Modern prediction methods in the monitoring process of security parameters

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Abstract: - The lack in exploiting the data resulted from the security parameters monitoring process represents a state of fact equivalent with economical losses.
In this paper, the authors recommend that some indirect parameters obtained by calculus to be taken into account. These parameters give us additional important clues regarding the forecast of monitored parameters.
Thus, two theoretical models have been proposed and the algorithms were conceived. The implemented calculation program has been tested using an artificial set of values for the monitored parameter.

Key-words: - monitored parameters, prediction, theoretical model, parameters dynamic, system status, regression filter, polynomial regression.

1. Introduction

The idea of the paper [1] was born when authors were evaluating, in purpose of certification, various monitoring systems designed for use in Ex classified [5, 10, 11] areas and post-accident evaluations.
The main purpose of this paper arouse as an observation made by the authors during post-accident evaluation and the evaluation for obtaining the certificate in purpose of using monitoring systems in Ex classified areas [7].
One of the important aspects observed at most monitoring systems is that, although these systems have a modern infrastructure (data acquisition and stocking, friendly interface), most of them are limited to this level without exploiting the data resulted from the measuring/monitoring processes.
Whether we are talking about monitoring systems interconnected in technological processes execution loops or independent monitoring systems, they all have the same functionary purpose: comparing measured values with certain limit-values imposed for monitored parameters and alarm triggers [2].
In this paper the authors carry through the importance of dynamic pointing and estimated time calculation until the undesirable event, which is reaching and even exceeding limit values imposed for these monitored parameters.
The first part of this paper contains several general aspects regarding monitoring systems [6]. A few extra conclusions, resulted from the evaluation of various monitoring systems, have been attached to them.
The second part has been dedicated to a review of the protection and functionality standard for monitoring systems.
The third part contains a short presentation of the theoretical models and their requirements.
The last part presents the applications of theoretical models that have been previously tested with a series of gross measurements resulted from the monitoring process.

2. Generalities

The monitoring process of the work [3] environment significant parameters is generally considered as an option and not a necessity resulted from interpreting the preventing attitude imposed by the law [4].
On the other side, practice has often shown that we tend to minimize the importance of statistical data resulted from monitoring processes, although this might constitute an important source of entry information for the process of preventing professional risks [3], according to article 2 of [4].
The general characteristic of these monitoring systems is a relatively common, invariable structure/topology.
Contrary to our expectations, the most important factors determining topological variations from one monitoring system to another are not the type and nature of monitored parameters.

Among the most important factors that determine structural variations from one monitoring system to another, there are:
- coverage requirement;
- necessity of interconnection with decision elements;
- necessity for measurement recordings historic.

3. Theoretical linear model for predicting monitoring parameters

One of the most important requests for the mathematical prediction model is, besides fidelity, the stability of provided values.
The rising evolution of parameters is, in most cases, due to accumulation phenomena. This gives us an important clue regarding the characterization of parameter evolution as being monotonous.
On the other side, the dynamics presented above is affected by different random disturbances (noise) caused mainly by errors in measurement devices and by variations of working conditions.
The suggested model regards prediction as based on calculating the "quietus" time interval up to the point where an undesirable event occurs (the reach of preset limits) for the parameter chosen on the basis of a linear extrapolation [8].
Linear extension is determined by regression of the last "n" values from the series of measured values.
Thus we have:

$$\Delta t_{\lim} = \frac{v_{\lim} - v_{med}}{m} - (t_0 - t_{med}) \qquad (1)$$

where:

$$m = \frac{\sum_{i=0}^{n-1}(v_i - v_{med})(t_i - t_{med})}{\sum_{i=0}^{n-1}(t_i - t_{med})^2} \qquad (2)$$

$$v_{med} = \frac{1}{n}\sum_{i=0}^{n-1} v_i \qquad (3)$$

$$t_{med} = \frac{1}{n}\sum_{i=0}^{n-1} t_i \qquad (4)$$

If the slope of the regression line has a negative value, then the possibility of exceeding the preset superior limit is out of the question.
Thus, the calculus of estimated time until undesirable event is made only if (8) and (9) formulas are true.
Further on, the problem of identifying a value for parameter "n" has to be solved. If the value taken into consideration is high, the theoretical model will have "high inertia", thus a greater delay. If the value is small, the theoretical model will provide fluctuant values. Other options are a constant (arbitrary) value and a variable value for parameter "n".
Considering the possible evolutions of these strings of values, it can be said that a growth of the standard deviation determines a drop in the value of "n" but not lower than a minimal value "n_{min}". Reversing the situation is also valid, including the superior limit of "n".
Although the methodology suggests two arbitrary values for the parameter "n", it has the advantage of offering a loop permitting a dynamic adjustment of this parameter during the monitoring process.
For a more rigorous restraint of the values for standard deviation based on an expected level of confidence, we can assume a normal distribution of values in relation to the regression line.
Taking into account the above-mentioned, we can dynamically adjust the value of the parameter "n" by considering an expected value for the level of confidence.
For the actual analysis "n" is considered to have a presumed value.

