3D REPRESENTATION OF OPERATIONAL AVAILABILITY OF BIHOR POWER SYSTEM EQUIPMENTS

Cîmpan M., Felea I., Boja I., Albuţ-Dana D., Rancov N.

Universityof Oradea, Energy Engineering and Industrial Management Faculty
mcimpan@uoradea.ro,ifelea@uoradea.ro

Abstract: The paper is part of traditional concerns of Energy Engineering Department from University of Oradea, aiming operational performances identification of equipment of power systems in collaboration with specialists who operates these systems. Based on previous analysis results, existing in databases which are updated yearly and using fundamental reliability indicators, this paper aims to highlight the 3D evolution of equipment operational availability, admitting a random variation of fundamental reliability and maintainability indicators of equipment. After justification of the need of these preoccupations, in the second part of paper, it is presented the mathematical model that stands at the base of 3D representation of operational availability. The third part contains the results referring to EEP from Bihor county PS. In the last part the conclusions are drawn.

Keywords: operational availability, electrical equipment, simulation

1. INTRODUCTION

The significance of operational reliability studies of electrical equipment (EEP) belonging to power systems is well known [1…4]. These studies assumes the constant tracking of behavior of EEP while operating, event recording, causes and failure modes identification, constant processing of results and operational reliability and availability indicators determination. The main objectives of operational availability studies are:

- Scientific substantiation of EEP stock and acquisition policy, at subsidiary level or at power transport and distribution branches level.
- Adequate elaboration of EEP maintenance strategies.
- Prediction evaluation concerning continuity indicators regarding supplying with power of consumers.

Establishing the real values for reliability/maintainability/availability indicators of EEP, values that are actually used in contractual relationship with power purchasers and in planning studies for SEE extension. The authors of current paper are involved in RMA (reliability, maintainability, availability) studies carried out on EEP and electrical installations from power system (PS), mainly Bihor county PS. In these RMAanalyses of whose results were used by some power distribution branches which they have ordered, RMA indicators have been determined for main components of power distribution network: power transformers 110kV/MV and MV/LV, MV and HV power switches, HV and MV power insulating switches, measurement transformers, power surge protector with variable resistance, OHL components and UELcomponents. The results were materialized, among others, by the existence of some values, which can be considered averages for RMA indicators: failure intensity((λ), corrective maintenance intensity((μ), MTBF, MTMC, reliability(R), maintainability(M), availability(A), distribution of random variables TBF and TMC and sometime evolution in time of indicators(R, M, A). This approach is considered by some of the authors as deterministic[5] while this paper propose a stochastic approach of RMA indicators and a 3D approach of operational availability for EEP. This approach rely on the hypothesis that, in fact, fundamental indicators (λ, μ, TBF, TMC) have random values which can have various distributions. So there are taken into account exponential, normal, Pert and triangle distributions [2, 6, 7, 8].The reference values (averages, minim, maximum, deviation) used to generate these distribution of random values are those obtained from RMA studies already carried out on equipment in question.

2. MATHEMATICAL MODEL

We are analyzing in term of 3D evolution **time availability of EEP**. The dedicate mathematical expression for it is [1, 2, 4]:

$$A(t, t_M) = R(t) + F(t) \cdot M(t_M) \qquad (1)$$

where:
t –RVoperation time
t_M – RV maintenance time

Now in EEP are distinguished more clearly two types of EEP:

- very important EEP for PS availability, on which are carried out diagnostics on-line or off-line when failure tendency(parametric) it's sensed and EEP is passed to maintenance status if necessary;
- less important EEP for PS availability (can be those in reserve) on which there are not carried out preventive maintenance works but only corrective maintenance works (on failure).

Associating preventive maintenance works that are carried out based on diagnostics with those of corrective maintenance (when we have a parametric failure) we can consider that basically expression (1) $t_M = t_{MC}$. RV(t,t_M) distributions can be various, most commonly being those listed in the first part of this paper that are also used on published papers. If the distributions of the two RV are exponential then the expression of "A" indicator becomes:

$$A[(t,t_M),(\lambda,\mu)] = e^{-\lambda t} + (1-e^{-\lambda t})(1-e^{-\mu t_M}) \qquad (2)$$

In expression (2) we've highlighted two sets of RV(λ,μ) and (t,t_M) which will be used to highlight 3D evolution of "A" indicator, the three dimensions being, as appropriate, (A,t,t_M) or (A,λ,μ).

Used distributions are:

a) Exponential distribution

Exponential distribution in @Risk is represented by RiskExpon(beta) function, where beta value must be positive. Average value of distribution is equal with beta value. This distribution represents the equivalent continuous time for geometrical distribution and waiting time for the first event that are expected to happen. This process is constant in time and in intensity and can be used for maintenance and failures modeling [9].

