THE OPERATIONAL RELIABILITY INDICATORS AT THE LEVEL OF THE HYDRO-GENERATOR GROUP FROM HPP TILEAGD, ROMANIA

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Abstract: The operational reliability studies of equipments from the hydroelectric power plant (HPP) are indispensable to obtain data to determine reliability indicators with adequate credibility.
To evaluate the operational reliability indicators of the hydro-generator groups from HPP Tileagd, we detailed the analysis to the level of the next subsystems of these: the globe valve (GV), hydraulic turbine (HT), interacting automatic control system (governor + pressure oil group) (ACS), hydro-generator (HG), group transformer (GT)
Using statistic data obtained from exploitation of hydro-power plant Tileagd, we composed a compendium with commentary referring to reliability indicators values, the distribution functions of randomized variables.

Keywords: Operational reliability indicators/ Lifetime(LT)/ Maintenance correcting time(MCT)/ Number of failures(NF)/ Mean time between failures(MTBF)/ Mean time maintenance correcting(MTM)/ Mean time of unavailability/ Mean number of failures

1. INTRODUCTION

Operational reliability 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).

2. METHODOLOGICAL CONSIDERATION ABOUT STATISTIC ESTIMATE

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).

2.1. Statistic estimate

The empirical functions for distribution that we want to model by the three distributions are:

- The empirical function of reliability suitable to the randomized variable LT:

$$R^*(t) = \begin{cases} 1, \ t < t_1 \\ \dfrac{n+1-i}{n+1}, \ t_i \le t < t_{i+1}; 1 \le i \le n-1 \\ 0, \ t \ge t_n \end{cases} \tag{1}$$

▪ The empirical function of maintainability suitable to the randomized variable MCT:

$$M^*(t) = \begin{cases} 0, \ t < t_1 \\ \dfrac{i}{n+1}, \ t_i \le t < t_{i+1}; 1 \le i \le n-1 \\ 1, \ t \ge t_n \end{cases} \tag{2}$$

The theoretical distribution functions expressions witch is tested are known [1]:

Exponential: $R(t) = e^{-\lambda \cdot t}, \ M(t) = 1 - e^{-\mu \cdot t}$,
Weibull:

$$R(t) = e^{-\left(\frac{t}{\eta}\right)^\beta}, \ M(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^\beta} \tag{3}$$

Normal: $R(t) = 1 - \dfrac{1}{\sigma \cdot \sqrt{2\pi}} \cdot \int_0^t e^{-\frac{(x-m)^2}{2\sigma^2}} dx, \ M(t) = \dfrac{1}{\sigma \cdot \sqrt{2\pi}} \cdot \int_0^t e^{-\frac{(x-m)^2}{2\sigma^2}} dx$

2.2. The statistical hypothesis verification

There are different types of tests to check the statistical hypothesis [3, 4, 5], and we mention:
• ***χ^2 test*** - it is a non-parametric test, that can be applied to every type of distribution function which involves a great number of statistical dates.
• ***Wald Test*** - can be applied for verification the obtained result by sequences tests.
• ***Kolmogorov test*** - it is a non-parametric test recommended for the cases when the empiric function it is built through points. To select the volume (n) of the randomized variable $X_n(x_1, x_2, \ldots x_n)$ we have to determine the values of the empiric function. We test the validity of the theoretical function F(x) by calculating:

$$\begin{cases} D^- = \max\limits_{1 \le i \le n} \left| F_i - F_{i-1}^* \right| \\ D^+ = \max\limits_{1 \le i \le n} \left| F_i^* - F_i \right| \\ D_{max} = \max\left(D^-, D^+\right) \end{cases} \tag{4}$$

where the empiric function:

$$F_i^* = \begin{cases} 0, \ x < x_1 \\ \dfrac{i}{n}, x_i \le x < x_{i+1}; 1 \le i \le n-1 \\ 1, \ x \ge x_n \end{cases} \tag{5}$$

We fix the signification degree (α) and from the table containing the critical values of Kolmogorov test [3, 4] we extract the critical rate D_{α}^{cr} .