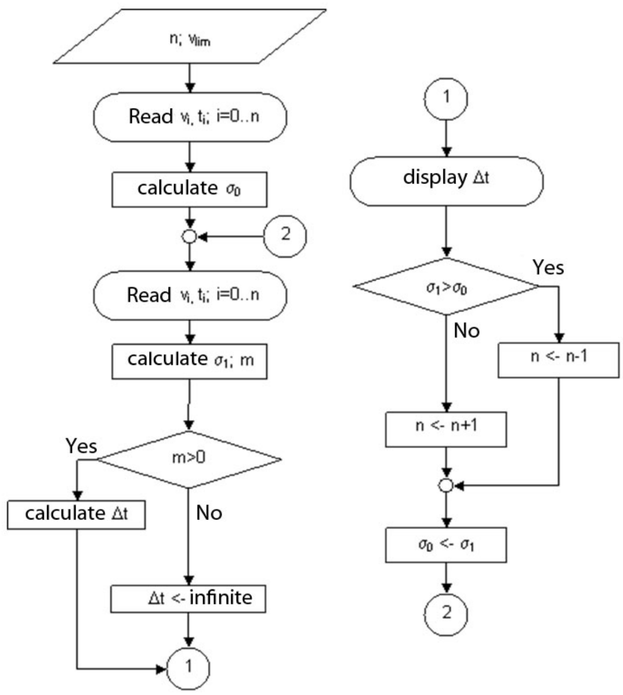

Fig 1. Logical diagram of linear prediction adaptive model

4. Parabolic theoretical model for prediction of monitoring parameters

By continuing previous issues and taking into account a polynomial second degree [9] expression the following relations results:

$$\Delta t_{\lim} = \frac{-b + k\sqrt{b^2 - 4a\left(c - v_{\lim}\right)}}{2a} - t_{n-1} \qquad (5)$$

where:

$$k = \pm 1 \qquad (6)$$

$$\begin{bmatrix} c \\ b \\ a \end{bmatrix} = \begin{bmatrix} n & \sum v_i & \sum v_i^2 \\ \sum v_i & \sum v_i^2 & \sum v_i^3 \\ \sum v_i^2 & \sum v_i^3 & \sum v_i^4 \end{bmatrix}^{-1} \cdot \begin{bmatrix} \sum t_i \\ \sum v_i t_i \\ \sum v_i t_i^2 \end{bmatrix} \qquad (7)$$

The calculus of estimated time until undesirable event is made only if (8) and (9) formulas are true.

$$2 \cdot a \cdot t_{last} + b > 0 \qquad (8)$$

$$v_{last} < v_{\lim} \qquad (9)$$

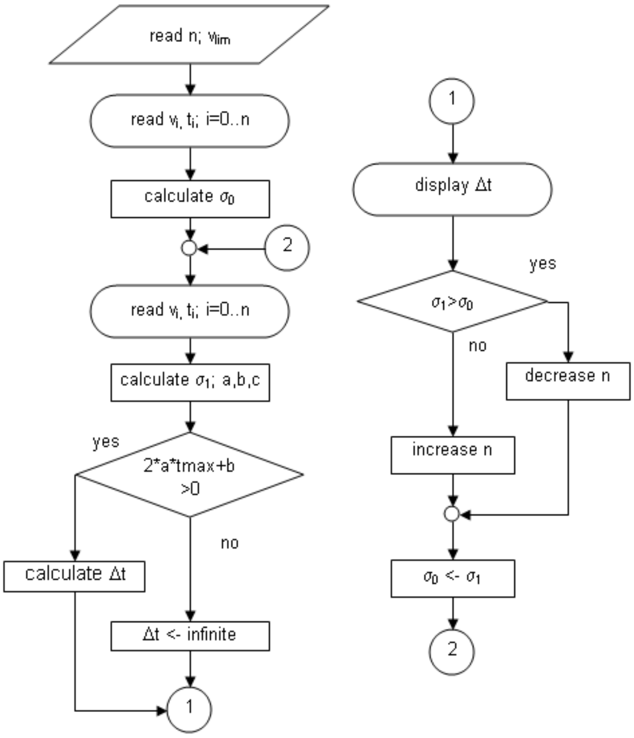

Fig 2 Logical diagram of parabolic adaptive prediction model

5. Proposed calculation algorithm

The logical diagrams from fig. 1 and fig. 2, for the specific calculation algorithm of each model, were created by taking into account the proposed mathematical models.

For both models the calculation algorithm starts with the standard procedure of reading input data n, v_i, t_i.

