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THE OPERATIONAL RELIABILITY OF EQUIPMENT FROM HYDRO POWER PLANTS STRUCTURE

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Abstract: The operational reliability studies of equipments from the hydroelectric power plant (HPP) are indispensable for obtaining adequate volume and statistical data on the bases of which to be established the values of reliability indicators and an optimal policy of maintenance. The paper presents the results from the case study regarding the operational reliability indicators evaluation of hydro-generator groups from HPP Tileagd and their equipments.

1. INTRODUCTION

Operational reliability (exploited) it is determined in real conditions of function. Studies on operational reliability of subsystems from HPP (hydro power plant) structure are essential in purpose to obtain volume and credibility statistic data adequate on which to establish the values of the indicators of reliability and an optimum politic on maintenance. Based a statistic data, obtained by auditing the equipment during exploit, there are three randomized variable, as:

- Lifetime (LT), representing the lifetime between successive falls;
- Maintenance correcting time (MCT), representing the time during defection;
- Number of failures per year (NF).

After the registration of statistic data, based on auditing the equipment during exploit, it goes on to working and interpreting the data with the purpose of a estimation on reliability (the type of distribution functions, distribution parameters). Auditing the equipment during exploit from HPP we obtain the values of randomized variable LT and MCT.

2. THE OPERATIONAL RELIABILITY INDICATORS EVALUATION OF THE HYDRO-GENERATOR GROUPS FROM HPP TILEAGD

The hydro-generator groups (HGG) can be interpreted as technical complex systems, compound of several subsystems. In the view of the operational reliability evaluation it is necessary to know the technological structure until the level of reliability analysis, the subsystems and their components functioning.

To evaluate the operational reliability indicators of HGG Tileagd the analysis has been detailed until the level of the next subsystems;

- ***the stop valve (SV)***
- ***the hydraulic turbine (TH)*** –9 MW
- ***the interacting automatic control system (governor –pressure oil group) (ACS)***
- ***the hydro-generator (HG)*** –HVS 380/90-28 10100 kVA, 6,3 kV
- ***the group transformer (GT)*** – 6,3/123 kV, 25 MVA

2.1. STATISTIC OF EVENTS

Using the values of randomized variable lifetime (LT) and maintenance correcting time (MCT), the operational reliability indicators of HGG and their subsystems are being determined

- Mean Time Between Failures (MTBF):

$$MTBF = \frac{\sum_{i=1}^{N_{LT}} LT_i}{N_{LT}} \quad (1)$$

- Mean Time Maintenance Correcting (MTM):

$$MTM = \frac{\sum_{i=1}^{N_{MCT}} MCT_i}{N_{MCT}} \quad (2)$$

- Mean time of unavailability:

$$\beta(T_A) = \frac{\sum_{i=1}^{N_{MTC}} MTC_i}{T_A \cdot N_e} \quad (3)$$

- Mean number of failures:

$$\nu(T_A) = \frac{N_{MTC}}{T_A \cdot N_e} \quad (4)$$

where: T_A – the analysis interval expressed in years (for the case study is $T_A = 9$ ani);

LT_i, MCT_i – the randomized variables values: lifetime (LT) and maintenance correcting time (MCT);

N_{LT}, N_{MCT} – the number of randomized variables LT, MCT;

N_e – the same type equipment number followed in this analysis (2 SV, 2 TH, 2 ACS, 2 HG, 1 GT and 2 groups).

These indicators for HGG Tileagd and theirs subsystems are presented in figures 1 ÷ 6.