The expression for exponential distribution is:

$$F(x) = 1 - e^{-x/\beta} \qquad (3)$$

where,

The random value x must belong to range:

$0 \le x < +\infty$

β- is the average of distribution, $\beta>0$;

b) Triangle distribution

Triangle distribution in @Risk is represented by RiskTriang (minim, most probable, maxim) function. Direction of "tilt" for triangle distribution is set by relative average value. This distribution is probably the most pragmatic and most easy to understand for basics models, having some properties including a simple set of parameters. Distribution is delimited at both ends which is a disadvantage because on everyday life the processes are delimited only on one end [8, 10].

$$F(x) = \frac{(x-x_{min})^2}{(m-x_{min})(x_{max}-x_{min})}; x_{min} \le x \le m \qquad (4)$$

$$F(x) = \frac{(x_{max}-x)^2}{(x_{max}-m)(x_{max}-x_{min})} m \le x \le x_{max} \qquad (5)$$

where,

x_{min} – minimal value of RV a VA "x";

x_{max} – maximal value of RV "x";

m - – average value of RV "x";

c) Normal distribution

Normal distribution in @Risk is represented by RiskNormal(average, standard deviation) function. Normal distribution is a symmetrical continuous distribution which is not delimited on both sides and is described by two parameters [8]:

The expression for normal distribution is:

$$F(x) = \emptyset\left(\frac{x-m}{\sigma}\right) = \frac{1}{2}\left[erf\left(\frac{x-m}{\sqrt{2}\sigma}\right)+1\right] \qquad (6)$$

$m = \frac{1}{2}\sum_i x_i$ - average

$\sigma = \sqrt{\frac{\sum_i (x_i-m_n)^2}{n-1}}$ - standard deviation

d) Pert distribution

Pert distribution in @Risk is represented by RiskPert(minim, most probable, maxim)function, which is a special shape of beta distribution, with minimal and maximum values specified. Shape parameter is calculated from defined value "most probable". This distribution is somehow like triangle distribution, meaning that it has the same three parameters. Technically is a special case of a scaled Beta distribution (or BetaGeneral). So it can be used as a pragmatic and easy to understand distribution [8, 11].

The expression for Pert distribution is

$$F(x) = \frac{B_z(\propto_1,\propto_2)}{B(\propto_1,\propto_2)} = I_z(\propto_1,\propto_2) \qquad (7)$$

$$z = \frac{x-x_{min}}{x_{max}-x_{min}} \qquad (8)$$

$$\propto_1 = 6\left[\frac{m-x_{min}}{x_{max}-x_{min}}\right] \qquad (9)$$

$$\propto_2 = 6\left[\frac{x_{max}-m}{x_{max}-x_{min}}\right] \qquad (10)$$

where,

B – is Beta function;

BZ – is incomplete Beta function.

Simulation is often done for 10000 iterations (maxim), but it can be done also for 5000, 1000, 500 and 100 iterations.

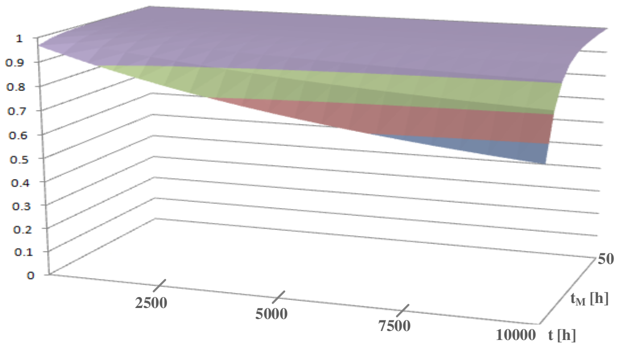
Usually to generate triangles distributions are taken as reference values (most probable) the values obtained from processing the operational data for fundamental indicators (λ, μ). Is allowed a 25% variation of these indicators, such as:

- maximum value (+ 10 %)as against to reference value;
- minimum value (- 15 %) as against to reference value.

