SIMULATION MODELS OF HYDRO ENERGETIC EQUIPMENTS DYNAMIC BEHAVIOUR

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Abstract The paper deals with the theoretical issues of the models of simulation of the dynamic behavior of the hydro energetic equipments in order to identify the nature and causes of malfunction. The construction of our model is based on the physics laws of the work process, expressed by non-linear, linear and ordinary differential equations, experimental measurements followed by the identification and adjusting procedure. We describe the dynamic models used in the identification process and different ways to describe these models.

1. INTRODUCTION

In order to model any process we need to have knowledge regarding: structure, expressed by means of mathematical relations, flowcharts and graphs; values of the parameters (structural atributes); values of dependent variables (variables of state). The structure is essential in building the model and its selection may be decisive on the outcome of an identification experiment.

Fig. 1. Representation of the observability of the signals.

As the observability of input-output signals and of the noise contamination of these signals is concerned, in the identification problems there exist the situations described in fig. 1. The values $u(t)$ and $y(t)$ are the input values and output values of the process and $v(t)$ is a noise that contaminates, usually, the output. This criteria is expressed as a quadratic error function, expressed by $J(y, y_M) = \int_0^T \varepsilon^2(t)dt$. In this relation y and y_M are the input values for the process and for the model, defined on the time interval $[0, T]$.

The error is expressed by $\varepsilon = y - y_M = y - M(u)$, where $M(u)$ represents the output value of the model, if its input is u.

2. CONSTRUCTION OF THE MODEL

The elaboration of the model may be achieved in two ways: applying the laws of physics which govern the base of the process; using the results of observations, materialized through measurements, on the functional attributes (input, output, state) of the process. The details are presented in fig. 2.

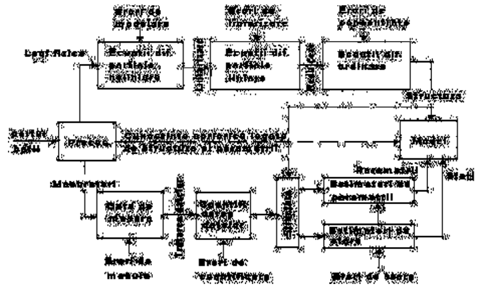

Fig. 2. Ways of elaboration of the model of a process.

The data obtained by measurements made with a frequency adequated to the dynamics of the process, are processed by some procedures (filtering, numbering, disposal of wrong data) before being used for the estimation of the parameters. The adjustment of the model is considered in the sense of adapting the parameters to a model with a fixed structure so that the transfer characteristics of the model to be as close as possible to the characteristics of the process in a way established apriori. The adjustment principle is imposed by the parity of the criterion with respect to the error (fig. 3).

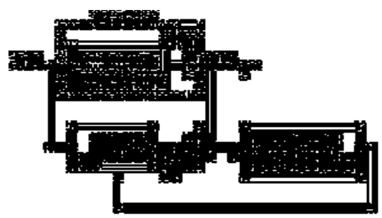

Fig. 3. Adjustment scheme of the model parameters.

Generally, we adopt even functions of the form $J = \int_0^T \varepsilon^2(t,\theta,\hat{\theta})dt = \int_0^T [y(t,\theta) - y_M(t,\hat{\theta})]^2 dt$, where $\hat{\theta}$ is the vector of parameters of the process; $\hat{\theta}$ is the vector of parameters of the adjustable model. The direction of optimal adjusting is showed by the first derivative by θ, that is $\frac{\partial J}{\partial \hat{\theta}} = \int_0^T \varepsilon(t,\theta,\hat{\theta}) \frac{\partial \varepsilon(t,\theta,\hat{\theta})}{\partial \hat{\theta}} dt$ and the rate of change of adjustment variation may be described as $\frac{d\hat{\theta}}{dt} = \hat{\theta} = -K\frac{\partial J}{\partial \hat{\theta}} = -2K \int_0^T \varepsilon(t,\theta,\hat{\theta}) \frac{\partial \varepsilon(t,\theta,\hat{\theta})}{\partial \hat{\theta}} dt = K' \int_0^T \varepsilon(t,\theta,\hat{\theta}) \frac{\partial y_M(t,\hat{\theta})}{\partial \hat{\theta}}$ where K and K' are proportionality factors. The problem arises due to the fact that neither $\frac{\partial J}{\partial \hat{\theta}}$ nor $\frac{\partial y_M(t,\hat{\theta})}{\partial \hat{\theta}}$ are measurable without additional instruments.