Then, based on parameter “n”, the initial segment of read values is dimensioned to calculate regression parameters and root deviation σ_0 of theoretical (parametric) regression model comparative to v_i, t_i measured values.

In the next place, the algorithm starts a cycle in purpose of retaining the historic for “n” measured values, also for regression parameters, and respectively for root deviation σ_0 of theoretical (parametric) regression model comparative to the last “n” measured values of v_i, t_i.

By comparing the last value of root deviation σ_1 with the precedent value σ_0, the decision of modifying the size of recorded values sample is taken through the algorithm.

Inside of the same cycle, the algorithm analyzes if the measured value is lower than the limit value and also if there is an increase tendency of the measured values. Then, if these conditions are simultaneously fulfilled, the value of estimated time until the occurrence of undesirable event (exceeding limit value) is calculated and displayed.

6. Theoretical model experiment by simulation

Practice has shown the existence of a string of measured values affected by various factors and reflected as noise in the measured value.

Supplementary, because of the declared purpose of paper, the proposed model had to be analyzed also from the false alarms point of view. Thus, a set of input data with a relatively simple evolution and that can be split in several regions, was generated.

A first region shows a stable evolution of parameter value followed by a sequence of ascending values that does not exceed the limit value and then by a resilience. The second region is alike the first one with observation that the values of the parameter exceeds limit value.

The input data described above and graphically presented in fig. 3 were processed according specific algorithms for linear theoretic and parabolic regression models.

The size of initial sample was set to 30 and the limit value to 0,8.

The measuring units were ignored for experimental purpose.

7. Simulation results

Considering the set of input data generated for the study of this theoretical model and the implemented algorithm (fig. 3) have resulted the variation diagrams of n, σ, Δt, β, a, b, c parameters.

In figures 4 to 9 are presented specific parameters values of the linear regression theoretic model and in figures 10 to 18 are presented specific parameters values of the parabolic regression theoretic model.

Figure 4 shows the evolution of monitored parameter values (violet) together with the regression function calculated value (red) according linear regression model.
Figure 5 shows the absolute error values of the regression function compared to the measured parameter values function of time.
The study of figures 4 and 5 shows the existence of an anomaly (deviation) for the regression function compared to parameter values.

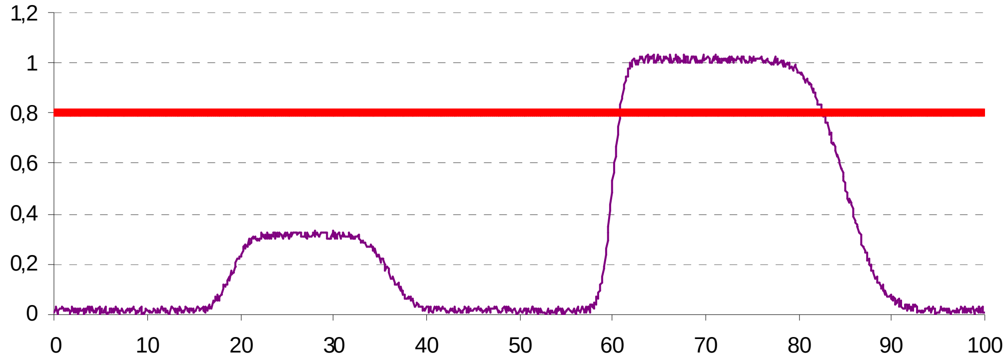

Fig.3 Measured parameter value function of time

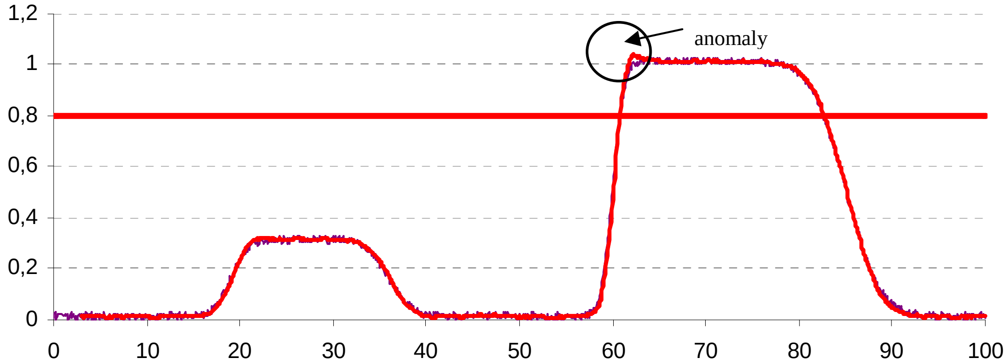

Fig. 4 Linear model – regression function value versus measured parameter values function of time

