Fuzzy with LabVIEW Software for Reliability Prediction at Nuclear Complex System (NCS)

VASILE ANGHEL
Research Department
National Research and Development Institute for Cryogenics and Isotopic Technologies – ICIT
Rm.Valcea, Str. Uzinei nr.4
ROMANIA
vasile.anghel@gmail.com

Abstract: - The reliability level for a nuclear installation is given in generally by the technological process quality of operation and maintenance and in particular by a lot of technical, technological, economic and human factors.
The maintenance role is fundamental for a nuclear installation.
In the maintenance activity as in any dynamic area, appear continuously new elements which, sometimes, require new methods of approach, thus for considered installation that is a Nuclear Detritiation Plant (NDP) existent as part of National Research and Development Institute for Cryogenics and Isotopic Technologies – ICSI, Rm.Valcea, for assurance the reliability level in operation is proposed for predictive maintenance the theory fuzzy, entropy theory and software LabVIEW. The final aim is to achieve the best practices for maintenance of Plant that process tritium.

Key-Words: - **simulation, nuclear, reliability, maintenance, LabVIEW**

1 Introduction

A Nuclear Complex System (NCS) suppose best practices for taken decision in many operational problems. For the activity of operative maintenance is proposed the entropy method for historical data of operational maintenance and for predictive maintenance is quantified the reliability prediction with fuzzy logic method.
The reliability in operation of the equipments from NCS is in pressing connection with the maintenance achieved those which has to improve the reliability through methods and advanced techniques.
For the complex equipments from NCS, the reliability is studied also in pressing connection with maintenance, which is defined as the ensemble of all actions that are associated, effectuated in the aim maintain or a reestablishment of industrial product up to achieve specified function.
The maintainability is the aptitude of an industrial product, in given utilization conditions, to be maintained and re-established up to achieve specified function, then maintenance is effectuated in given condition, with proceedings and specified remedies.
At the general mode the reliability on some interval is a conditioned probability by good operation at the beginning of the interval, representing thus the probability as the element which operated at t = t0 to operate in the interval (t0; t1), too.
The failure is the fundamental event in the reliability theory. Through breakdown (failure) is understood the stop process of the function imposed of a product, the failure representing the effect of the process. The operation of a product on a certain duration can be a “success" or a “failure".
Through present paper is followed the realization of a quantify method of the reliability NCS through monitoring of vibrations and choose the best activity of operative maintenance in given conditions from determined alternate like in figure 1 of complex equipments applying the fuzzy theory.
The fuzzy technique for modelling is a model informational, used in special for the systems for which structured identification is difficult or impossible.
The fuzzy systems are based on rules, obtained through the experimental behaviour observation of real system, applied of a linguistic variable.

2 Problem Formulation

It is considered as the technology of process in installation NCS is normal therefore unchanged. The fuzzy system conceived as model is foreseen with a linguistic input variable: likelihood of failure based on vibration monitoring (P) and a value of exit: reliability level as the maintenance for reliability (CD). It is considered that is not intermediate variables.
The fuzzy logic principles have been adopted in many different fields. In this paper and in addition (Ref. 1) is applied the fuzzy logic for maintenance domain,

respective for taken decision in operative maintenance that process in a nuclear plant.
This paper represents another aspect for implementation fuzzy logic in prediction of reliability level for a nuclear plant.
For the reliability level assessment will be analyzed three input data:

- Operational problem which is the entropy for alternate activities in operative maintenance (Figure 5);
- Probability (P) - probability of failure;
- Consequence of severity (CD) – critic aspect.

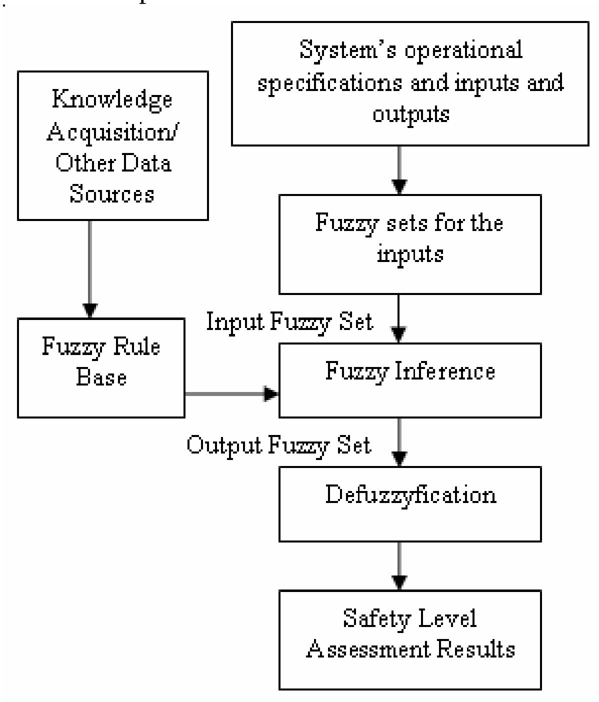


Fig. 1. The conceptual model (general process for system design) of the fuzzy logic reliability level assessment system