3. THE RESULTS

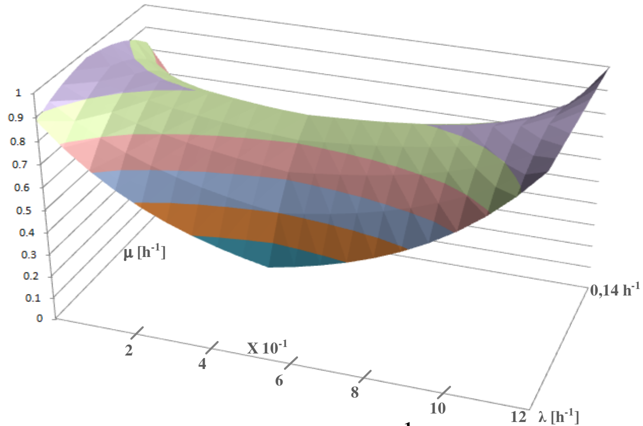
In this frame are presented the results referring to some of EEP from Bihor county SP.

In figures 1 and 2 are shown 3D representations of availability for power transformers with rated power between 1 kVA and 250 kVA from Bihor county PS, considering the triangle distributions for RV (t, t_M) and for RV (λ, μ).



$t_M \in [0; 50]$ h

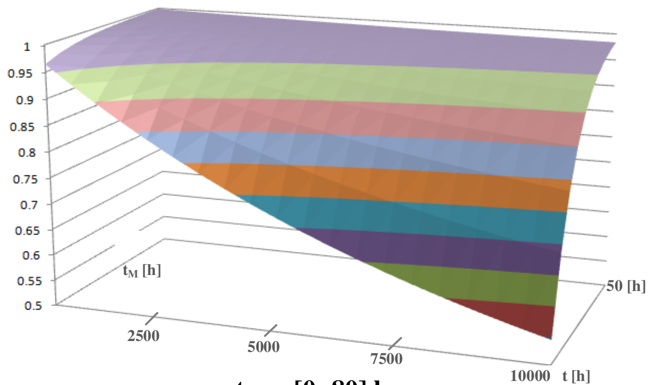
Fig. 1 - 3D representation of PT availability for RV (t, t_M)



$\mu \in [0,02; 0,14]$ h^{-1}

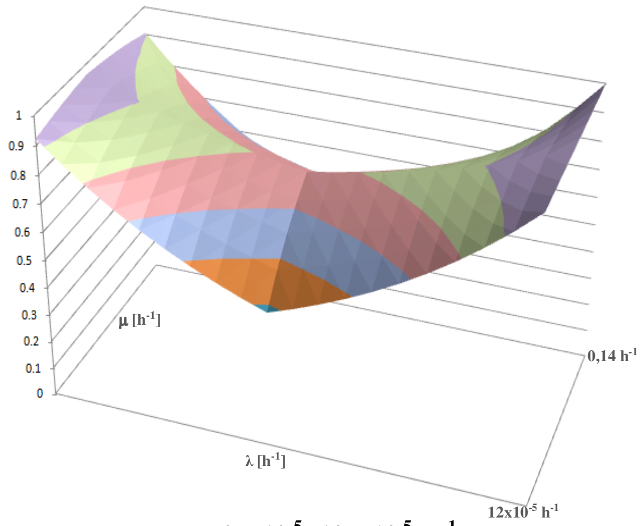
Fig. 2 - 3D representation of PT availability for RV (λ, μ)

In figures 3 and 4 are shown the 3D representations of HV-S availability from Bihor county PS, considering the triangle distribution of RV (t, t_M) and for RV (λ, μ).



$t_M \in [0; 80]$ h

Fig. 3 - 3D representation of HV-S availability for RV (t, t_M)