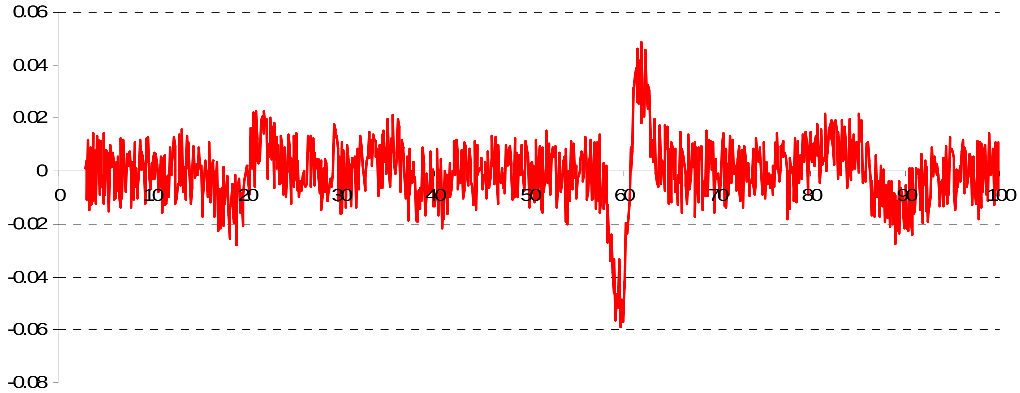

Fig. 5 Linear model – absolute error value of regression function compared to measured parameter values function of time

By the above proposed algorithm the size of the recorded values sample is adjusted function of sample capacity to permit a precise theoretical modeling by regression.

Figure 6 shows the size evolution of recorded sample.
Figure 7 shows the root deviation at the level of the recorded sample for the calculated values by linear regression theoretical model compared to parameter values.

Comparative analysis of diagrams from figures 6 and 7 shows an expected correlation. Thus, around 60 for the time value, an increase of root deviation and a decrease in parameter value for the measured values of the sample, are found.
The diagrams 6 and 7 show also the adaptive behavior of the proposed algorithm.

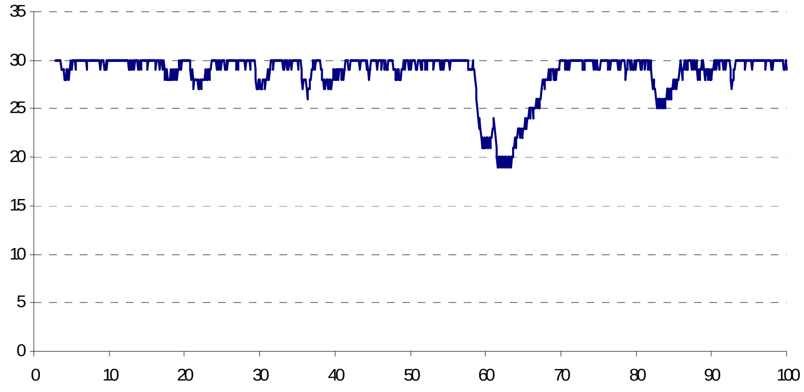

Fig.6 Linear model - size of the sample with the last measured values function of time

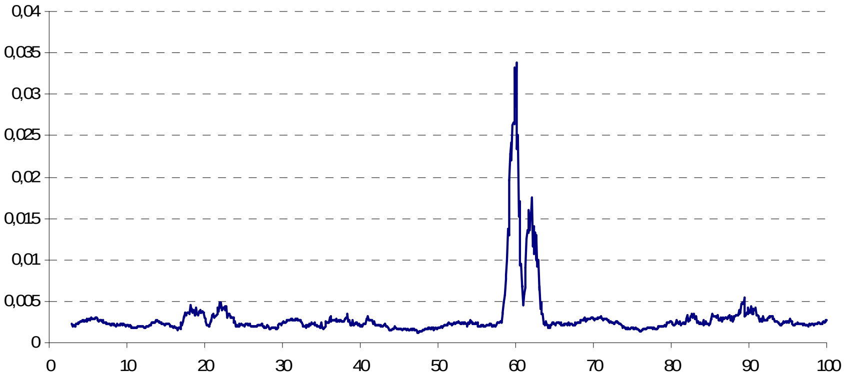

Fig.7 Linear model - the value of the root deviation relative to the instantaneous regression line function of time

The purpose of the diagram from figure 8 is to inspect the "operating" mode of the linear regression theoretical model. The study of the figure 8 diagram indicates the parameter variation tendency reflected by the slope of instantaneous regression line.