3 Problem Solution

The availability problems become extremely complex, characterizing through methods of calculation, proper economical and organization principles.
Bellow we will develop the principal aspects of conception, organization and efficiency of the availability.
The efficiency measure of the designing action is realized in the maintenance stage as product, through the availability level, on which technical designed system has it, because a big part of the maintenance and reliability is defined at designing.
The unavailability problems become a reality that must substantiate scientific, for to offer support in designing or re-designing through the feedback that can be realized on life cycle of the product.
The studies achieved in world plan, demonstrated that the preoccupations for elimination of the unavailability entrain incomparably smaller expenses than damages produced by function in conditions by deficit of the technical complex system like is for example an industrial installation by type process. The cause that sustain the mentioned aspects is that exist a lack of the "guarantees" scientific substantiated and quantified, of the equipments suppliers, of the designing and assembly organizations, of the organizations for training design, exploitation and maintenance personnel towards technical and technological operational effects quantified to beneficiary.
In this context present a real interest the conception demarche for unavailability elimination to the administration beneficiary of services with technical system considered. So, the compulsions which beneficiary is supposed, as example by nuclear regulation and authorization for the operation TCS nuclear considered, respectively compulsions of terms and costs from final customer, beneficiary of services will be well supported.
Starting from the general model in Figure 2, for generating and accumulating knowledge [12], it will be helpful in understanding design for nuclear maintenance of the complex systems and of the research afferent processes: The knowledge for design is generated and accumulated through action.
The process is shown that a cycle in which knowledge is used to create design works and works are evaluated to

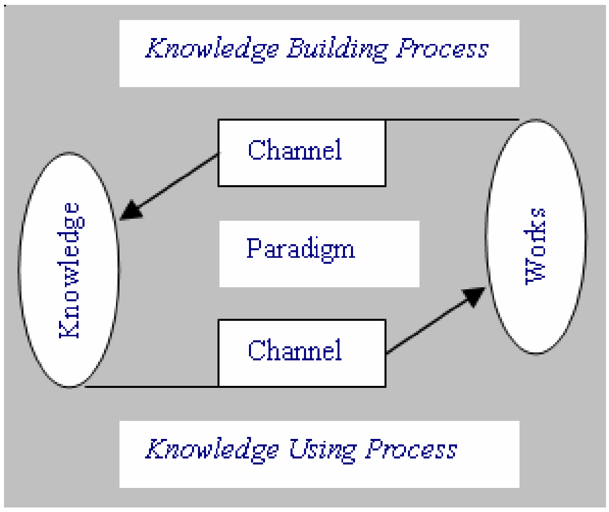


Fig. 2. A General Model for Generating and Accumulating Knowledge

build knowledge. The *channels* in the diagram of the general model are the systems of conventions and rules under which the life cycle operates.

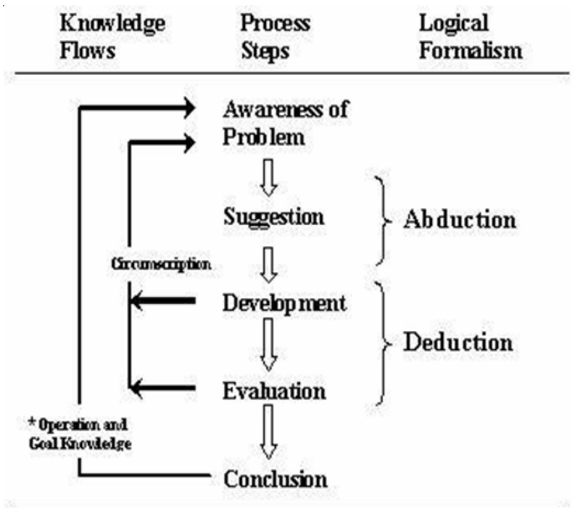
It is analyzed for knowledge process (Figure 2), the reasoning that occurs in the course of general design cycle illustrated in Figure 3. This diagram can be interpreted as an elaboration of the *Knowledge Using Process* arrow in Figure 3. In following the flow of creative effort through this diagram the types of new knowledge that arise from design activities and the reason that this knowledge is most readily found during a design effort will become apparent.

Depending on the role and complex technical system destination (by type nuclear process), respective the task curve covering of the nuclear system, the availability and unavailability indicators are defined on basis of time, power and energy statistics.

At conception phase the TCS designer, pre-determine (prognosis) the availability indicators of the designed objective, planning the medium process production annual (e.g. Energy, Heavy Water Detritiation, etc.).

The availability indicators prognosis suppose like in Figure 4:

- The reliability indicators knowledge of the component elements from statistic of similar elements function, from processing of resulted data, from the tests accomplished by supplier or from special studies achievement in this scope;



* An operational principle can be defined as “any technique or frame of reference about a class of products or its characteristics that facilitates creation, manipulation and modification of forms” [15]; [16].

Fig. 3. Reasoning in the Design Cycle

- The using of the most adequate probabilistic model (Binomial Method, The method of Markov Chains with continuum or discreet time, the Monte Carlo simulation method, the method of events and failure tree, etc.) in purpose of reliability and availability indicators calculus at the TCS level;
- The context knowledge in which has been determined the reliability and availability indicators of the components elements and of the conditions in which will evolve the new objective.

Usually the obligations of equipments suppliers are stipulated in technical conditions or sale/buying papers through general foresights, un-quantified and insufficient of precise formulated. In present is determined that more firms in world organize their reliability and availability services and they are in position to offer guarantees.

The statistic studies accomplished and the numerous case analyses has emphasized the objective necessity as supplier to offers guarantees concerning: the reliability indicators, the availability indicators, life cycle of the equipment with indication of lapping, maturity and ageing periods (life curve of the equipment) and to transmit to beneficiary the concrete instructions concerning the maintenance conditions and professional structure of the maintenance equipments, the spare parts stock, etc.