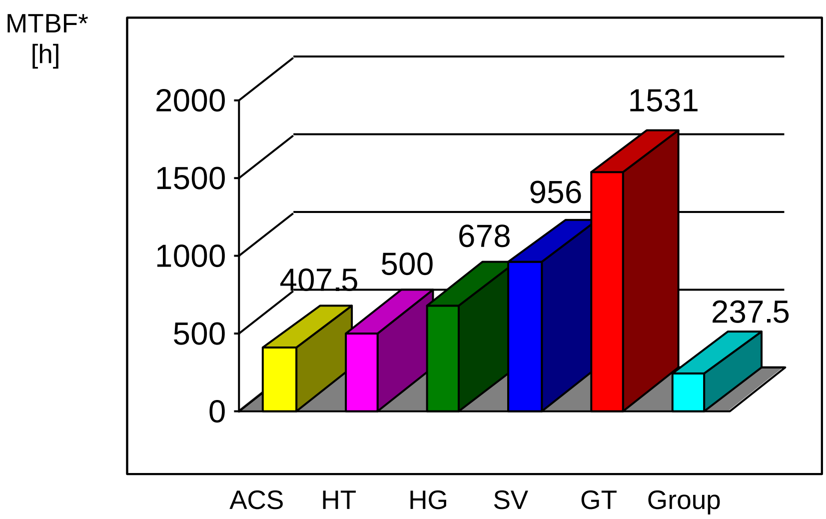

Fig. 1 – The values of Mean Time between Failures

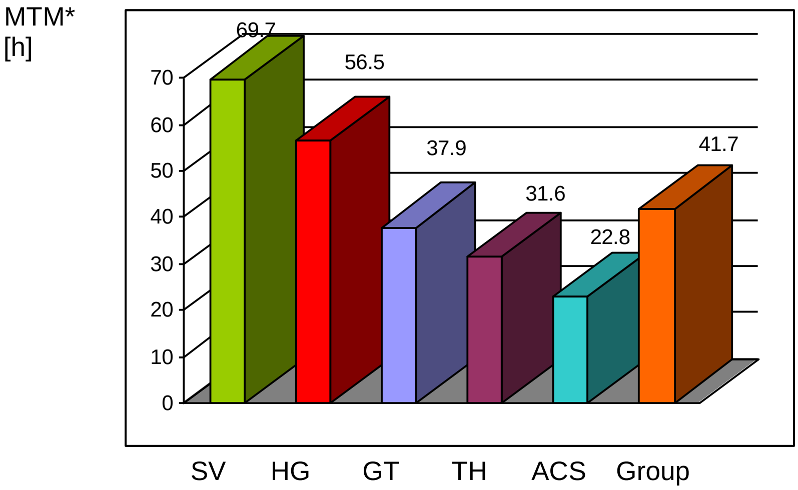

Fig. 2 – The values of Mean Time Maintenance Correcting

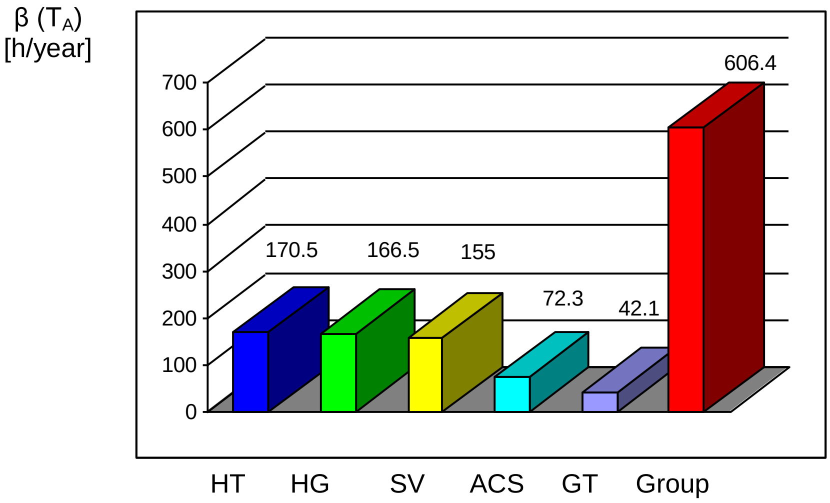

Fig. 3 – The values of Mean time Unavailability

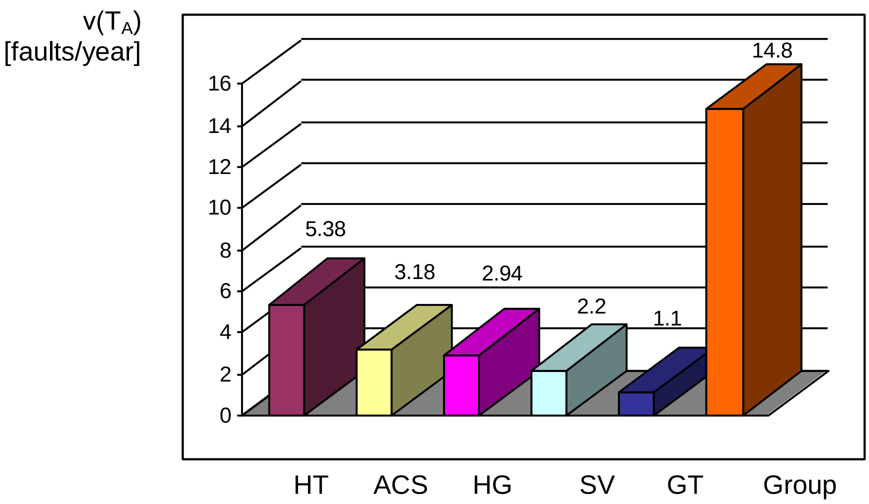

Fig. 4 – The values of Mean Number of Failures

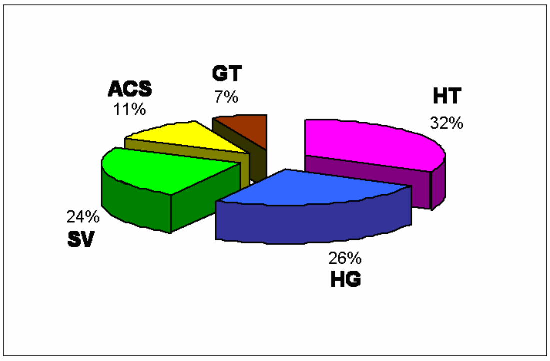

Fig. 5 – The Mean Time of Unavailability subsystems distribution

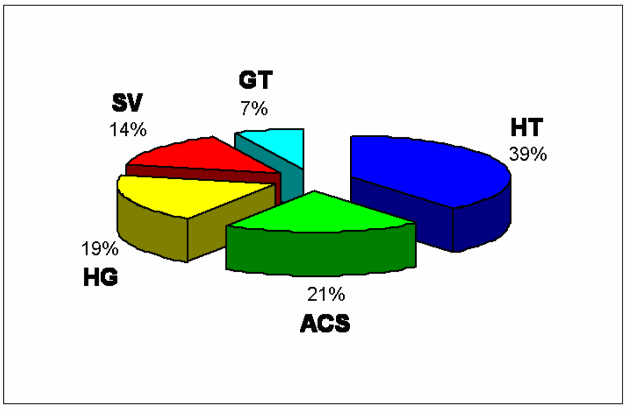

Fig. 6 – The Mean Number of Failures subsystems distribution

2.2. THE DISTRIBUTION FUNCTIONS TESTING FOR RANDOMIZED VARIABLES LT AND MCT

