter, synchronous detector, low-frequency filter and integrator. Distinctive peculiarity of a regulator is presence of analogy filters, ensuring allocation of average value of a discharge current $\bar{I}_d$ and an amplitude of the discharge current oscillations $\bar{I}_p$.

The block diagram of extreme system with memorising of extremum is presented on Figure 2 and contains: SPT as object of control, analogy filters, ensuring allocation of average value of a discharge current $\bar{I}_d$ and amplitude of a discharge current oscillations $\bar{I}_p$, block of calculation of the criterion value, block of memorising of a current value of extremum, comparator which is calculating $Q = F(t) - F_{min}$, relay element and integrator.

3. DETERMINATION OF THE REGULATORS PARAMETERS.

For a method of synchronous detecting it was necessary to determine the following parameters of a regulator: time of averaging T for calculation of average value of amplitude of discharge current oscillation $\bar{I}_p$ and average value of the discharge current $\bar{I}_d$; weight factors in criteria of quality; frequency and amplitude of a search signal; delays on a phase φ in a contour of control; the order and range of a passband filter; the order and range of the low-frequency filter; factor of transfer of the integrator.

In result of spent researches the following parameters of an extreme regulator were chosen:

- time of averaging - T = 10 μsec;
- weight factors of criterion of quality $K_{Id}=1$; $K_{Ip}=1$; $K_E=0.3$;
- amplitude of a search signal A = 0,2 and frequency of a search signal $\omega = 20$ Hz;
- the phase delay in a contour of control was determined as a sum of phase shifts of a thruster, passband filter, filter for determination $\bar{I}_p$ and $\bar{I}_d$;
- factor of transfer of the integrator K=5.

At modelling a contour of extreme control filters Batterwourt were used: passband filter 6-th order with a range 15-25 Hz and low-frequency filter with a passband 10 Hz.

For a method with memorising extremum it was necessary to determine the following parameters of a regulator: the size of a tolerance zone of a relay element - δ and size of factor of transfer of the integrator - K. The other parameters of a contour of extreme management (T, K_{id}, K_{ip}, K_E) are similar to parameters of a contour with synchronous detecting.

4. RESULTS OF MODELLING OF EXTREME CONTROL CONTOURS WORK.

On Figure 3 the diagram of criterion of quality $F(I_m)$ is submitted as the dependence from input signal Im which is possible to operate. The presence of local minimum on the diagram of quality criterion is explained by casual character of value of an average discharge current and value of average amplitude of the discharge current oscillations. The diagram of criterion on Figure 3 corresponds to a set of parameters of an extreme regulator above presented. At increase of averaging time T the size of local minimum decreases but thus speed of extremum search decreases.

The process of extremum search in a contour with synchronous detecting is illustrated by Figure 4 on which process of change of an electromagnet current during a search of extremum is shown. Modelling processes in system was carried out at the following parameters of the unit: Vd = 300 V, m = 100 % from rating value. The size of initial value of an electromagnet current is $I_m = 3$ A, optimum size of an electromagnet current for values of weight factors above presented is 3.08 A. Process of extremum search is characterised significant changes of an electromagnet current and as a consequence significant time of extremum search.

The process of extremum search in a contour with extremum memorising is illustrated by Figure 5. Modelling processes in system was carried out at the same values of an extreme system parameters as for a

contour of synchronous detecting. The size of initial value of an electromagnet current made 4.5 A that corresponds to a real conditions of turn on of SPT-100. The process of extremum search for the given contour occurs without big changing of value of an electromagnet current and duration of process of extremum search less then similar time for a contour to synchronous detecting.

The change of value of criterion of quality for a contour with extremum memorising during search of optimum value of an electromagnet current is presented on Figure 6. The diagram confirms that the founded value of an electromagnet current is optimum for given structure and above presented values of weight factors of quality criterion.

5. REFERENCE

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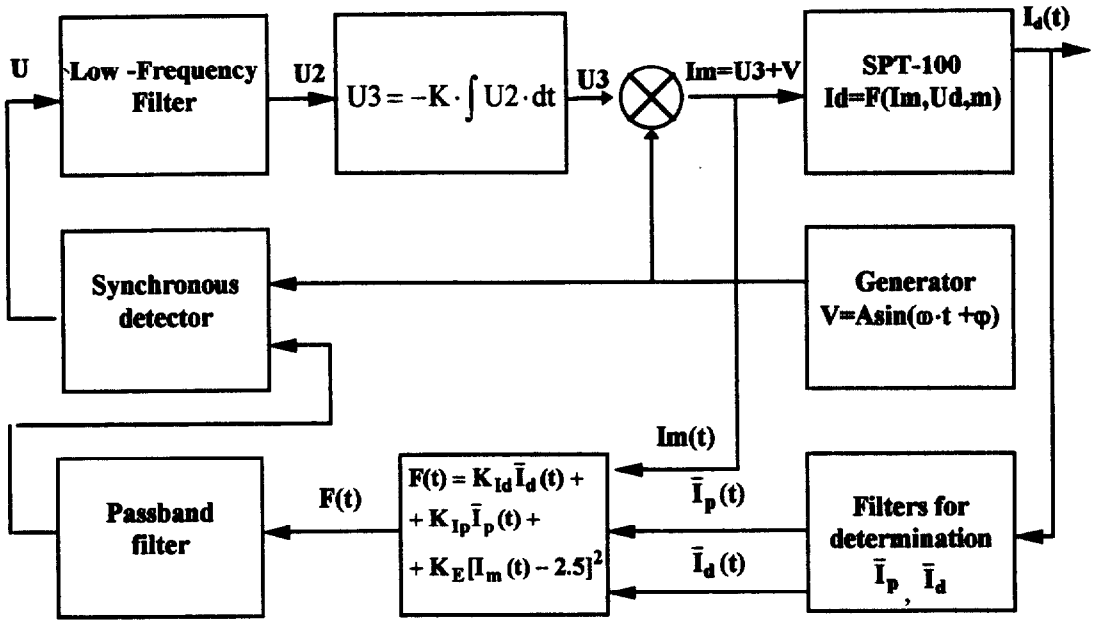