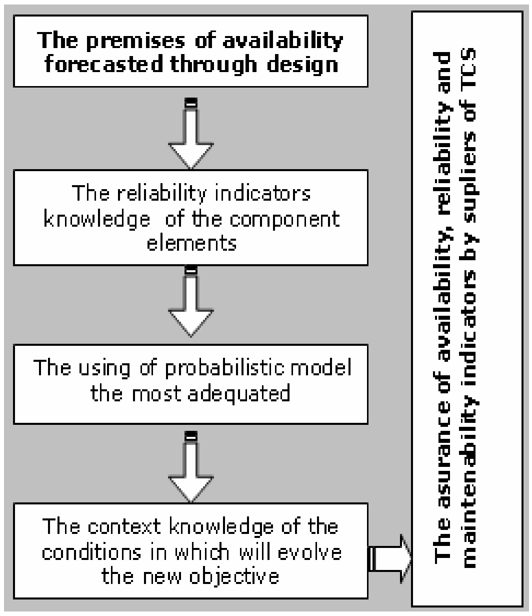


Fig. 4. The integrated availability engineering in designing

3.1 The reliability indicators knowledge of the components elements

The availability, respective the unavailability of a TCS defines the capacity/ incapacity of the system to accomplish a given function at a given moment or in certain time interval, if respect the following conditions:

The availability D(t) and the unavailability U(t) have signification of probabilities;
The sum of the availability and unavailability at a given moment or for a time interval is:

$$P(D)+P(U)=1 \quad (1)$$

The availability of a system with ***n*** elements connected in series:

$$D=\prod_{i=1}^{n} D_i \quad (2)$$

The availability of a system with ***n*** elements connected in parallel:

$$D=1-\prod_{i=1}^{n} U_i \quad (3)$$

The instantaneous values and medium values of the availability and unavailability for the systems in function are determined on basis of time, power and energy statistics;
The availability value is determined by component elements reliability, by technical level of the maintenance actions and by the personal training degree;
The maintainability (M) is the probability as an element or a system to be restored in function in a certain time interval and the actions that assure the achievement of the maintainability indicator are named maintenance actions:

$$M=1-e^{-\mu t_0} \quad t<t_0; \quad \mu=\frac{1}{M[T_0]}[h^{-1},s^{-1}] \quad (4)$$

The maintainability constitutes the totality of the scheduled and unscheduled actions of testing, maintenance and repair with a view to obtaining of safety given level, of a wanted level of availability and security;
For as in ensemble the operative maintenance activity to be efficient, the next factors have to be taken in consideration still from the first phases of the designing and progressive improved according as the project advance: the criteria concerning repairs; the analyses and the maintainability predictions; the factors specific to the project that affect the maintainability; the human factors that affect the maintainability;
The availability and unavailability indicators at TCS in function are determined on time basis as:

$$T_c=T_f+T_{ment.prev}+T_d \quad (5)$$

The calendar time (T_c), at the level of a year is decomposed in function period (T_f), preventive maintenance periods ($T_{ment.prev}$) and failure periods (T_d) or corrective maintenance.
In these conditions the indicators A and U will have the expressions:

$$D=\frac{T_f}{T_f+T_{ment.prev}+Td}100\% \quad (6)$$

$$U=\frac{T_d+T_{ment.prev}}{T_f+T_{ment.prev}+Td}100\% \quad (7)$$

In this context a real interest presents the comparison of the availability indicators prognosis in the project phase with the operational availability indicators determined on basis of exploitation data. The maintainability were neglected long time in the process of applicative product research, which led at higher prices for settlement, putting into operation, maintenance and repair of the products in the guarantee period and after guarantee period.
The maintainability analysis is based on requirements identification concerning the operative maintenance and on the technologies and methodologies choice that assure the satisfaction of these requirements. In such of analysis are contained the following activities:

- The description of the maintenance activities tasks (for example the preventive maintenance);
- The choice of the repairs criteria;
- The establishment of the components, subsystems and systems repairs duration;
- The elaboration of localization methods of the failures;
- The requirements specification concerning the attempt equipments and the devices for repairs;
- The conditions establishment that have to achieve the technical books and spare parts;
- The specification of the number and of the personal categories necessary for maintenance and also of its training necessities.
- The reliability indicators are characteristic measures that permit the quantitative appreciation of the devices reliability level.

The reliability function represents the probability as at the considered moment *t*, a device found in given utilization conditions to achieve the specific functions and the probability as the moment *T* at which is produced the failure has to be bigger than the current moment, *t*.

$$R(t)=\frac{N(t)}{N_0} \quad (8)$$

For $t=0$, R, $R(0)=1$
For $t\rightarrow\infty$, $R(\infty)=0/N_0=0$
Where: *N (t)* is the devices number found in good stage of function at the ***t*** moment;
N_0 – the devices number from who were made initially the sample subdued to observation.
The reliability function permits:

The appreciation of the trust level in the utilization of a device at a certain moment *t* from his life;
The comparison of the reliability level of a devices achieved by different producers;
The comparison of the utilization conditions of some devices achieved by the same producer, but found at the different users.
In general reliability is:

$$R(t) = e^{-\int_0^t z(t)\,dt} \tag{9}$$

If $z(t) = const. = \lambda$, $R(t) = e^{-\lambda t}$

The probability as a device that was found in good stage of function at t_1 moment to be in the same stage also at the moment $t_2 > t_1$.

$$R(t_2) = e^{-\int_0^{t_2} z(t)dt} = e^{-\int_0^{t_1} z(t)dt - \int_{t_1}^{t_2} z(t)dt} = R(t_1)\cdot e^{-\int_{t_1}^{t_2} z(t)dt}$$

$$R(t_2 / t_1) = e^{-\int_{t_1}^{t_2} z(t)\,dt} = \frac{R(t_2)}{R(t_1)} \tag{10}$$