On the basis of statistic data, the tested distribution functions for randomized variables LT and MCT are exponential, Weibull and normal. For this purpose it has ben used the calculation program “FRVA” [2]. The figures 7, 8 indicate the graphical form of the reliability functions, respectively maintainability functions (empiric and modeled through theoretical distribution, for HGG Tileagd.

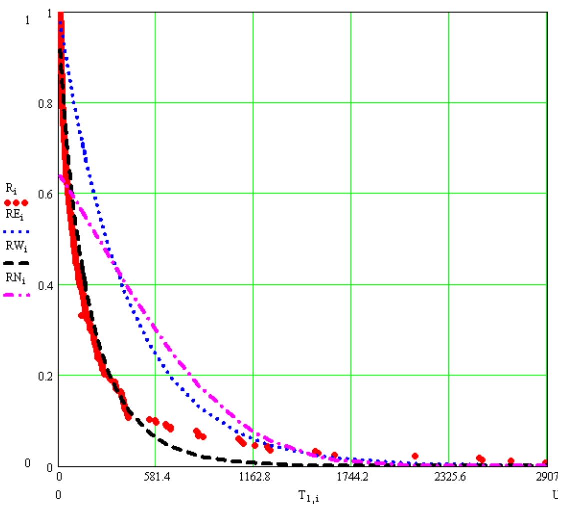

Figure 7 – HGG reliability function

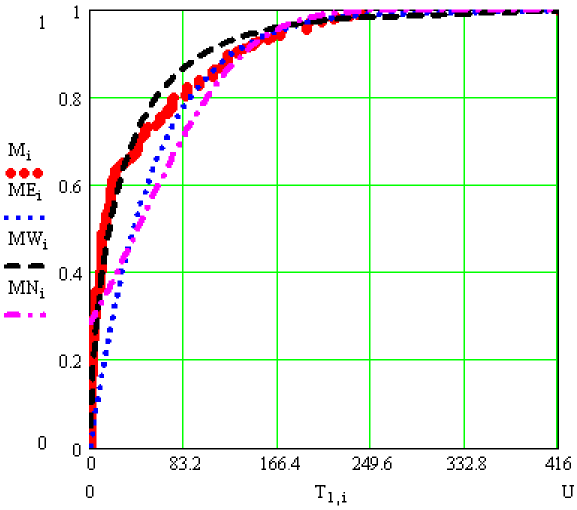

Figure 8 – HGG maintainability function

The analytic expressions of the reliability, respectively maintainability functions, for hydro-generator groups and their subsystems, are presented in table 1.

Table 1 – **The reliability and maintainability functions for HGG Tileagd and their subsystems**

