Bulletin of the *Transilvania* University of Braşov • Vol. 9 (58) - 2016
Series I: Engineering Sciences

DIRECT IDENTIFICATION IN CLOSED LOOP OF THE DYNAMIC PROCESS PARAMETERS

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Abstract: *This paper approached aspects related to direct identification in closed loop of dynamic processes parameters (electric drive system), and are specified peculiarities of adaptive self-tuning controllers. The identification methods in the closed loop, with the direct estimation of process parameters based on the prediction error one step, can be applied also to both closed-loop and open-loop. The article analyzes the direct algorithm identification of a process affected by noise, but without external interference.*

Key words: *dynamic processes parameters, self-tuning controller, direct identifications.*

1. Introduction

The various changes in the operation of a dynamic process (e.g. electric drive system) influence the automatic adaptive regulator parameters [1-3]. In analyzing the stability and convergence properties of the system of unknown parameters are considered constant process. After the identification process, the regulator parameter values can be determined by a method of designing and adjust online although initially the process is unknown, adaptive regulator parameters will tend to these values [4]. The regulator ensures the required performance and closed loop system is called self-tuning regulator.

Self-tuning regulator, Figure 1 contains a classical control loop, which has a forward path a regulator and a controlled process; regulator parameter adjustment is achieved by feedback process inputs and outputs.

If the identification process model underlying the design of the control system the identification will occur in closed loop. Considering the convergence conditions, in the first phase are identified open-loop identification method that can be applied in closed loop system.

The convergence of the cross-correlation function between the input signals *u(k)* and output *y(k)* requires a recorrelation between signal *u(k)* and the noise *v(k)* that contaminating signal *y(k)*. As the negative feedback generates such a correlation, methods based on correlation cannot be directly applied to closed-loop identification.

For the parameter estimation, only the error signal $e(k)$, does not have to be correlated with the elements of the vector data $\Psi^T(k)$, which facilitates identifying parameters in a closed loop [5], [6].

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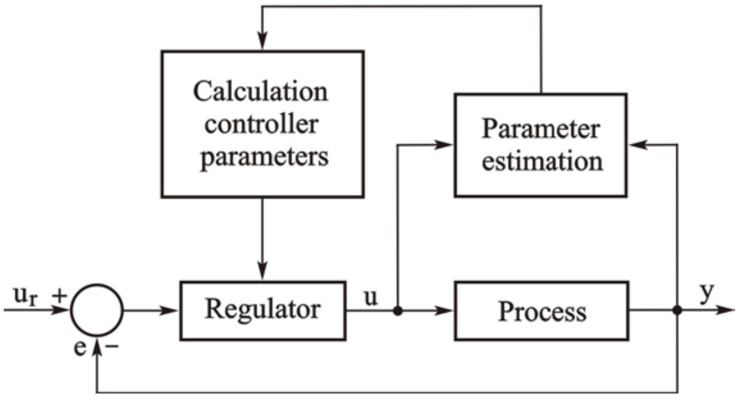

Fig. 1. *Self-tuning controller scheme*.

The process can be identified directly or indirectly. In the first case, if the regulator is known, can identify a pattern of closed-loop process. The direct identification of process regulator should not be known; the process model is identified directly, and is no necessary for closed loop model as an intermediate result [7].

2. Objectives and Methods

This paper analyzes the direct identification algorithm of a process affected by noise, and without external interference. Figure 2 shows a block diagram of the closed loop process which must be identified.

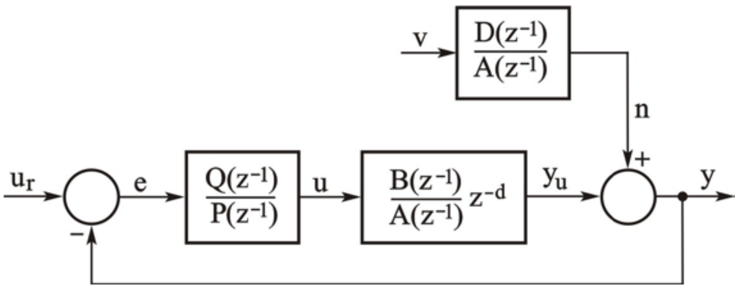

Fig. 2. *Block diagram of process which must be identified*.