3.2 The utilization of the most adequate probabilistic model

For the emphasizing of this stage is had in sight for nuclear TCS the preliminary approaching of the informational entropy method combined with economical method of evaluation of the operational maintenance in the context of operation in safety. The optimum management of TCS needs the circulation of a big volume of information of which collecting, processing and storage oblige us to the organization of a hierarchic informational system structured and superposed to the basis system.
The nuclear TCS in its ensemble and the component subsystems evolve through normal stages and failures stages for each from these stages, could so be affected the afferent probabilities of success and unsuccessful.
In this meaning will consider that M_s represents the set of components subsystems of a TCS where:
i=1,2,3,…n and $M_s=\{S_1, S_2,\dots S_n\}$ (11)

If we note M_{sk} the subsystems set of which failure of any from the set subsystems M_{si}, the failure of some from the set subsystems M_{sSTC} has as consequence non-function of some subsystems belonging to the M_{si} set. From here we deduce that the well function of the whole system TCS depend finally by well function of the components subsystems of the M_{sk} set, meaning that any from systems belonging to M_{sk} set imposes the function regime to the whole system TCS.

$$M_{sk} = \{S_1, S_2, \dots, S_n\} \tag{12}$$

$$M_{si} = \{S_{n+1}, S_{n+2}, \dots S_{n+p}\} \tag{13}$$

$$M_{sSTC} = \{S_{u-n+1}, S_{u-n}, \dots S_u\} \tag{14}$$

Let's be $E(S_1)$, $E(S_2)$,..., $E(S_n)$, the events to not function any from the set subsystems M_{sSTC} and *E(S)* the events non-functional TCS. In these conditions results:

$$E(S') = E(S_1) U E(S_2) U \dots U E(S_n), \tag{15}$$

respective the event of well function of the system will be:

$$C_E(S') = C_E(S_1) \cap C_E(S_2) \cap \dots \cap C_E(S_n) \tag{16}$$

If: $q(S_k)$, means the probability to failure any from the subsystems belonging to the $M(S_k)$, in hypothesis that the failure of each from the S_k subsystems is independent, meaning that the $E(S_k)$ events are independent results that the probability of well function of the energy system will be:

$$q[C_E(S_1) \cap C_E(S_2) \cap \dots \cap C_E(S_k)] = \prod_{k=1}^{n} q.C_E(S_k) \tag{17}$$

The entropy expression of the energetic system stage that it was associated the events field with the probabilities of appearance p_i will be:

$$H = -\sum p_i [H(S_k) \log p_i [E(S_k)] \tag{18}$$

For a complete field of events with the probabilities p_i, respective

$$\sum p_i = 1, \ H = -p_i \log p_i \tag{19}$$

The matrix of events and of the probabilities associated has the form:

$$\begin{pmatrix} E_1 & E_2 & E_3 & \dots & E_n \\ p_1 & p_2 & p_3 & \dots & p \end{pmatrix}, \text{ with } \sum_{i=1}^{n} p_i = 1 \tag{20}$$

If we consider that the system evolves in two stages: one of function with the probability ***p*** and another of failure with the probability ***q***, the system entropy expression will be:

$$H = -(p \log p + q \log q) = -[p \log p + (1-p) \log(1-p)] \tag{21}$$

In the TCS case we are interested to determine the entropy evolution to the probability variation of success or of damage under form:

$$H = f[p(E)] \tag{22}$$

The matrix of events field $E(S_k)$ will be by form presented previous and if we take as basis only the function stages *(F)* and damage *(D)* with the probabilities associated p and q, respective $1\text{-}q$ and q, where p is the probability of function and q is the probability of failure:

$$M = \begin{pmatrix} F & D \\ p & 1-p \end{pmatrix} \quad (23)$$

$$H = -[(1-q)\log(1-q) + q\log q] \quad (24)$$

Where $q \in [0,1]$

To find the maximum point of entropy will derive in report q, respective:

$$\frac{dH}{dp} = 0 \quad (25)$$

and will find that

$$H = \log 2 \quad (26)$$

and for q=0,5 results H_{max}=1, who represents the point of total uncertainty, so by maximum entropic activity, respective the highest point of disorganization of the system.

From the function graphic $H=H(q)$ is observed that for q>0,5 the entropy increase, but this area don't represent interest from the point of view of the system exploitation: the signification of the entropy increasing $q \in [0{,}5;1]$ will be that the system is approached more and more sure by a stage on non-function, so we have a certainty more and more bigger concerning the system disorganization.

It is constituted that the increasing of the entropic level is obtained through the increasing of events appearance probability $E(S_k)$, meaning of failure appearance of any from the sub set subsystems M_{sk}.

Consequently the entropy law application to the designing and the exploitation of the nuclear complex technical systems can be changed in a choice criterion of the variants, having priority the variants with a lower level of entropy.

Of course that this represent only a criterion that will must in practice associated to other criteria and finally to the total expenses actualized method who synthesize the influence factors totality, but must have in sight that this criterion put in evidence the tendencies of input in abnormal stages, that oblige us to give it an major importance. The importance of the "minimum entropy production" criterion appears also from the point of view practice as a result of influence that have it the maintenance activities, the training level of the exploitation personal, etc.