Subsystem	Theoretical distribution	The reliability function R(t)	The maintainability function $M(t_M)$
0	1	2	3
SV	Exponential	$e^{-6{,}97\cdot t\cdot 10^{-4}}$	$1-e^{-52{,}62\cdot t_M\cdot 10^{-4}}$
	Weibull	$e^{-\frac{t^{0{,}72}}{116{,}08}}$	$1-e^{-\frac{t_M^{0{,}747}}{22{,}721}}$
	Normal	$1-\frac{10^{-3}}{1{,}976\cdot\sqrt{2\pi}}\cdot\int_0^t e^{-\frac{1}{2}\cdot\left(\frac{x-956{,}14}{1{,}976\cdot 10^3}\right)^2}$	$\frac{1}{86{,}93\cdot\sqrt{2\pi}}\cdot\int_0^{t_M} e^{-\frac{1}{2}\cdot\left(\frac{x-69{,}75}{86{,}93}\right)^2}dx$
TH	Exponential	$e^{-12{,}8\cdot t\cdot 10^{-4}}$	$1-e^{-88{,}9\cdot t_M\cdot 10^{-4}}$
	Weibull	$e^{-\frac{t^{0{,}87}}{180{,}3}}$	$1-e^{-\frac{t_M^{0{,}556}}{5{,}39}}$
	Normal	$1-\frac{10^{-3}}{1{,}152\cdot\sqrt{2\pi}}\cdot\int_0^t e^{-\frac{1}{2}\cdot\left(\frac{x-500}{1152}\right)^2}dx$	$\frac{1}{53{,}94\cdot\sqrt{2\pi}}\cdot\int_0^{t_M} e^{-\frac{1}{2}\cdot\left(\frac{x-31{,}63}{53{,}94}\right)^2}dx$
ACS	Exponential	$e^{-14{,}13\cdot t\cdot 10^{-4}}$	$1-e^{-286\cdot t_M\cdot 10^{-4}}$
	Weibull	$e^{-\frac{t^{0{,}893}}{170{,}6}}$	$1-e^{-\frac{t_M^{0{,}9}}{13{,}91}}$
	Normal	$1-\frac{10^{-3}}{1{,}103\cdot\sqrt{2\pi}}\cdot\int_0^t e^{-\frac{1}{2}\cdot\left(\frac{x-407{,}5}{1103}\right)^2}dx$	$\frac{1}{51{,}58\cdot\sqrt{2\pi}}\cdot\int_0^{t_M} e^{-\frac{1}{2}\cdot\left(\frac{x-22{,}83}{51{,}58}\right)^2}dx$
HG	Exponential	$e^{-12{,}49\cdot t\cdot 10^{-4}}$	$1-e^{-132\cdot t_M\cdot 10^{-4}}$
	Weibull	$e^{-\frac{t^{0{,}767}}{136{,}47}}$	$1-e^{-\frac{t_M^{0{,}673}}{12{,}81}}$
	Normal	$1-\frac{1}{956{,}03\cdot\sqrt{2\pi}}\cdot\int_0^t e^{-\frac{1}{2}\cdot\left(\frac{x-678{,}26}{956{,}03}\right)^2}dx$	$\frac{1}{97{,}53\cdot\sqrt{2\pi}}\cdot\int_0^{t_M} e^{-\frac{1}{2}\cdot\left(\frac{x-56{,}56}{97{,}53}\right)^2}dx$
GT	Exponential	$e^{-4{,}03\cdot t\cdot 10^{-4}}$	$1-e^{-169\cdot t_M\cdot 10^{-4}}$
	Weibull	$e^{-\frac{t^{0{,}66}}{114{,}9}}$	$1-e^{-\frac{t_M^{0{,}56}}{7{,}2}}$

	Normal	$1-\frac{10^{-3}}{3,278\cdot\sqrt{2\pi}}\cdot\int_0^t e^{-\frac{1}{2}\left(\frac{x-1531}{3278}\right)^2}dx$	$\frac{1}{75,12\cdot\sqrt{2\pi}}\cdot\int_0^{t_M} e^{-\frac{1}{2}\left(\frac{x-37,9}{75,12}\right)^2}dx$
HGG	Exponential	$e^{-24,4\cdot t\cdot 10^{-4}}$	$1-e^{-182\cdot t_M\cdot 10^{-4}}$
	Weibull	$e^{-\frac{t^{0,85}}{81,34}}$	$1-e^{-\frac{t_M^{0,65}}{9,04}}$
	Normal	$1-\frac{1}{643,15\cdot\sqrt{2\pi}}\cdot\int_0^t e^{-\frac{1}{2}\left(\frac{x-237,5}{643,15}\right)^2}dx$	$\frac{1}{73,04\cdot\sqrt{2\pi}}\cdot\int_0^{t_M} e^{-\frac{1}{2}\left(\frac{x-41,68}{73,04}\right)^2}dx$

3. CONCLUSIONS

1. In order to evaluate the reliability indicators of HPP equipments it has been recommended that the statistical estimation to be made through the linearization method combined with the least-square method. The audit of the statistical hypothesis should be done with the Kolmogorov test.

2. Based on operational reliability indicators values established during the study case, it has been ascertained that the HGG Tileagd hydraulic turbine and hydro-generator are subsystems with the weakest behavior. Their contributions to the group not- functioning time is 32, 4 %, respectively 26 %.

3. Analyzing the results presented in table 1 we arrived to the conclusion that the best model of the randomized variables LT and MCT empiric distribution, all cases is Weibull distribution.

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