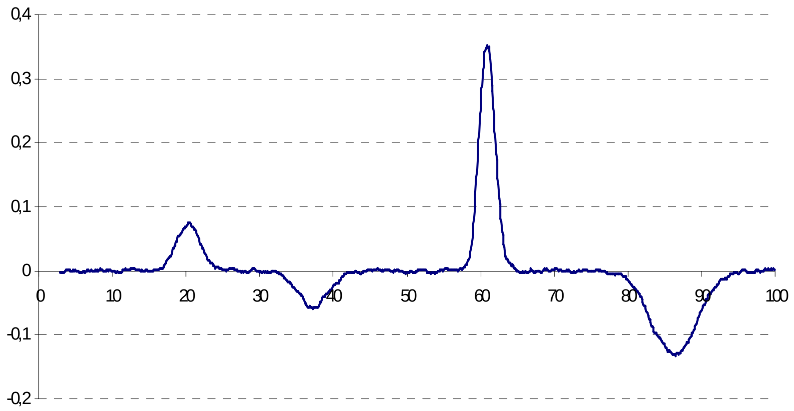

Fig.8 Linear model - instantaneous regression line slope value function of time

The main parameter which characterizes the purpose of the paper regarding the prediction capacity is represented by the calculated value of the remaining time until the undesirable event that is exceeding the limit v_{lim}.
The calculated value evolution for the time remained until the occurrence of undesirable event is presented in figure 9.
The analysis of diagram from figure 9 shows a "break", determined by the lack of implementation for the limit exceeding scenario. Practically, the "break" is perfectly synchronized with the time period during the parameter exceeds the limit value.
Also, around the value of 20 for the time, a significant decreasing of the calculated value for the time remained until the occurrence of undesirable event is observed.
This represents the test conceived for verification of theoretical model and algorithm to indicate false alarms.
Because of excessive jump in the values of the time remained until undesirable event occurrence, for diagram in figure 9, a logarithmical representation of ordinate line was chosen.

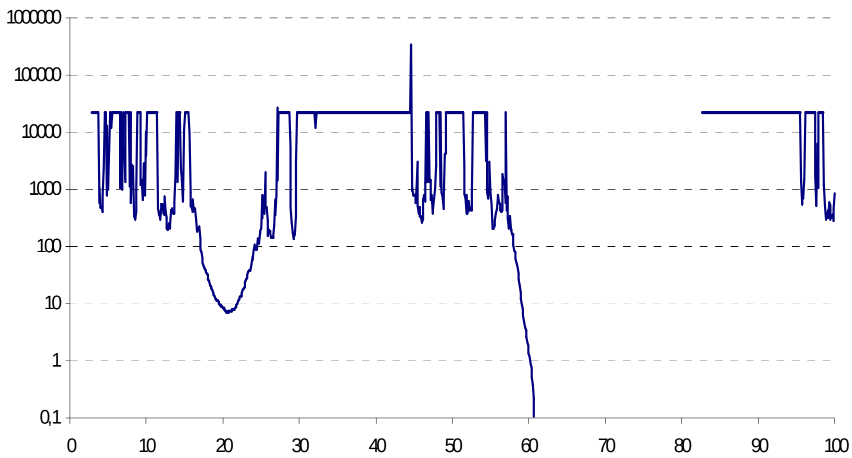

Fig.9 Linear model - the value of estimated time until maximal limit function of time

The declared purpose of this paper is to underline the importance of meta-parameters resulted in processing the monitored parameter values.
Besides the estimated time until the undesirable event occurrence, taking into account the variation rate of monitored parameter can provide supplementary information if the phenomena that determines variation of the monitored parameter value are characterized by a specific(accelerated) dynamic.
If the theoretical expression proposed for linear model is analyzed, it is obvious that the regression line slope represents, in its value, even the variation rate of the monitored parameter.
Taking into account the above mentioned, one can say that using a parabolic regression theoretical model will bring a plus of advantage regarding the supplementary quantity of information (meta-parameters).
This represents the primary motive why the parabolic regression model was taken into account.
In diagrams 10 to 18 are presented the evolutions of parabolic regression theoretical model parameters values resulted after applying the calculus algorithm over the same set of input data.
Figure 10 presents the accuracy of the parabolic regression theoretical model by the parameter calculated value (red) relative to the monitored parameter (violet).
Diagram 11 presents the absolute error values function of regression relative to the measured parameter values function of time.
The comparative analysis of diagrams from figures 9 and 10 shows an anomaly, similar to the one observed in case of linear regression theoretical model.

