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Reliable Measurement and Influence of Measurement Errors on the Balance Algorithm of Physical Parameters (Application on a Rectification Vacuum Column)

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Abstract

During the automation and exploitation of a production (or a manufacturing) process the measurement is and will always be a current problem faced by engineers for a long time. Its importance and urgent industrial use become more and more obvious for an optimal exploitation through a highly reliable automatic command.

In this work our interest goes to measurement, measurement errors and their influence as well as their reliability on input and output of the petroleum equipment (rectification vacuum column)

Object of the command: After having studied a series of algorithms we finally found a weighting algorithm for the studied case.

Key words: Reliable measurement, Measurement errors, Algorithm, Balance (weighting), Command, Optimal exploitation.

1 Introduction

In fact, during the exploitation of petroleum industrial equipment such as the rectification vacuum column, the measurement and exploitation of the different parameters of input and output are performed with a certain measurement error.

This work is undertaken with the aim of finding a solution approach by the adaptation and study of a correction algorithm of weighting and stabilisation coefficients during the automatic command of a rectification vacuum column in order to get an optimal exploitation.

2 Analysis of the influence of measurement errors on the algorithm

Let us examine the influence of errors δx_j and δy on the quality of the following algorithm given in the matrix form

$$\hat{A}(i) = \hat{A}(i-1) + \frac{y(i) - \hat{A}^T(i-1)X(i)}{\gamma + X^T(i)X(i)} X(i). \tag{1}$$

Instead of x_j we have $x_j^* = x_j + \delta x_j$, and instead of y we will have $y^* = y + \delta y$. Let only the input parameter y be regarded and measured with a certain error. Algorithm (1) will take the form

$$\hat{a}_j(i) = \hat{a}_j(i-1) + \frac{y(i) + \delta y(i) - \sum\limits_{j=1}^{n} \hat{a}_j(i-1) X_j(i)}{\gamma + \sum\limits_{j=1}^{n} x_j^2(i)} x_j(i). \tag{2}$$

In a vector form (2) will be

$$\Delta A(i) = \Delta A(i-1) - \frac{\Delta A^T(i-1)X(i) - \delta y(i)}{\gamma + X^T(i)X(i)} X(i). \tag{3}$$

The necessary condition so that $\hat{A}(i)$ tends to the real value $A(i)$ is that the mathematical expectation of error of the first act of correction be smaller than that of the $(i-1)$-st act in the conditions $M\{\delta y\} = 0$, this condition must satisfy

$$M\{\Delta y(i)\} > M\{\delta y^2\}. \tag{4}$$

The true value of the parameter $\hat{A}(t)$ will be corrected and weighted correctly by the algorithm (2) whenever the error will no more be smaller. Condition (4) corresponds to the appropriate conditions of the model of the present study.

Similarly for the case of input parameters, we will have

$$\hat{a}(i) = \hat{a}(i-1) + \frac{y(i) - \sum\limits_{j=1}^{n} \hat{a}_j(i-1) x_j^*(i)}{\gamma + \sum\limits_{j=1}^{n} x_j^{*2}(i)}. \tag{5}$$

In a vector form we will have

$$\Delta A(i) = \Delta A(i-1) - \frac{\Delta A^T(i-1)X^*(i) - A^T(i-1)\delta x(i)}{\gamma + X^{*T}(i)X^*(i)}. \tag{6}$$

For $M\{\delta x_i\} = 0, \quad \gamma = 0$ and δx_j are not correlated between themselves and those of input. So $\hat{A}(i)$ tends to A_t,

$$\left(\sum_{j=1}^{n} \Delta a_j(i) x_j(i) + \sum_{j=1}^{n} \Delta a_j(i) \delta x_j(i) \right) > \sum_{j=1}^{n} a_j(i) \delta x_j(i). \tag{7}$$

By deduction we will have the improvement of the tendency with the increase of the measurements, this leads to the decrease of measurement errors δx_j and δy.

The optimal value of the coefficient y is obtained after solving the equations (3) and (6) with respect to the parameter γ.

For the case of the input parameter y measured with error we will have

$$\gamma_{opt} = M\left\{\delta y^2\right\} M \left\{ \frac{X^T(i)X(i)}{\Delta A^T(i-1)X(i)^2} \right\}. \tag{8}$$

And for $X(i)$ and δx_j,

$$\gamma_{opt} = \frac{X^{*T}(i)X^*(i)}{\left[\Delta A^T(i-1)X^*(i)\right]^2} \sum_{j=1}^{n} a_j^2(i)\gamma x_j(t). \tag{9}$$

For the input and output parameters:

$$\gamma_{opt} = \frac{\sum\limits_{j=1}^{n} X^T(i) \left\{ \varepsilon^2(i) + \left[\sum\limits_{j=1}^{n} a_j^2(i) \delta x_j(i) \right] \right\}}{\Delta A^T(i-1)X^*(i)}. \tag{10}$$

The disadvantage of these algorithms is their heaviness and their difficulty to get the errors of the measurement of the parameters.