Figure 1. Block scheme of an extreme system with sinchronous detector.

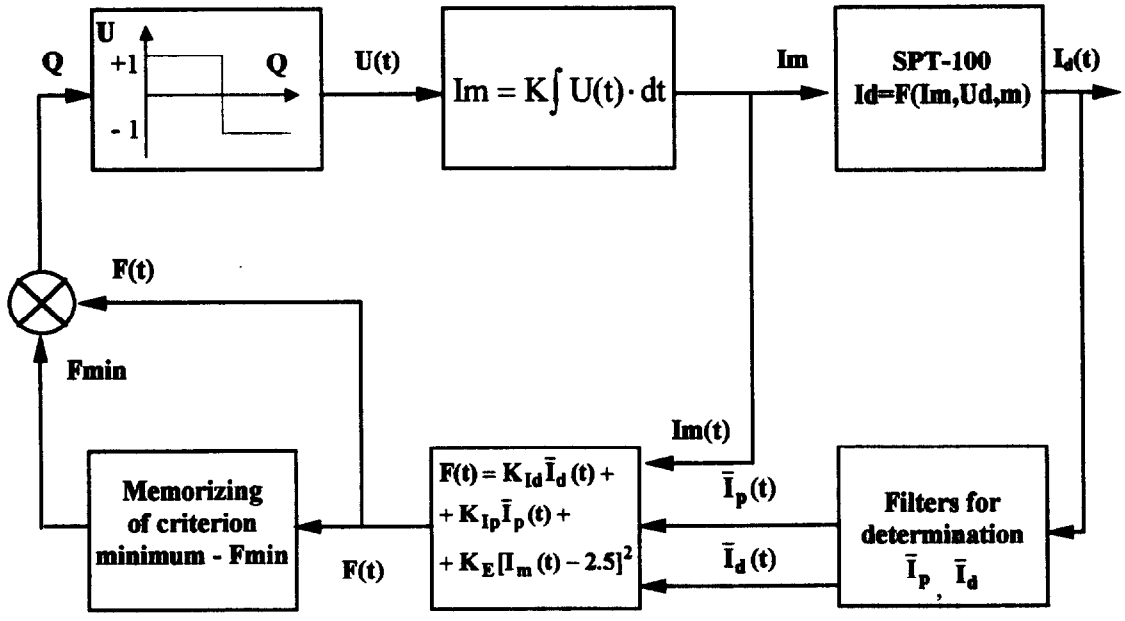

Figure 2. Block scheme of an extreme system with extremum memorising.