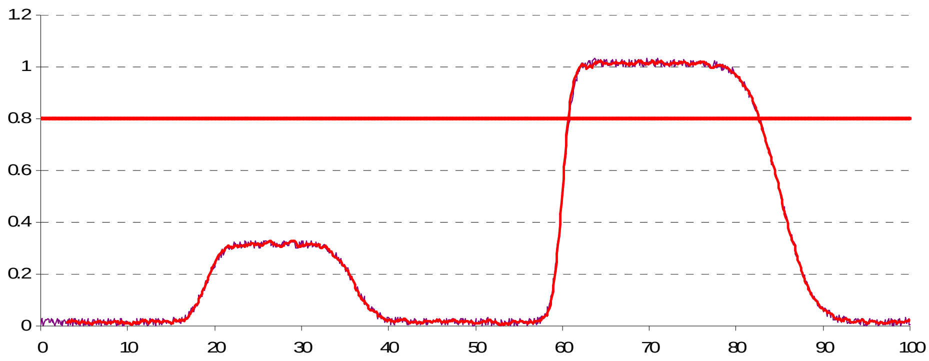

Fig. 10 Parabolic model - regression function value versus measured parameter values function of time

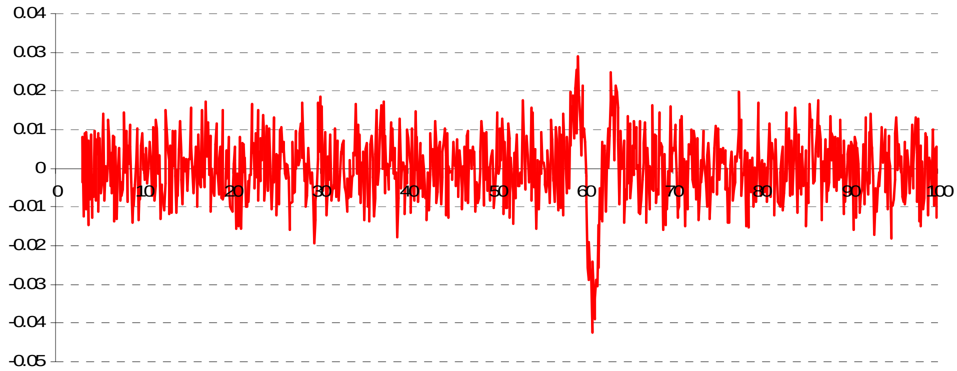

Fig. 11 Parabolic model – absolute deviation value of regression function relative to measured parameter values function of time

Figure 12 shows the size evolution for the recorded sample and figure 13 shows the root deviation at the recorded sample level for calculated values by the parabolic regression theoretical model relative to parameter's values.
The analysis of diagrams from figures 12 and 13 shows an expected correlation. Around the value of 60, for time, it can be observed an increase of root deviation and a decrease of the size value for the sample of measured values.
Diagrams 12 and 13, like in case of linear regression theoretical model show the adaptive behavior of the proposed algorithm.

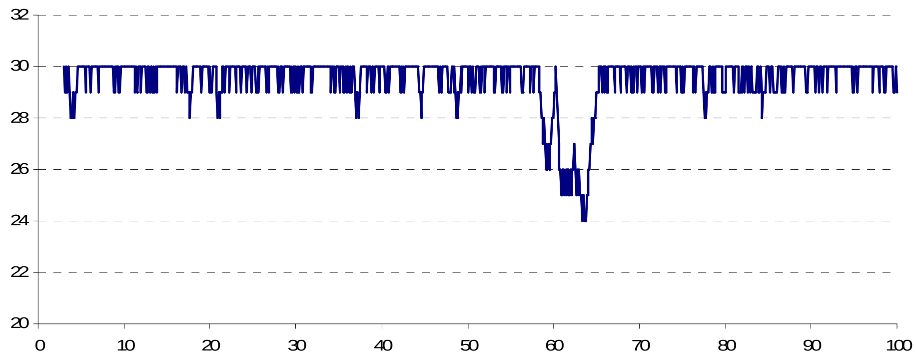

Fig.12 Parabolic model - size of the sample with the last measured values function of time

Fig.13 Parabolic model - the value of the root deviation relative to the instantaneous regression line function of time

Evolution of resulted values for the parabolic regression theoretical model specific parameters a, b and c is shown in the diagrams from figures 14 to 16.