The hypothesis that F(x) is the distribution function which reflects the analyzed selection we accept that:

$$D_{max} \le D_{\alpha}^{cr} = \frac{\lambda_{\alpha}}{\sqrt{n}} \tag{6}$$

In contrary, the hypothesis is rejected.

3. THE OPERATIONAL RELIABILITY INDICATORS OF HYDRO-GENERATOR GROUP TILEAGD, ROMANIA

To evaluate the operational reliability indicators of the hydro-generator groups from HPP Tileagd, we detailed the analysis to the level of the next subsystems of these:

- The stope valve (SV)
- Hydraulic turbine (HT)
- Interacting automatic control system (governor + pressure oil group) (ACS)
- Hydro-generator (HG)
- Group transformer (GT)

The function time under analyzed it is extended on a period of 9 years (1995-2003). The values of the randomized variable LT and MCT at the level of subsystems of the groups and also the causes that lead to damage, being overtaken from the register card and from the operative reports that exists in HPP Tileagd.

After the registration of statistic data, the tested distributions for randomized variable LT and MCT are exponential, Weibull and normal.

It has been work out a calculation program FRVA [2] (Repartition functions of the randomized variable) which allows: the determination of the parameters for the three tested distributions and the maximum variation towards the empiric distribution, to verify the statistical hypothesis with the help of Kolmogorov test and the graphical draw of the reliability functions and so of maintainability.

3.1. Consideration about statistic estimate

Auditing the equipment during exploit from HPP we obtain the values of randomized variable LT and MCT. Using these values we determined the operational reliability indicators for the hydro-generator groups and there subsystems.

- Mean Time Between Failures (MTBF):

$$MTBF^{*} = \frac{\sum_{i=1}^{N_{LT}} LT_i}{N_{LT}} \tag{7}$$

- Mean Time Maintenance Correcting (MTM):

$$MTM^{*} = \frac{\sum_{i=1}^{N_{MCT}} MCT_i}{N_{MCT}} \tag{8}$$

- Mean Time of Unavailability:

$$\beta(T_A) = \frac{\sum_{i=1}^{N_{MCT}} MCT_i}{T_A \cdot N_e} \tag{9}$$

- Mean Number of Failures:

$$\nu(T_A) = \frac{N_{MCT}}{T_A \cdot N_e} \tag{10}$$

where:

T_A – the interval of analysis expressed in years (for the case presented $T_A = 9$ years);
LT_i, MCT_i – the values of randomized variable lifetime (LT) and maintenance correcting time (MCT);
N_{LT}, N_{MCT} – the number of randomized variable LT, MCT;
N_e – the number of equipment of the same type followed in the framework of analysis (2 stop valves, 2 turbines, 2 interacting automatic control systems, 2 hydro-generators, 1 group transformer, 2 groups).

The values of these indicators, at the level of group and of component part systems are present fig. 1 ÷ fig. 6.