The TCS systems are characterized in normal way through a information flux cvasiconstant composed from two components:

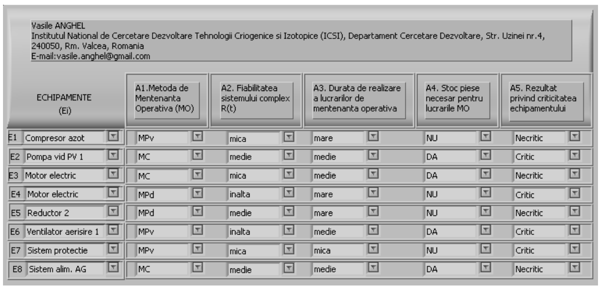
Continuous information, delivered by meters;

Discontinuous information delivered by the failure stages from system with a distribution somehow equable during the year.

Consequently in the cvasinormal regimes of the system that represent in fact the normal situation, the entropy H=0. The extended failures of system or the failures generalized at level of nuclear installation modules are characterized through a specific informational level very high (million of bits/h).

In such situations the entropy tend to H_{max} and this level must interpreted as a moment of maximum confound, moment in which appear the logical engineering decisions of failure extension liquidation, of reputing into operation of a new nuclear modules, etc. In the concrete case of the nuclear systems, even in the situation of a extended failures of systems q<0,5 and $H<H_{max}$.

The proposed fuzzy logic for reliability level prediction of technical system assessment consists in: achievement entropy for considered attribute of operative maintenance condition from historic data (Figure 2), the



Vasile ANGHEL
Institutul National de Cercetare Dezvoltare Tehnologii Criogenice si Izotopice (ICSI), Departament Cercetare Dezvoltare, Str. Uzinei nr.4, 240050, Rm. Valcea, Romania
E-mail:vasile.anghel@gmail.com

ECHIPAMENTE (Ei)	A1.Metoda de Mentenanta Operativa (MO)	A2. Fiabilitatea sistemului complex R(t)	A3. Durata de realizare a lucrarilor de mentenanta operativa	A4. Stoc piese necesar pentru lucrarile MO	A5. Rezultat privind criticitatea echipamentului
E1 Compresor azot	MPv	mica	mare	NU	Necritic
E2 Pompa vid PV 1	MC	medie	medie	DA	Critic
E3 Motor electric	MC	mica	medie	DA	Necritic
E4 Motor electric	MPd	inalta	mare	NU	Critic
E5 Reductor 2	MPd	medie	mare	NU	Necritic
E6 Ventilator aerisire 1	MPv	inalta	medie	DA	Critic
E7 Sistem protectie	MPv	mica	mica	NU	Critic
E8 Sistem alim. AG	MC	medie	medie	DA	Necritic

Fig. 5. Simulation for historic data of operative maintenance

realization modeling and simulation for the considered attributes A_1, A_2, … A_5, for equipments E_1, E_2, … E_8 and in the second step realization the fuzzy rule base, fuzzy inference engine, fuzzyfication and defuzzyfication like in Figure 9.

It is notes with A_1 the methods for operative maintenance: Preventive Maintenance (MPv), Corrective Maintenance (MC) and Predictive Maintenance (MPd); with A_2 historic reliability; with A3 the time for operative maintenance; A_4 the store pare parts and with A_5 the criticity for the equipment E_i, with i= 1 …8.

The entropy expression of the nuclear system stage that it was associated the events field with the probabilities of appearance p_i will be:

$$H = -\sum p_i[H(S_k)\log p_i[E(S_k)]$$

For a complete field of events with the probabilities p_i, respective $\sum p_i = 1$,

$$H = -p_i \log p_i$$

The matrix of events and of the probabilities associated has the form:

$$\begin{pmatrix} E_1 & E_2 & E_3 & \dots & E_n \\ p_1 & p_2 & p_3 & \dots & p \end{pmatrix}, \text{ with } \sum_{i=1}^{n} p_i = 1$$

If we consider that the system evolves in two stages: one of function with the probability ***p*** and another of failure with the probability ***q***, the system entropy expression will be:

$$H = -(p\log p + q\log q) = -[p\log p + (1-p)\log(1-p)]$$

In the NCS case we are interested to determine the entropy evolution to the probability variation of success or of critic damage under form $H = f[p(E)]$.
The matrix of events field $E(S_k)$ will be by form presented previous and if we take as basis only the function stages (F) and damage (D) with the probabilities associated p and q, respective 1-q and q, where p is the probability of function and q is the probability of failure:

$$M = \begin{pmatrix} F & D \\ p & 1-p \end{pmatrix}$$

$$H = -[(1-q)\log(1-q) + q\log q] \text{ where } q \in [0,1]$$

To find the maximum point of entropy will derive in report q, respective: $\frac{dH}{dp} = 0$ and will find that