Transfer functions are:

$$P(z) = \frac{y_u(z)}{U(z)} = \frac{B(z^{-1})}{A(z^{-1})} z^{-d} = \frac{b_1 z^{-1} + ... + b_{m_b} z^{-m_b}}{1 + a_1 z^{-1} + ... + a_{m_a} z^{-m_a}}, \quad (1)$$

for noise filter:

$$P_v(z) = \frac{n(z)}{v(z)} = \frac{D(z^{-1})}{A(z^{-1})} = \frac{d_1 z^{-1} + ... + d_{m_d} z^{-m_d}}{1 + a_1 z^{-1} + ... + a_{m_a} z^{-m_a}} \quad (2)$$

and for regulator:

$$R(z)=\frac{U(z)}{e(z)}=\frac{Q(z^{-1})}{P(z^{-1})}=\frac{q_0+q_1z^{-1}+...+q_\upsilon z^{-\upsilon}}{1+P_1z^{-1}+...+P_\mu z^{-\mu}} \tag{3}$$

where the signals are:

$$y(z)=y_u(z)+n(z), \tag{4}$$

$$e(z)=U_r(z)+y(z). \tag{5}$$

Estimation algorithm can be simplified if for the noise filter (2) is considered $D(z^{-1})=A(z^{-1})$.

Typically is considered $U_r(z)=0$, so $e(z)=-y(z)$, and the noise $V(k)$ is no measurable.

In this circumstances resulting:

$$\frac{y(z)}{V(z)}=\frac{P_v(z)}{1+R(z)P(z)}=\frac{D(z^{-1})P(z^{-1})}{A(z^{-1})P(z^{-1})+B(z^{-1})z^{-d}Q(z^{-1})}=\frac{1+\beta_1z^{-1}+...+\beta_rz^{-r}}{1+\alpha_1z^{-1}+...+\alpha_lz^{-l}}=$$
$$=\frac{B(z^{-1})}{A(z^{-1})}, \tag{6}$$

where polynomials have orders $r=\max[m_a+\mu]$ and $l=\max[m_a+\mu, m_b+\upsilon+d]$, with m_a and m_b unknown parameters of the process, and *d* idle time.

Closed loop process is identifiable parametric when estimation parameters are consistent by using a method of identifying appropriate:

$$\lim_{N\to\infty}E\{\hat{\Theta}(NT)\}=\hat{\Theta}_0, \tag{7}$$

where $\hat{\Theta}_0$ is the real vector of parameters, and *NT* is measurement/estimation time.

In closed loop, for direct identification of dynamic process model, two conditions must be accomplished [8].

Expression of the equation of the dynamic process in *z* domain

$$Ay=Bu+Dv, \tag{8}$$

can be rewritten considering regulator equation:

$$Ay=B\left(-\frac{Q}{P}\right)y+Dv. \tag{9}$$

Equation (9) is summate with certain polynomial $S(z^{-1})$ followed by amplification with Q and convenient grouping terms, it get to the equation (11):

$$Ay+Sy=B\left(-\frac{Q}{P}\right)y+Sy+Dv, \quad \Rightarrow (A+S)y=B\left(-\frac{Q}{P}\right)y+Sy+Dv, \tag{10}$$

$$\left(A+S\right)Qy = \left(BQ-SP\right)\left(-\frac{Q}{P}y\right)+QDv. \quad (11)$$

In equation (11) are introduced notations $\left(A+S\right)Q = A^*$, $BQ-SP = B^*$ and $DQ = D^*$, and this equation can be written as:

$$A^* y = B^* u + D^* v, \quad (12)$$

that highlight for the process models, *B*/*A*, and noise, *D*/*A*, it can use expressions:

$$\frac{B^*}{A^*} = \frac{BQ-SP}{AQ+SQ} \quad (13)$$

and

$$\frac{D^*}{A^*} = \frac{DQ}{AQ+SQ} \quad (14)$$

that do not introduce changes to the signals *u*(*k*) and *y*(*k*) for noise *v*(*k*).

Whereas, the polynomial $S(z^{-1})$ is arbitrary, order of polynomials *A* and *B* cannot be determined from the measurement of the signals *u*(*k*) and *y*(*k*); therefore it is mandatory to be known accurately the process orders and noise patterns.