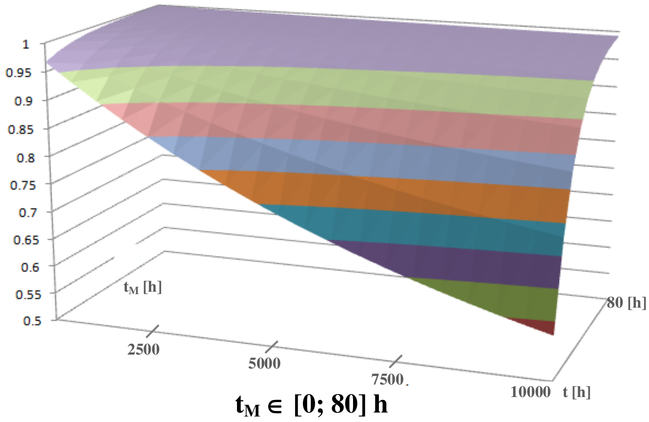


$\lambda \in [2 \times 10^{-5}; 12 \times 10^{-5}]$ h^{-1}

$\mu \in [0,02; 0,14]$ h^{-1}

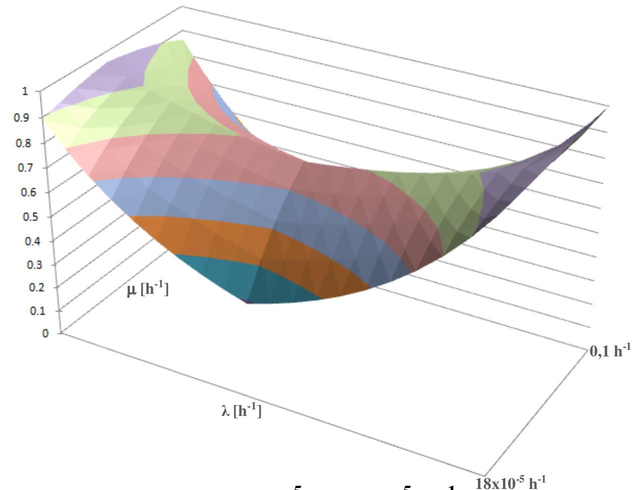
Fig. 4 - 3D representation of HV-S availability for RV (λ, μ)

În figures 5 and 6 are shown 3D representation of availability for MV-S from Bihor county PS, considering the triangle distribution for RV (t, t_M) and for RV (λ, μ).



$t_M \in [0; 80]$ h

Fig. 5 – 3D representations of MV-S availability for RV (t, t_M)

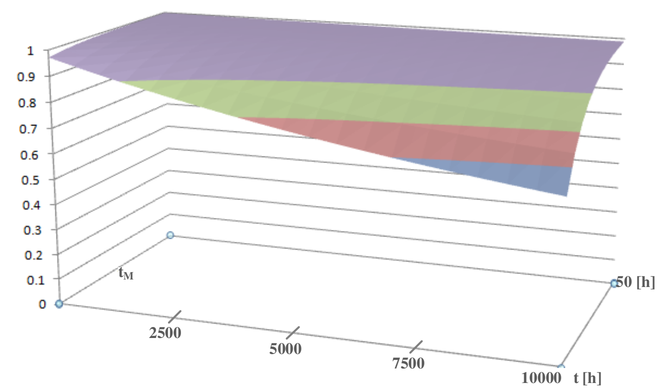


$\lambda \in [2 \times 10^{-5}; 18 \times 10^{-5}]$ h^{-1}

$\mu \in [0,01; 0,1]$ h^{-1}

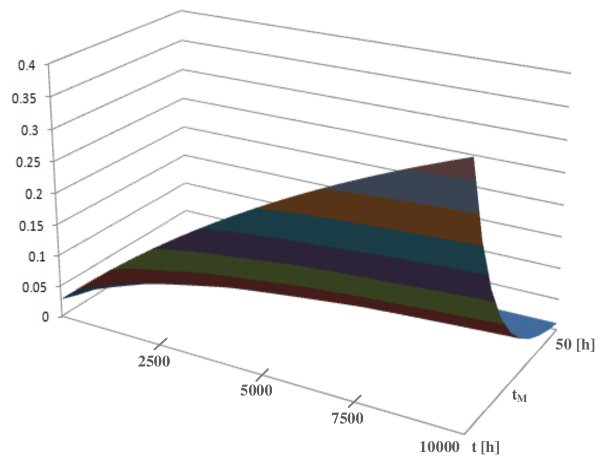
Fig. 6 – 3D representation of MV-S availability for RV (λ, μ)

În figures 7 and 8 are shown 3D representation of availability and unavailability for MV isolating switches (MV-IS) from Bihor county PS, considering the triangle distribution for RV.



$t_M \in [0; 50]$ h

Fig. 7 – 3D representation of MV-IS availability for RV (t, t_M)



$t_M \in [0; 50]$ h

Fig. 8 - 3D representation of MV-S unavailability for RV (t, t_M)

$\lambda \in [2 \times 10^{-5}; 14 \times 10^{-5}]\ h^{-1}$
$\mu \in [0{,}01; 0{,}1]\ h^{-1}$

4. CONCLUSIONS

To increase the evaluation accuracy and to get a more comprehensive on availability evolution of EEP from PS may be used the 3D representation of availability, using reliability and maintainability fundamental indicators calculated for random values. Stochastic treatment of EEP availability it can be done in relation with RV doublets (t, t_M), - operation and maintenance times, respectively (λ, μ) – failure and repairing rates, starting from empirical distribution, identifying the most suited , by theoretical distribution with application of some established tests, operating an adequate software package. The results for EEP from Bihor county PS reflects the following:

In cases of all equipment the most adequate distribution are triangle and normal.

PT, HV-S and HV-IS availability decreases with the increase of operation time and decreasing of preventive maintenance duration, the evolution and values being specific to every type of equipment.

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