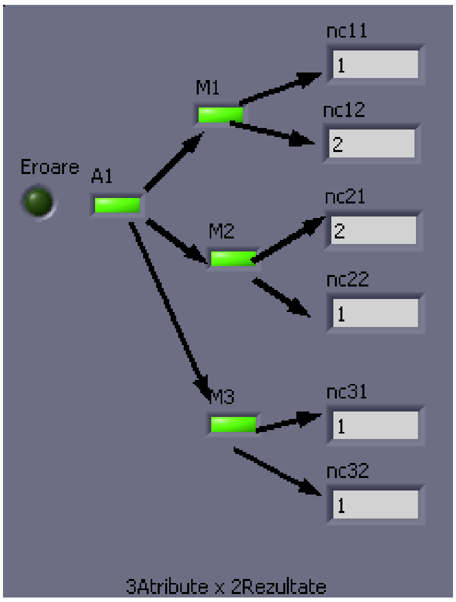


Fig. 6. Simulation for A_1 entropy

$H = \log 2$ and for q=0,5 results H_{max}=1, who represents the point of total uncertainty, so by maximum entropic activity, respective the highest point of disorganization of the system.
From the function graphic H=H(q) is observed that for q>0,5 the entropy increase, but this area don't represent interest from the point of view of the system exploitation: the signification of the entropy increasing $q \in [0,5;1]$ will be that the system is approached more and more sure by a stage on non-function, so we have a certainty more and more bigger concerning the system disorganization.
It is constituted that the increasing of the entropic level is obtained through the increasing of events appearance probability $E(S_k)$, meaning of failure appearance of any from the sub set subsystems M_{sk} which mean A_i for historic operational maintenance data.
For the emphasizing of this stage is had in sight for NCS the preliminary approaching of the decision trees, respective of the informational entropy method combined with economical method of evaluation of the

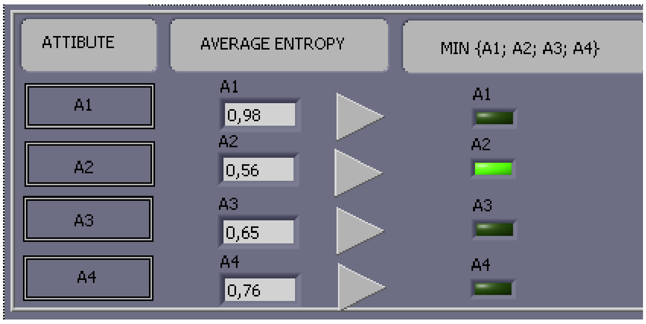


Fig. 7. The minimum entropy determined through simulation

operational maintenance in the context of operation in safety. The optimum management of NCS needs the circulation of a big volume of information of which gathering, processing and storage oblige us to the organization of a hierarchic informational system structured and superposed to the basis system.
It is started from the existent data at tree and is computed the medium entropy of the complete data set for each from 4 attributes.
It is computed the entropy for A1 attribute (the Operative Maintenance Method) like in figure 6. In the same way are computed the entropy for attribute A2, A3 and entropy for attribute A4.
In the end step of first stage is determined the minimal entropy, respective the distribution for the first variable inclusive in fuzzy method (consequence of severity), which variable pertain (0 …1).

$$H=\sum_{M}\left[\left(\frac{n_{ci1}+n_{ci2}}{n_{cijTOT}}\right)x\left[\sum_{c}-\left(\frac{n_{cij}}{n_{ci1}+n_{ci2}}\right)\log_2\left(\frac{n_{cij}}{n_{ci1}+n_{ci2}}\right)\right]\right] \qquad (27)$$

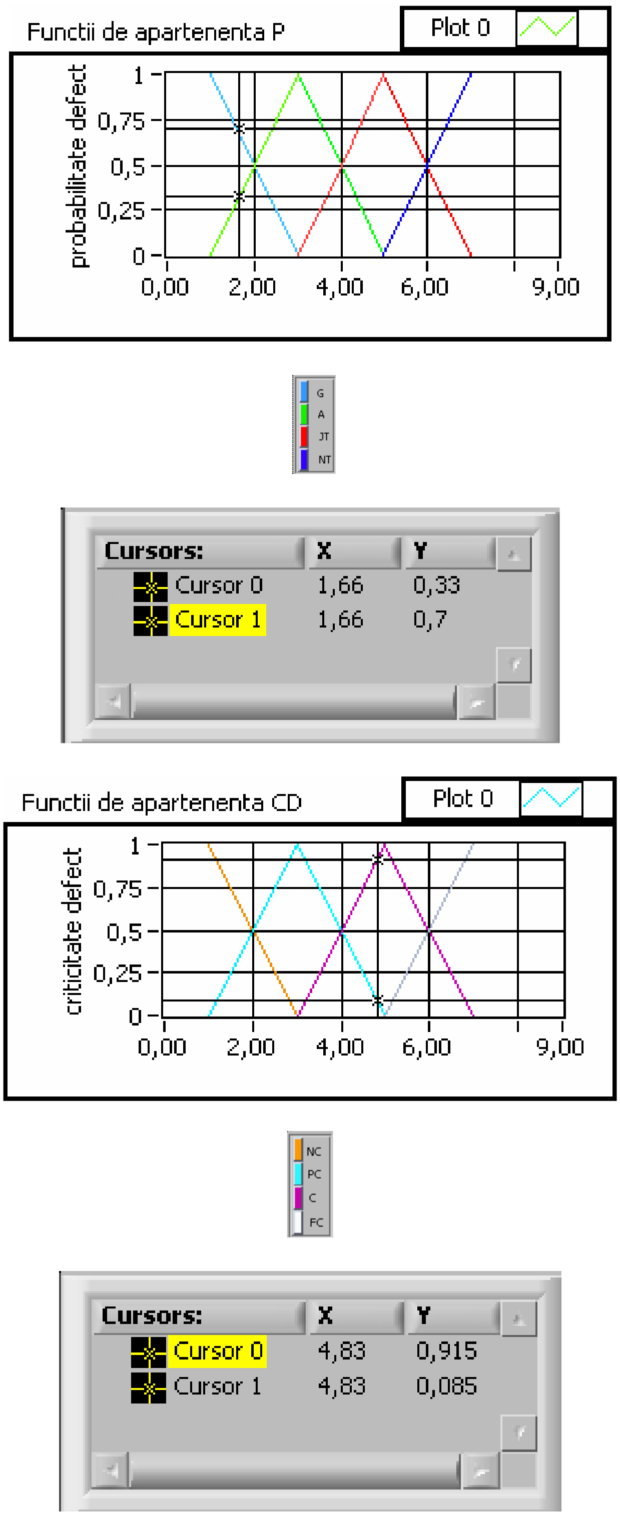


Fig. 8. The membership function with LabVIEW softv
Likelihood (P) and Consequence of severity (CI

The fuzzy rule base in the study estimates each safety level (SL) in three different aspects using two fuzzy (linguistic) variables, i.e. Probability (P) and consequence of severity (CD).