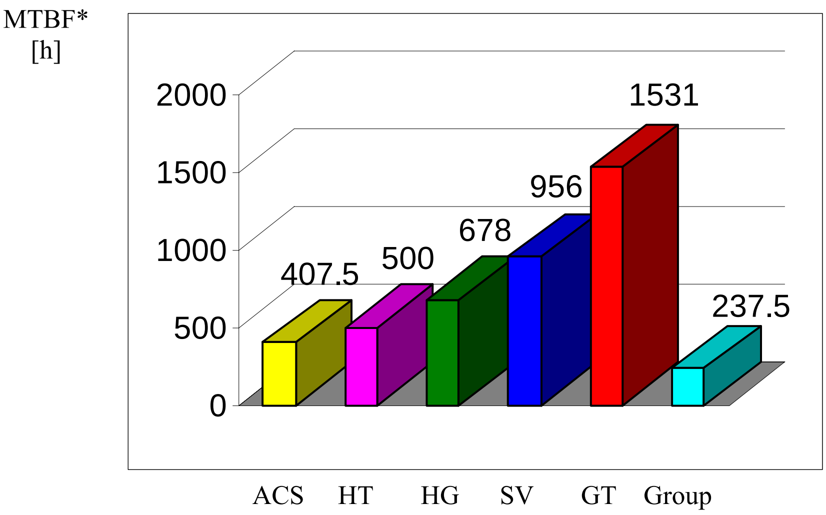

Fig. 1 – The values of Mean Time between Failures

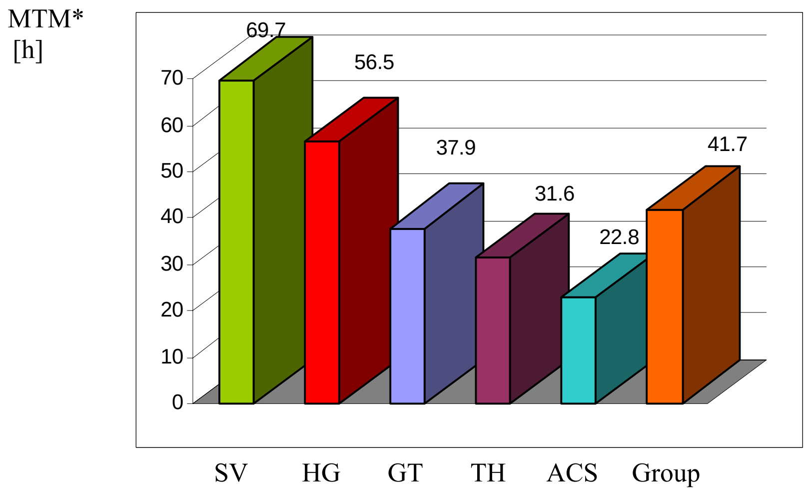

Fig. 2 – The values of Mean Time Maintenance Correcting

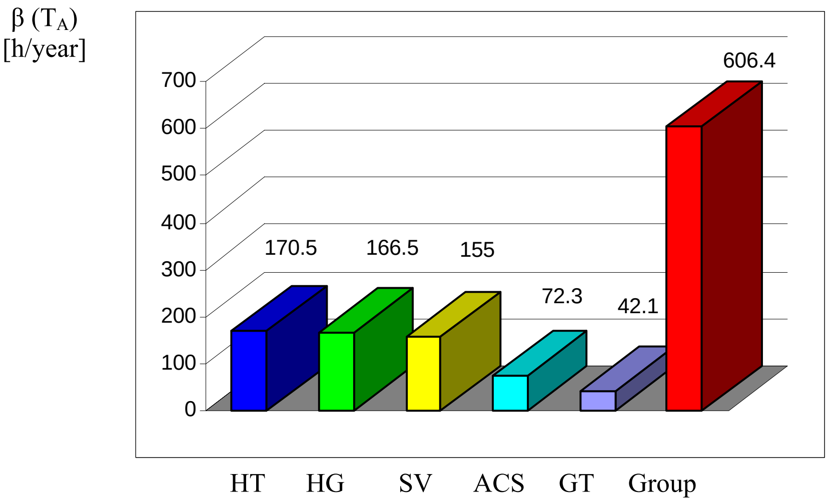

Fig. 3 – The values of Mean time Unavailability

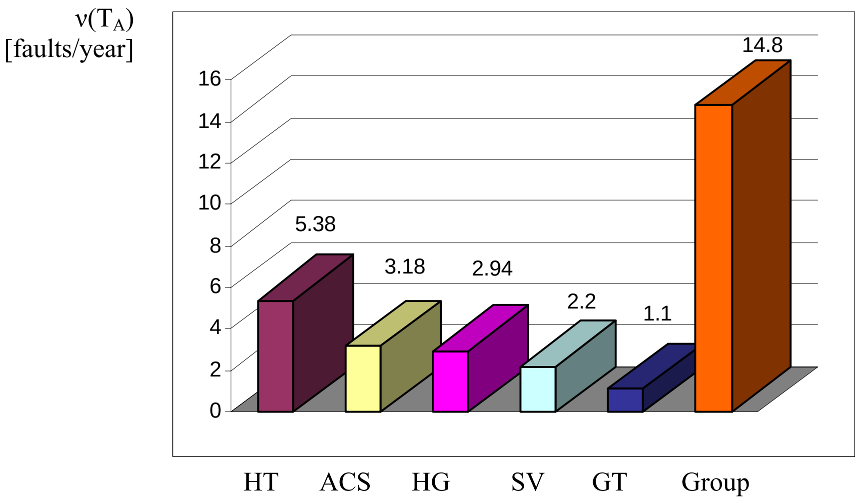

Fig. 4 – The values of Mean Number of Failures

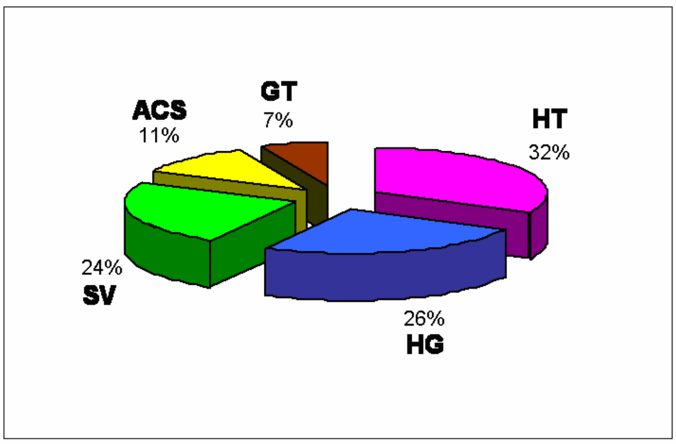

Fig.5 – The Mean Time of Unavailability subsystems distribution

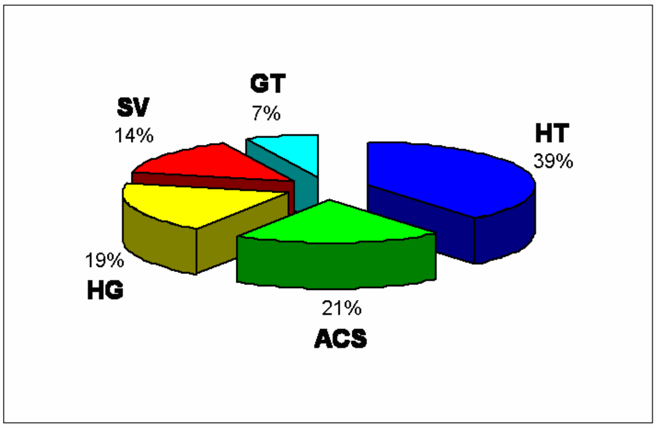

Fig.6 – The Mean Number of Failures subsystems distribution

4. CONCLUSIONS

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Following the studies and the analysis we made and also based on the obtained results we can conclude as it comes:

- To evaluate the reliability level of an HPP implies the knowledge of reliability indicators of the equipment he is composed with which imposes analyze of the operational reliability for these. For the results of the analyze, to be truthful as much as possible, it is necessary that the period of analysis to be extended on a large period of time (in order of years) and also the number of the observed equipment to as big as possible.
- To evaluate the reliability of indicators of the equipment from HPP we recommend that statistical estimation to be made through the linearization method combined with the least- square method and the audit of the statistical hypothesis to be made with Kolmogorov test;
- The volume of the statistical data processing does not allow the formulation of definitive conclusions;
- In the case of the groups from HPP Tileagd the less reliable subsystems are hydraulic turbine and the hydro-generator, their contribution at the duration of non-functioning of the group are 32 % and respectively 26 %. Evidently that on these equipments must be auctioned with the view of improving the groups behavior according to reliability aspect

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