IMPROVING THE PERFORMANCES OF THE CONTINUOUS TRANSPORT INSTALLATIONS WITH BAND
PART I – USUAL PROBLEMS OF OPTIMIZING THE ACTION SYSTEMS OF THE BAND TRANSPORTERS

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Abstract: *Most of the systems of electric action are non-linear systems, including the continuous transport systems with band, that could be brought by linearization and negligence at the linear system. The latest news in the field of static convertors, of the new transfer schemes of electric energy, make possible the analysis of the action systems of the continuous transport installations with band as linearisable systems. For the linearisable action systems described by state equations, there are two consecrated calculation methods of the optimal trajectory of the system, the variational calculation and the Euler-Lagrange algorithm, as the latter one is considered by the specialty literature as an optimum generator, and the first one as an extremum generator. But the two methods need conditions reviewed enough in the Euler-Lagrange conditions.*

Keywords: continuous transport, non-linear systems, Euler-Lagrange algorithm

1. Introduction.

The optimal systems theory belongs to the general theory of systems and represents the most evolved and important part of this field. Systems in general and the automatic systems in particular cannot be conceived without considering their efficiency degree, the framing in the minimum consumptions of time, energy, and materials, how much all the available resources are required and capitalized, the minimum production costs, etc. For this reason, any problem of calculation, projection, analysis and functioning of the continuous transport systems is subordinated to the optimality requirements.

2. Usual problems of optimizing the action systems of the band transporters

Any process or technological installation, including the continuous transport installations with band may be treated as a multivariable oriented system with memory, benefiting from mathematic representations spotlighting its causal structure by input variables u, state variables x and output variables y (fig. 1 *Multivariable Oriented System*)

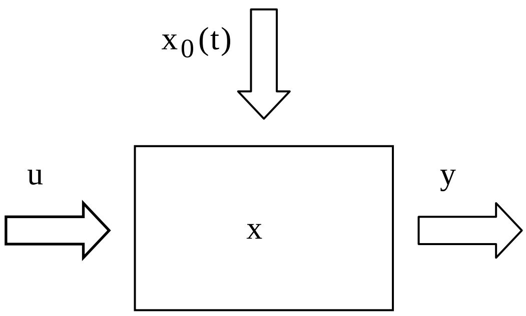

Figure 1. *Multivariable Oriented System*

A first mathematic description of the dynamic system is expressed by the initial mathematic model. Considering the system as a flat system with concentrated parameters, the mathematic model may be brought to look like a system of differential equations of first order:

$$F(x,\dot{x},t)=0 \qquad (1)$$

By separating the variables according to a causality criterion in input variables, state variables and output variables, the model may be expressed in the 2 state equations:

$$\begin{aligned}\dot{x}&=F(\dot{x},u,t)\\ y&=G(x,u,t)\end{aligned} \qquad (2)$$

In calculating, projecting and functioning any system, we should consider the limitations of the components of the system and the signals transmitted between these elements. These limitations are called restrictions and they are generally of the (3) form and the finding of an optimal solution should satisfy the conditions of the imposed restrictions:

$$r \le (x,t) \le \Gamma \qquad (3)$$

The proper (active) **input variable** is real and limited by the fact that it should be admitted at the system input under the physical nature aspect, under the aspect of the values it may have and forming the vectorial input space, $u \in U \subseteq \Re^{p}$ and under the aspect of the functioning giving in time these values that form the set of admitted input functions (non-void set),

$$u=\omega(t)\in\Omega, \quad t\in T, \quad \Omega=\{\omega : T\to U\}$$

The input variables may be continuous and derivable in report to t in a neighbourhood of interval $[t_0, t_1]\subset T$, and the space the these sizes U is considered as open; flat on portions in the interval $[t_0, t_1]$. Any element u(t), oh set U providing the system evolution in the initial conditions in the final conditions by respecting the properties of controllability, tangibility and observability is called an admitted order.

The state variable may be submitted or not to restrictions according to the specific of the optimization problem, as there are the following situations:

- the set χ, where the system is defined, has no restrictions and it may cover the entire space $\Re^{n}$;
- the set χ is limited and opened in $\Re^{n}$;
- the set χ where the admitted states are restrained, is limited and closed in $\Re^{n}$

The output variable is real and it depends on the values of the input variable and on the system structure, and the set Y may be submitted or not to restrictions. The total values of the constructive parameters p_c and functional ones p_a, admitted by the system, forms the admitted fields P_a and respectively P_c,

$$p_a \in P_a \subseteq \Re^l, \quad p_c \in P_c \subseteq \Re^k,$$

that are compact fields, usually limited and closed ones. From the analysis of the previous restrictions, we notice that, for the good functioning of the system, the values admitted both for the variables attached to the action system (input, state, output) and for the functional and constructive parameters certain value intervals are found.
The admitted field of the system is definited by the total admitted values,

$$DA = \{U, \chi, Y, T, P_a, P_c\}$$

that will have the respective restrictions as frontier. The admitted field imposes for the system evolution to occur only inside it, so the solution of the optimization problem should be found inside the admitted document.