If the polynomials *D* and *S* are irreductible, unique determining of the process parameters involves the following relationships: $l \geq m_a + m_b$, or

$$\max[m_a + \mu, m_b + \upsilon + d] \geq m_a + m_b,$$

$$\max[\mu - m_b, \upsilon + d - m_a] \geq 0. \quad (15)$$

With these clarifications, for the regulator orders polynomials, results that:

$$\upsilon > \mu - d + m_a - m_b,$$

i.e.

$$\upsilon \geq m_a - d$$

or

$$\mu \geq m_b. \quad (16)$$

Polynomials regulator orders are influenced by the value of idle time, *d*: if $d = 0$ polynomials orders will satisfy the condition $-\upsilon \geq m_a$ or $\mu \geq m_b$; if the regulator generates $d > 0$, result:

$$\upsilon \geq m_a - d$$

or

$$\mu \geq m_b. \quad (17)$$

When polynomials *D* and *A* have *p* common pole, the process is identifiable if:

$$\max[\mu - m_b, \upsilon + d - m_a] \geq p. \quad (18)$$

Direct identification in closed loop of dynamic processes [10] involves verifying the two conditions, from the criterion function $V = \sum_{k=1}^{n} e^2(k)$, which relate to the unknown parameters of the process, to have a unique minimum; estimated process model is:

$$\hat{A}(z^{-1})y(z) - \hat{B}(z^{-1})z^{-d}u(z) = \hat{D}(z^{-1})e(z), \quad (19)$$

$$\frac{1}{\hat{D}(z^{-1})}\left[\hat{A}(z^{-1}) + \hat{B}(z^{-1})z^{-d}\frac{Q(z^{-1})}{P(z^{-1})}\right]y(z) = e(z). \quad (20)$$

where $\hat{D}(z^{-1})e(z)$ is the correlated error signal.

Based on the transfer function (3), $Q(z^{-1})y(z) = -P(z^{-1})u(z)$, is determined expression signal *u(z)*, and the process model (20) follows.

The minimum of function *V* will be unique if there is a single dependency of process parameters by the error signal:

$$\frac{1}{\hat{D}(z^{-1})}\left[\hat{A}(z^{-1}) + \hat{B}(z^{-1})z^{-d}\frac{Q(z^{-1})}{P(z^{-1})}\right]y(z) = \frac{\hat{A}(z^{-1})P(z^{-1}) + \hat{B}(z^{-1})z^{-d}Q(z^{-1})}{\hat{D}(z^{-1})P(z^{-1})} = \frac{A}{B}. \quad (21)$$

This function is similar with equation (6); if two conditions are fulfilled, the polynomial parameters $\hat{A}$, $\hat{B}$ and $\hat{D}$ are unique determinate by use transfer function $y(z)/v(z)$. The convergent, $e(z) = v(z)$, it is accomplish if: $\hat{A} = A$, $\hat{B} = B$ and $\hat{D} = D$.

3. Results and Discussions

Online identification of dynamic process is accomplished if the computer it is running online simultaneously with the process [2], [5], [9].

Adaptive regulators are parametric and nonparametric [1], [4] [10]. At first regulators the process model is parametric and in the case of nonparametric self-tuning regulators the process has a nonparametric variation.

For self-tuning regulators unknown parameter estimation is performed independently of regulator design; estimated parameters are considered real and the estimation errors are insignificant. Self-tuning regulators can be applied to discrete systems, continuous or hybrid.

In the case of identifiable systems identification methods in the closed loop, with the direct estimation of process parameters based on the prediction error one step, can be applied to both closed-loop and open-loop [3], [5].

The identifying in closed loop without external disturbance, with linear regulator time invariant and no noise can highlight the following aspects:

For the system to be identifiable, at prediction in closed loop (direct or indirect) it is necessary that conditions 1 and 2 to be satisfied [11];

If the regulator does not fulfill condition 2 due the order is too small, the system is identifiable by switching loop of two regulators with different parameters, the introduction of a idle time $d \geq m_a - \upsilon + p$ on the reaction pathway, or using a linear regulator.

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