The magnitudes of the linguistic variable of the input and output are described in term of words (linguistic values) such as good (G), allowable (A), just tolerable

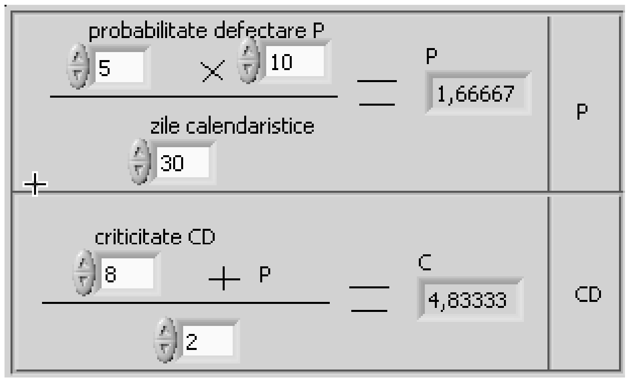


Fig. 9. The quantification of data input for operational problem

(JT) and not permissible (NP) or uncritical (NC), low critic (PC), critic (C), high critic (FC) and very low (VLo), low (Lo), medium (M), respective high (H).

A complete fuzzy rule is written as follow:

"IF (P) is good and (CD) is low critic (PC) THEN SL is low".

Since all rules are initial in crisp form for fuzzy rule base are necessary linguistic values, thus must be a process to convert from quantitative (crisp) values of input data sets to linguistic fuzzy values. This process is called fuzzyfication.

After fuzzyfication process it is necessary to specify the universe of discourse and membership functions.

Membership function decides the characteristic of a fuzzy set and represented with special shapes, height and lines styles (Figure 5).

The input parameter will have to quantify the internal problems and the existent failures for maintainable considered technical objective.

Each from input parameters is quantified in 4 terms of P and CD between 0 and 8 which will be noted with P_T and CD_T and the output of the safety degree (or risk) will be noted with SL_T.

The membership function will be noted corresponding to the used parameters with µP(t), µCD(t) and respective µSL(t).

Based on a universe of discourse and membership functions, the fuzzy sets can be built like in Figure 8.

3.1. The quantification of the input data set for safety

The probability value is directly reported to the number of recordings about the problems appeared in operation registered and monitoring through vibrations analysis for

30 days from the moment in condition exchange by function when the amplitude of vibration for the equipment considered begin to increase.
So:

$$P_{T=}\frac{quantity\_of\_reported\_defaults}{30}\times 10 \qquad (28)$$

On the other side the consequences because the severity of the failure belonging the operational considered problem depend by P_T value.

$$CD_T=\frac{estimation\_of\_the\_consequences\_\deg ree+P_T}{2} \qquad (29)$$

In this case the values for membership function i.e. for input P will be $\mu(1{,}66)$ like in Fig. 8.

3.2. Fuzzy rule base

After the quantification of the input data the linguistic values can be determined by membership functions. Using the membership functions which have been created and base of fuzzy rules the possible output of the safety level (risk) (SL) can be found in fuzzy rules base (Fig. 6). For different pairs of input data will be found different outputs for safety levels from same base of rules.

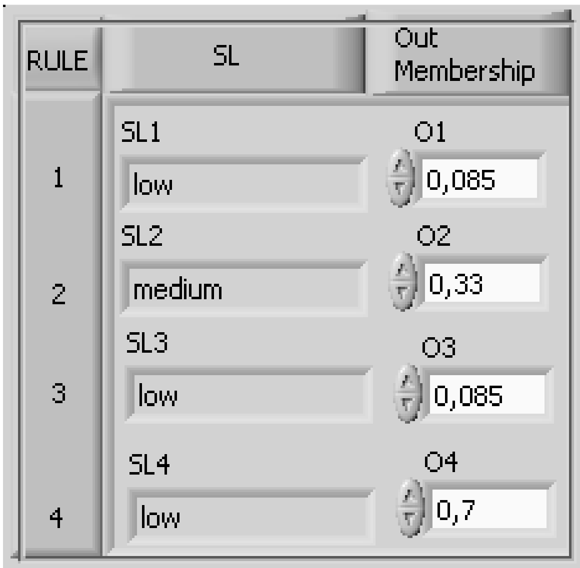


Fig. 10. The outputs values of the membership functions and linguistic values of the SL_T

From Figure 5 is observe the fuzzy inference process in operational problem i.e. that $\mu(1{,}66)$, determined two values 0,33 and 0,7 and $\mu(4{,}8)$, determined two values 0,085 and 0,915.