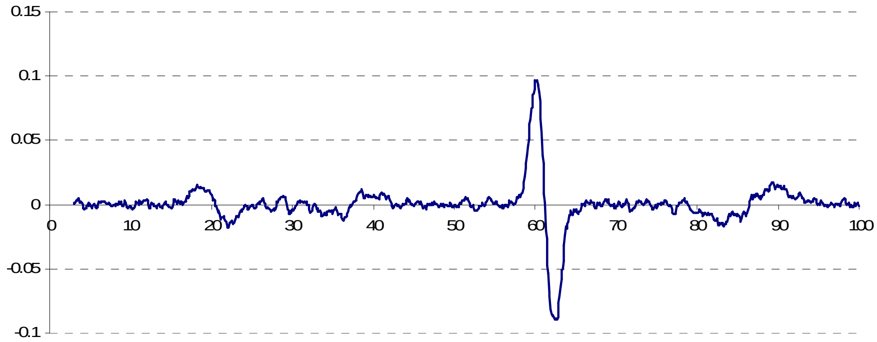

Fig 14 Parabolic model – value of „a” coefficient function of time

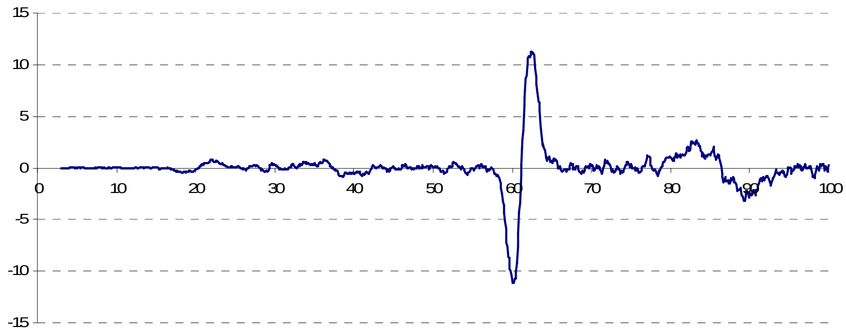

Fig 15 Parabolic model – value of „b” coefficient function of time

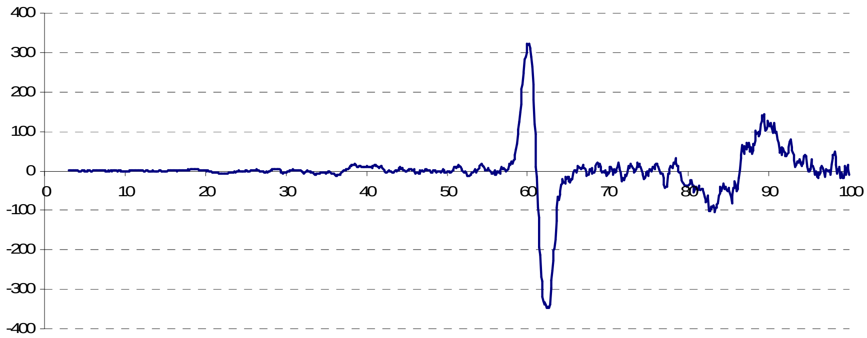

Fig 16 Parabolic model – value of „c” coefficient function of time

Like in case of linear regression theoretical model, the diagram from figure 17 has the purpose to inspect the "operation" mode of the parabolic regression theoretical model. The study of this diagram shows the parameter's variation tendency, reflected by the slope of instantaneous regression parabola which expression is given in the left member of relation (8).

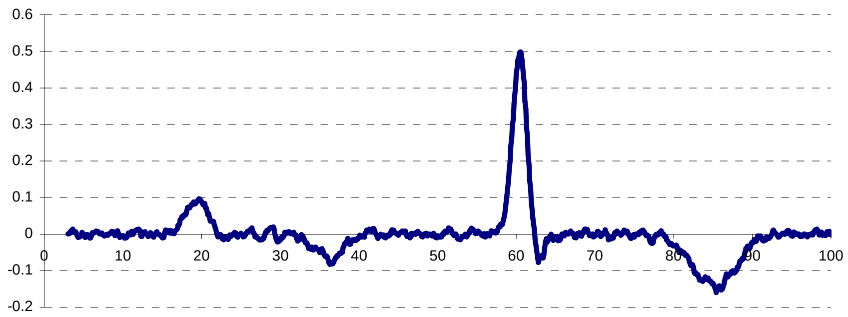

Fig.17 Parabolic model – slope value of the instantaneous regression parabola function of time

The prediction capacity indicated by the calculated value of the time remained until the occurrence of undesirable event, which is exceed of limit value v_{lim}, is presented in figure 18.

The study of diagram in figure 18, like in case of linear regression theoretical model shows a "break", determined by the lack of implementation for the limit exceeding scenario. The "break" is perfectly synchronized with the time period during the parameter exceeds the limit value.

Around the value of 20, for time, a significant decreasing of the calculated value for the time remained until the occurrence of undesirable event is observed.

The diagram in figure 18 shows, in a direct manner, the capacity of the algorithm to indicate false alarms. The sharp evolution for the values of the time remained until undesirable event occurrence, for the diagram in figure 9, was the determinant factor why a logarithmical representation of ordinate line was chosen.