From the systemic viewpoint in optimizing the electric actions of the continuous transport installations with band, we should consider two aspects:

- the stationary system of determining optimal values of some sizes (speeds, accelerations) and of constantly keeping them on relatively long times, without considering a detailed study of the transitory systems;

- the dynamic system, having as an objective the determination of the parameters of the automatic regulator providing a transitory system as short as possible.

The most often, the functioning cycle of an electric action system supposes a succession of a finite number of stationary systems, a succession imposing the solving of both of the optimization problems.

The result of this combination mostly leads to the accomplishment of a costly adaptive optimal system. For removing this disadvantage, we adopt optimal solutions of the stationary and suboptimal systems for the dynamic system problem.

Typical problems referring to the optimization of the functioning systems of the electric action systems by particularizing the optimization criterion are:

a) The problem of minimum time has as an objective the minimization of the lapse of time necessary for passing the system from the initial state to the final state by means of an admitted order.

b) The problem of the minimum energy consumption supposes the determination of that admissible order for which the system evolves from the initial state $x_0 \in \chi_0$ to the final state $x_1 \in \chi_1$, mostly fixed in case of the electric actions, in the imposed lapse of time $[t_0, t_1]$ or not, so that the energy consumption should be minimum.

c) **The problem of minimizing the final dispersion,** existing in the minimization of the positive-defined square shape,

$$J = \frac{1}{2} x^T(t_1) M x(t_1) \qquad (4)$$

d) The problem of final control. The optimization types imposing the problem of final control are Mayer or Bolza problems, having as a purpose the determination of the free initial or final states. These problems are mostly doubled by conditions derived from the necessity of a minimum energetic consumption.

3. **Conclusions on the optimization methods**

Most of the systems of electric action are non-linear systems, including the continuous transport systems with band, that could be brought by linearization and negligence at the linear system.

The latest news in the field of static convertors, of the new transfer schemes of electric energy, make possible the analysis of the action systems of the continuous transport installations with band as linearisable systems.

For the linearisable action systems described by state equations, there are two consecrated calculation methods of the optimal trajectory of the system, the variational calculation and the Euler-Lagrange algorithm, as the latter one is considered by the specialty literature as an optimum generator, and the first one as an extremum generator.

The difference of expression between the two methods consists of the fact that the variational method considers the quality index dependent on the state vector and on its derivate, and the optimal order is obtained from the state equation after calculating the optimal trajectory and Euler-Lagrange algorithm replaces the derivate of the state vector with the order variable. But the two methods need conditions reviewed enough in the Euler-Lagrange conditions.

The problems of minimum time are reducible to the Euler-Lagrange equations if the state derivates do not depend explicitly on time. Introducing the restrictions in the performance criterion for these problem types decreases the number of possible solutions.

Solving an optimization crosses several stages, among which we mention:

- in a first stage, it is determined the mathematic model that should mathematically describe the system functionality accomplished by differential equations. In case of linear systems, the description may be expressed by means of the differential equation of input-output, by means of the state equations, by means of the operational equation of input-output as the changed Laplace, or by means of the transfer function. At the same time, we should spotlight the initial and final conditions, the potential restrictions and the admitted field;
- in the second state, the optimization criterion is adopted and formulated mathematically;
- the third state is consecrated to formulating the optimization problem. The optimization problem consists of determining the optimal values of decision in case of the static optimization and in determining the optimal function of the order variable and of the extreme trajectory that should transfer the system from the initial state to the final state in case of the dynamic optimization, by providing the extreme optimization criterion, by satisfying the existing connections and restrictions. Here, we also include the potential changes or the necessary reductions.
- the following state is represented by the effective determination of the optimal solution. Starting from the necessary extreme condition, we accomplish the necessary calculations, and in most of the cases the computer is necessary, and in the end we analyse the nature of the global extreme (minimum or maximum) and we check the sufficiency condition.

-the last stage consists of implementing the optimal solution in practice. This is possible only by means of certain professional calculation equipments and of structures of purchasing and processing data.

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