To obtain the adequate values of the parameters of the studied object on the basis of the measurement of the inputs / outputs we suggest the following algorithm:

$$a_j(i) = a_j(i-1) + \gamma \frac{y(i) - \sum\limits_{j=1}^{n} a_j(i-1) x_j(i)}{\sum\limits_{j=1}^{n} x_j^2(i)} x_j(i), \tag{11}$$

in a vector form

$$A(i) = A(i-1) + \gamma \frac{y(i) - A^T(i-1)X(i)}{X^T(i)X(i)} x(i),$$

where

$$\gamma = \begin{vmatrix} P & 0 & 0 & 0 & 0 \\ 0 & P & 0 & 0 & 0 \\ 0 & 0 & P & 0 & 0 \\ 0 & 0 & 0 & P & 0 \\ 0 & 0 & 0 & 0 & P \end{vmatrix} = EP,$$

E – the unity matrix, P – a scalar.

In the case of the mission of the different parasites and disturbances, the "step by step" algorithm tends to cases with simple constraints. This is largely sufficient when the input parameters change in a linear way and the diagonal elements of the matrices are the same.

The convergence speed of the algorithm is obtained if the input vectors are in an orthogonal position in the different cases.

In a normal exploitation of the grinding vacuum tower this phenomenon is almost impossible.

The algorithm can be written, in a different simple structure

$$\Delta_j(i) = \Delta_j(i-1) - \frac{\gamma \sum\limits_{j=1}^{n} \Delta_j(i-1) x_j(i)}{\sum\limits_{j=1}^{n} x_j^2(i)} x_j(i). \tag{12}$$

The sum of the squares of errors is

$$\sum_{j=1}^{n} \Delta_j^2(i) = \sum_{j=1}^{n} \left(\Delta_j(i-1) - 2\gamma \frac{[\Delta_j(i-1)x_j(i)]^2}{\sum\limits_{j=1}^{n} x_j^2(i)} + \gamma^2 \frac{[\Delta_j(i-1)x_j(i)]^2}{\sum\limits_{j=1}^{n} x_j^2(i)} \sum_{j=1}^{n} x_j^2(i) \right) \tag{13}$$

or

$$\sum_{j=1}^{n} \Delta_j^2(i) = \sum_{j=1}^{n} \Delta_j(i-1) + \left(\gamma^2 - \frac{2\gamma}{B} \right) A^2 \tag{14}$$

with

$$\begin{aligned} A &= \sum_{j=1}^{n} \Delta_j(i-1) x_j(i), \\ B &= \sum_{j=1}^{n} x_j^2(i). \end{aligned} \tag{15}$$

From the equation (14) it arises that to obtain a decrease of error during the correction of the coefficients, it is essential to satisfy the following condition

$$\sum_{j=1}^{n} \Delta_j^2(i) - \sum_{j=1}^{n} \Delta_j(i-1) < 0. \tag{16}$$

The identification will converge in a monotonous way if

$$0 < \gamma < 2/B. \tag{17}$$

The adaptation of the model to the working conditions of the process of vacuum column will be done on the basis of the equality of the calculated and corrected model and the reference model.

The model will be adequate if it satisfies the following conditions

$$\Delta = |Q_{cal} - Q_2| \leq \Delta^*. \tag{18}$$

In this case, the model is considered if the regressing coefficients must be corrected again and the optimum values of the corrected coefficients are acceptable if $D \rightarrow$ Min.

Let us look for what values of the weighting speed of the algorithm we can get a maximum weighting speed of the algorithm.

From the model equation, equation (11), we get

$$y_s(i) = \sum_{j=1}^{n} a_j(i)x_j(i) = \sum_{j=1}^{n} a_j(i-1)x_j(i) + \gamma \frac{y_\infty(i) - \sum\limits_{j=1}^{n} a_j(i-1)x_j(i)}{\sum\limits_{j=1}^{n} x_j^2(i)} \sum_{j=1}^{n} x_j^2(i), \tag{19}$$

$$\begin{aligned} y_{s-1}(i) &= \sum_{j=1}^{n} a_j(i-1)x_j(i), \\ y_s(i) &= y_{s-1}(i) + \gamma[y_\infty(i) - y_{s-1}(i)], \end{aligned} \tag{20}$$

from which we find

$$\gamma_{opt} = \frac{|y_{s-1}(i) - y_s(i)|}{|y_{s-1}(i) - y_\infty(i)|}. \tag{21}$$

On the basis of a number of experimental data ($N = 15$) and the use of the proposed algorithm, we have defined γ_{opt} and the results of the calculation of the weighting coefficients tend to the coefficients obtained using the method of the least squares.

3 Conclusion

The system of a petroleum equipment such as the grinding vacuum column as a regulated object must correct and weight the coefficients during the measurement of its input /output parameters such as rate, temperature, load etc. by a recursive algorithm which gives us the quality of values as it is shown by the results of the study quality of command of such an object.

The results of the experiments in the article illustrate the use of such an algorithm for its exploitation.

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