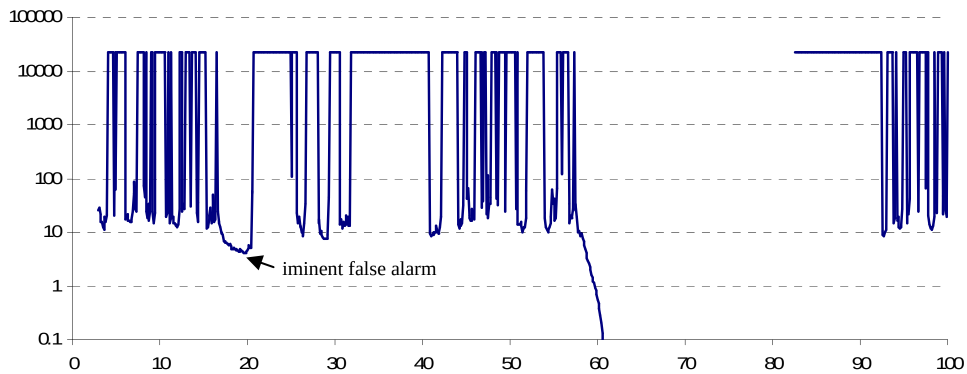

Fig.18 Parabolic model - the value of estimated time until maximal limit, function of time

Comparative analysis of the diagrams that shows the specific parameters evolution in the approached theoretical models shows the following aspects:

- parabolic regression theoretical model is superior to the linear one, regarding the amplitude of root deviation evolution;
- parabolic regression theoretical model determines a smaller variation in the size value of the recorded sample;
- parabolic regression theoretical model has a better fidelity regarding the simulation of the monitored parameter value;

8. Considerations regarding the monitoring systems particularities

In purpose of prediction, a few methods for theoretical estimation of the time until occurrence of undesirable event were presented above.

Taking into account the fact that the normal evolution of the monitored parameter values shows a certain limited variation, interpreted like noise, can say that different statuses in the technological system can exist. Each of these statuses has an influence over the variation dynamic of the monitored parameter value.
In a harsh way, it can be sad that multitude statuses of technological system can be divided in two large groups. One of them represents the multitude of normal operating statuses and the other group represents the multitude of abnormal operating statuses with the effect of escalating the measured parameter values.
The issue of identifying “normal” behavior regarding variation dynamics of the monitored parameter is brought forward.
If the “abnormal” evolution of the monitored parameter value is taken into account, this can be determined by an accumulation, explosion or release phenomena.
Forward, an attempt is made to underline the specific “abnormal” character in the variation dynamics of a release phenomenon, for the monitored parameter, by using the previously presented and experimented theoretical models.
Intuitional, by taking into account that the pneumatic systems present a quadratic dependency of the pressure loss relative to flow rate, one can say that the prominent parabolic evolution appreciation can reveal an “abnormal” release phenomenon in the technological system.
Thus, if the evolution dynamic of the monitored parameter value is a positive one and “a” coefficient is positive also, one can appreciate, function of the value of this coefficient, that the technological system has a specific abnormal dynamic for a release phenomenon.
In the diagram from figure 19 the value of “a” parameter, function to the evolution dynamic value of the monitored parameter value, is presented.
Analysis of the diagram in figure 19 shows a similar evolution both for the first region of the monitored parameter values and for the second region of it, that is OAB~OCD.
In this deformed triangles, the sequences OA and OC respectively, correspond to the increase region of the monitored parameter value. The sequences ABC and CDO respectively, correspond to the region with a negative dynamic of the monitored parameter value.
The identical part of OA and OC sequences shows a clue about a common characteristic of the two evolutions. This situation leads us to an identical qualitative manifestation.
Points A and C are critical points in evolution of the monitored parameter value on the two regions.

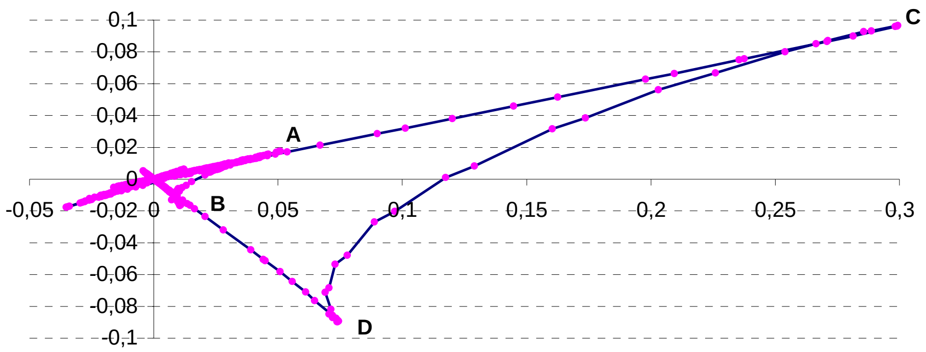

Fig. 19 Parabolic model – value of “a” coefficient function of time

9. Conclusions

Taking meta-parameters (derived parameters) into consideration, such as estimated time lapse until undesirable event occurrence and variation rate of monitored parameter, represents a justified effort.
Filtering the noise associated to measured parameter can be efficiently made by using polynomial regression theoretical models.
Consideration of some higher-degree polynomial regression models permits to obtain better predictions.
The initial choose for the sample size of the last measured values remains a challenge.
Usage of monitoring systems represents an efficient possibility to identify instantaneous status of associated technological systems and also their possible evolution.

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