It will be applied the operator AND which will select minimum of these two values as consequence. The applying of the fuzzy operator give results like those shown in Figure 10 for each rule involved in the evaluation process.
The implications methods are implemented for each rule.
The membership value given by fuzzy operator AND (μ_R) in previous stage become membership value for the output of the consequences level of the failures (SL_T).
The outputs of the rules are combined in only one fuzzy set.
In this stage all four rules are combined in only one membership set for SL_T.
It is used the maximum method.
The maximum of the value for the rule 1, 3 and 4 is the value 0,7 and for rule 2 is 0,33.
Through defuzzyification for the set of values 0,7 and 0,33 is obtained an only value (output) for SL_T.
It is used the method of weight centre in the defuzzyfication process where the mathematical formula is:

$$D_x=\frac{\sum x_i w_i}{\sum w_i} \qquad (30)$$

D_x the defuzzyfication centre of the singular value (crisp) of output which represents SL_T in this case;
X_i: the value of the weight centre of the linguistic value (i);
W_i: the membership value of the fuzzy values set (i).
At completion the defuzzyfication process it is found an equilibrium point. One way to do this using software LabVIEW is with “Center of Gravity method” (Dx).
Using the determined result in aggregation step and equation (30) the final value (crisp) can be obtained as in Figure 11.
The defuzzyfication result is given by 3,64 which means that SL_T is estimated as 3,64 and is in the area between Low and Medium.
It results that the safety during the operational problem considered (vibration) is between (Low critic and Critic).

4 Conclusion

The analysis accomplished over the availability, reliability and maintenance on basis of proper experience and of the information collected from some countries developed showed that the obtaining of some superior indicators can be assured only through an approach on basis of science and technology methods of an ensemble of technical-organizational measures.
The reliability and availability has to become a component of the human behavior, a fundamental component of the modern man conception who carry on their existence in a medium more technique.

Having in sight the characteristic and the specification of nuclear TCS is imposed the elaboration of proper conceptions on the quality programs system.
The quality programs represents an ensemble of indicators, principles, procedures that settle on a

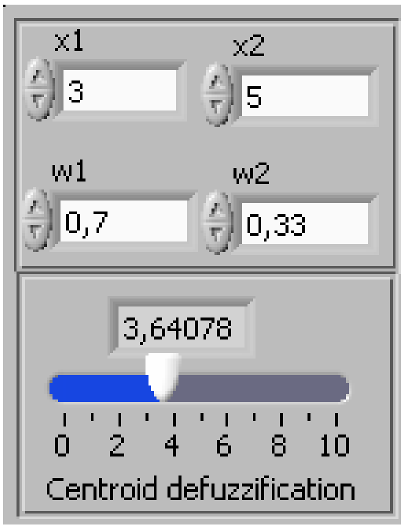


Fig. 11. Center of Gravity (crisp value)

quantified basis and strictly legislated the relationship between designers, suppliers, beneficiaries leading to the followed purposed by maintenance integrated on the life cycle of TCS scientific substantiated.
Using the reliability prediction the decision for maintenance can give an very good answer for the maintenance preventive measures.
As result of the prediction can be considered a evaluation method of the measures which will be taken during life cycle of the considered installation.
Using presented method, respective with a LabVIEW software support and a adequate hardware is realized in final the reliability of the considered plant assuring in fact a dynamical quality in keeping with of the evolution of the monitoring variable for diagnosis through vibrations corresponding behavior of the equipment considered.

References:

[1] Vasile ANGHEL and G. E. DRAGHICI *Simultion for Complex Systems Through Predictive Maintenance*, Modelling of Complex Systems and Environments, July 16-18, 2007 Ho Chi Minh City, Vietnam, p. 189 (2007).
[2] Lawless, J. F. (1987). *Regression methods for Poissonprocess data*. J. Amer. Statist. Assoc. 82 808–815.
[3] Lindqvist, B. H., Støve, B. and Langseth, H. (2006). *Modelling of dependence between critical failure and preventive maintenance: The repair alert model*. J. Statist. Plann. Inference 136 1701–1717.
[4] Pe˜na, E. A. (2006). *Dynamic modelling and statistical analysis of event times*. Statist. Sci. 21 487–500.
[5] Rausand, M. and Høyland, A. (2004). *System Reliability Theory: Models, Statistical Methods and Applications*, 2nd ed.Wiley, Hoboken, NJ
[6] J.. Reifman, Thomas Y. C. Wei, “PRODIAG: A Process-independent Transient Diagnostic
[7] W.W.Lowrance, “Of Acceptable Risk”, William Houfmann, Inc., Los Altos CA, 1976
[8] http://search.ni.com/nisearch/nisearchservlet?nistype=default&ddown=4&filter=%2Btaxonomy:academic&q=fuzzy
[9] L.A Zadeh, “Fuzzy sets”, Information and Control, Vol. 8, 1965, pp.338-353.
[10] V. I. Nitu „*Disponibilitate – Eficienta – Organizare Economicitate*, Buletin ISPE, 1986
[11]V. Panaite, R. Munteanu, *Control statistic si fiabilitate*, Editura Didactica si Pedagogica, Bucuresti, 1982.
[12] Owen, C. (1997). "*Design Research: Building the Knowledge Base*." Journal of_the Japanese Society for the Science of Design 5(2): 36-45.
[13]Takeda, H., Veerkamp, P., Tomiyama, T., Yoshikawam, H. (1990). "Modeling Design Processes." AI MagazineWinter: 37-48.
[14]Dasgupta, S. (1996). *Technology and Creativity*. New York, Oxford University Press.
[15]Purao, S. (2002). “*Design Research in the Technology of Information Systems: Truth or Dare.*” GSU Department of CIS Working Paper. Atlanta
[16] Vasile ANGHEL *New conceptual method in maintenance with application in cryogenics pilot plant (CPP)*, WSEAS-Transactions-on-Environment-and-Development. July 2006; 2(7): 968-72 Journal-Paper