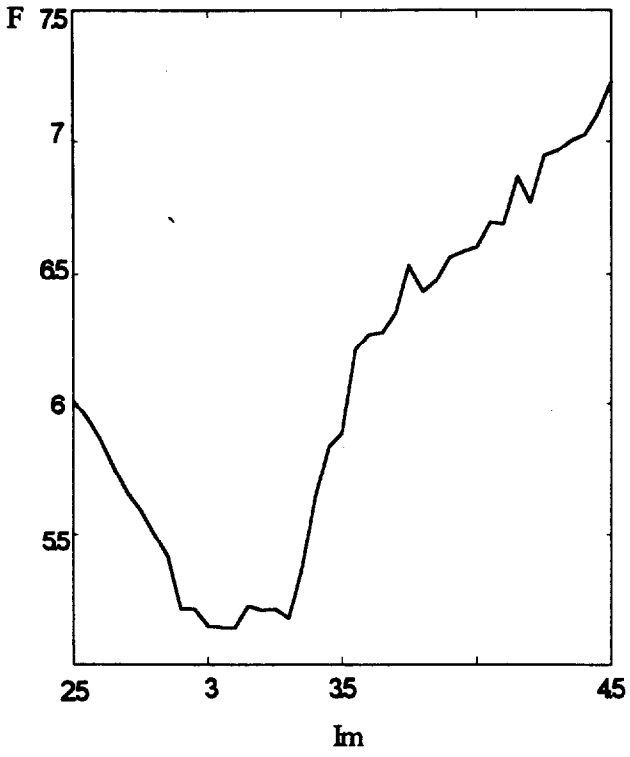

Figure 3. The dependence of the quality criterion from an electromagnet current

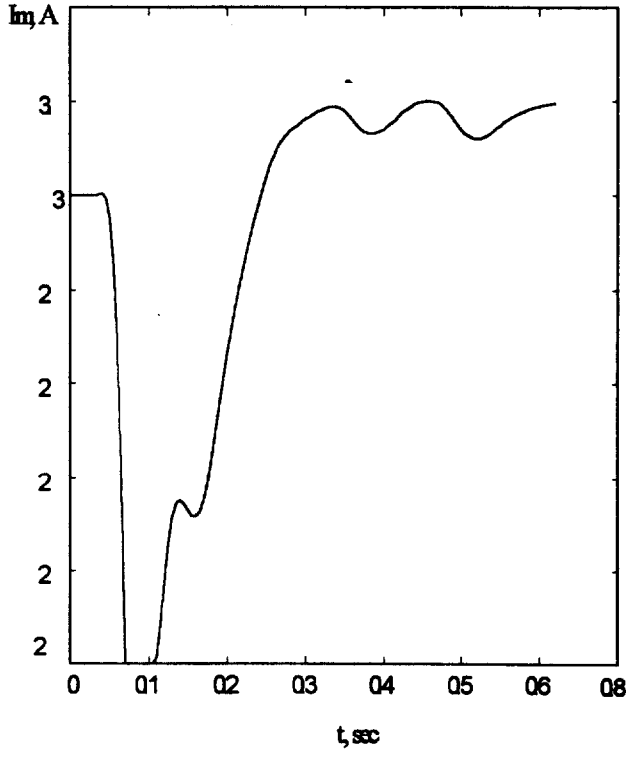

Figure 4. The dynamics of the extremum search process for system with synchronous detector.

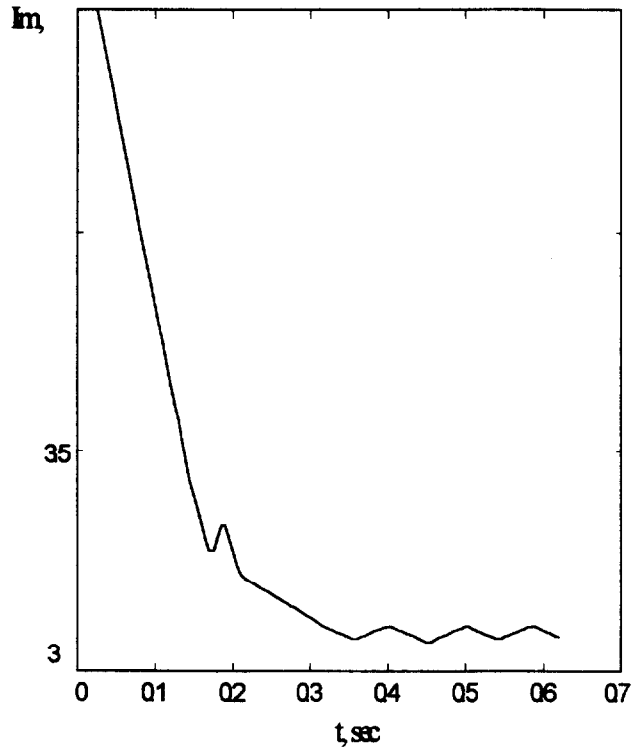

Figure 5. The dynamics of the extremum search process for system with the extremum memorising.

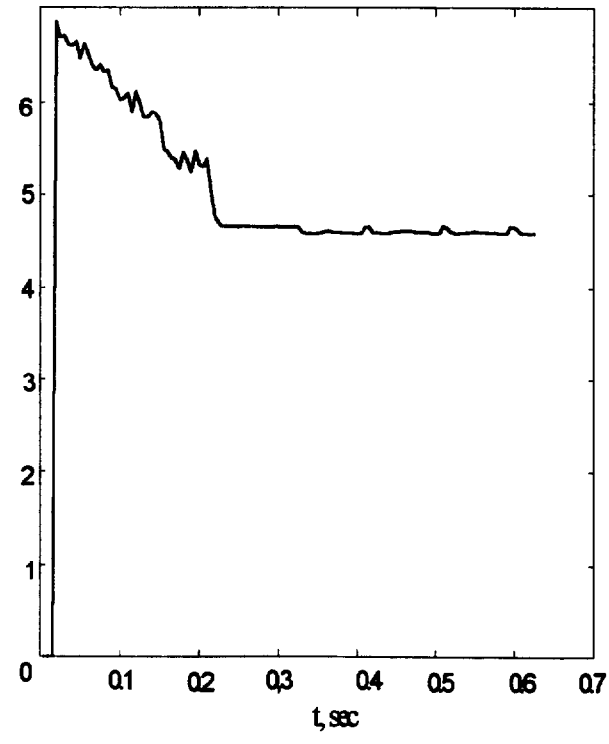

Figure 6. The dynamics of quality criterion changing during the process of the extremum search.