The correctness of the adjustment does not necessitate by all means the use of the size of these gradients but only their direction, so that the problem can be solved. If the rate of change of the process parameters is much slower than the speed of adjustment then the last relation offers a satisfactory description for the dynamics of the adjustment. The base relation used for this is the linear equation with finite differences $y(t)+a_1y(t-T)+a_2y(t-2T) = b_1u(t-2T)+b_2u(t-3T)$, or $y(t) = -a_1y(t-T)-a_2y(t-2T)+b_1u(t-2T)+b_2u(t-3T)$. These relationships allow us to express the output values $[y(t)]$ if the input values are known $[u(t)]$. The output at the moment t is computed as a linear combination of the previous inputs and outputs. The problem that was solved in the process of identification consists in using the measured inputs and outputs to determine the coefficients of the equation: a_1, a_2, b_1, b_2, to determine the number of delays in the output $(y(t-T), y(t-2T))$ and the number of delays in the input $u(t-2T)$ and $u(t-3T)$. The number of delayed inputs and outputs used define de order of the model.

3. WAYS OF DESCRIBING THE MODEL

A linear model defined on the space of states may be described by the equation $y = Gu + He$, where y is the output value; G is transfer function that describes the effect of inputs on the outputs; u is the value of the input; H is the transfer function that describes the effect of perturbations on the outputs; e is the value of the perturbations.

The representation in the state space is given by the following relations

$$x(t+1) = Ax(t) + Bu(t) + Ke(t),\ y(t) = Cx(t) + Du(t) + e(t)$$

where $x(t)$ is the vector of state variables; A is the matrix that defines the effect of previous states on the current state; B is the matrix that defines the effect of current inputs on the current state; K is the matrix that defines the effect of perturbations in the current state; C is the matrix that defines the effect of current states on the output; D is the matrix that defines the effect of inputs on the outputs.

The order of the model corresponds to the number of state variables.

4. DETERMINING MODEL CHARACTERISTICS

For the characterization of the models, in practice we use a series of methods that can simplify the measurements and offer sufficient information on the model. The most widely used methods are: the response to a signal of type unitar impulse of a dynamic model is the output that follows after applying an input of type impulse, whose value is 0 for any moment t, except for the moment $t = 0$, when the value of the input $u(0) = 1$; the response to a step signal of a dynamic model is the output that follows after applying an input of type step, with $u(t) = 1$ for all positive values of t; the response in frequency describes the system behavior when it is excited with a sinusoidal signal. If the input is sinusoidal with a given frequency, then the output will be also sinusoidal with the same frequency, but the amplitude and phase modified. The resulted phase and amplitude are represented by two diagrams, both of a function of the frequency, known as Bode diagrams; poles and zeros. The determination of „poles" and „zeros" is an equivalent mode of finding the coefficients of the last equation for an ARX model. Poles are connected to the output side and the zeros are connected to the input side. The number of poles and zeros is identical to the number of intervals between the largest and smallest delay in the system. By rearranging the poles of an equation we can obtain command structures that lead to the stability of the system.

5. CONCLUSION

For the simulation of the dynamic behavior of the hydroenergetic equipments it is necessary to identify them, so that we can establish an exact connection between the model and the process. In this paper, for the simulation of the dynamic behavior of the hydroenergetic equipment, we prove the necessity for a building o dynamic model based on measurements on the values of the process, this being the case of experimental identification. This way, the existence of apriori knowledge on the structure of the process or the values of some parameters, may be used for narrowing the area of search in a class of models or in the space of parameters. The data obtained from the measurements, made with a frequency adequated to the dynamics of the process, is processed by means of some procedures (filtering, numbering, disposal of wrong data) before being used for estimation of the parameters.

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