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RELIABILITY ANALYSIS OF BUTTERFLY VALVE (BV) USING HER FUNCTIONS IN FRAMEWORK OF HPP REMEȚI

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Abstract: The reliability level of hydro mechanical equipments can have a major impact on the operational reliability of HPP. In consequence, there are justified the concerns regarding the predictive reliability of them. In this paper, these studies of hydro mechanical equipments predictive reliability will be made taking into consideration their functions in framework of hydro energetic arrangement.

1. Introduction

In every hydro energetic arrangement, the water approaches, in differently construction elements and trough them, are equipped with valves. These valves assure the normal functioning of equipments, respectively there operatively insulation in case of failures or repairs.

The accomplished studies [3, 4], indicate that some valves type are more performant under the reliability aspects than other equipments (hydraulic turbines). In succession, on the reliability studies, the valves are treated as bivalent elements (Functioning; Faulting). The predictive reliability analysis of hydro mechanical equipments it has been made using their functions and structure in framework of hydro energetic arrangements.

The butterfly valve equipment, BV 360-170, is a complex ensemble used like stopper in front of the hydraulic turbine FVM 52-320, in case of revision. During the hydraulic turbine on-off process, the butterfly valve it's controlled. The BV performed one's functions namely, the safety device for turbine in case of failure.

During the reliability analysis, the butterfly valve (BV) from HPP Remeți, it has been regarded like a system compound of following subsystems (fig. 1):

- The closing subsystem (CSS);
- The sealing subsystem (SSS);
- The control subsystem (NSS);
- The operate subsystem (OSS);
- The protection subsystem (PSS).

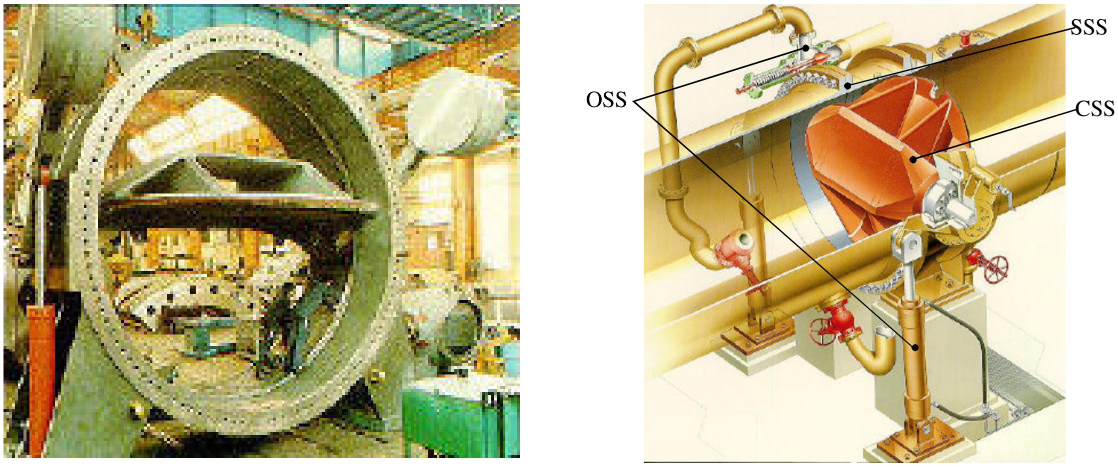

Fig. 1 The butterfly valve structure and subsystems

2. The reliability analysis depending on BV structure

According to previously specifications (for the simplified reliability analysis) BV it has been treated as a system compound of five subsystems. In consequence, it can represent the simplified equivalent diagram, who reflects the necessity that, all the subsystems to be in work for satisfied all the butterfly valve functions.

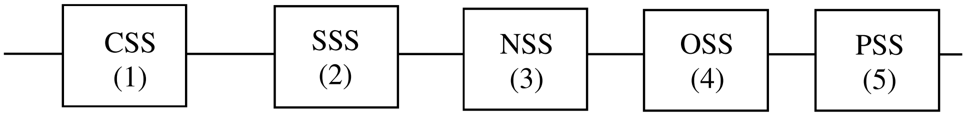

Fig. 2 The equivalent diagram of BV

The reliability states graph is typical of series systems.

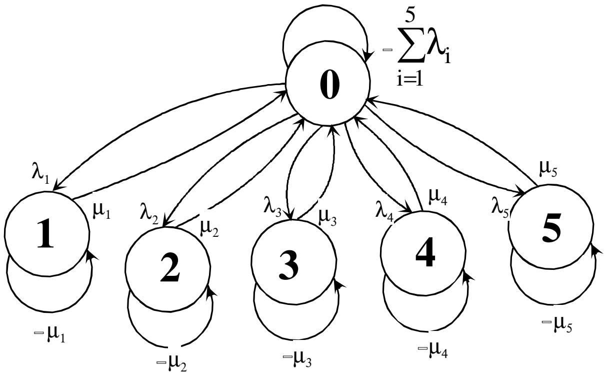

Fig. 3 The reliability states graph for butterfly valve

Using the graph represented in figure 3 it can applies the Markov model to evaluate the reliability indicators $\lfloor R; F; \alpha(T_A); \beta(T_A); \nu(T_A); MTBF; MTM; \lambda_e; \mu_e \rfloor$ [1].

3. The predictive analysis of BV using her functions in HPP Remeți

The detailed reliability analysis of the butterfly valve from HPP Remeți, it's make, defining her functions and related the analysis to them:

- f_1 – self-protection function;
- f_2 – closing-sealing function;
- f_3 – associate-protection (of turbine and hydro-generator) function.

The f_1 function it's report to the valve possibility to provides the intrinsic safety by adequately response of the PSS elements.

***The f_2*, closing and sealing function** is a double function. It can be regards from two perspectives: in the first row it is report at keeping of displacement performances, the synchronized CSS elements motion, in time and space; in the second row it is report at keeping the pshycal-chemical and mechanical properties of the sealing subsystem elements, in view of insurance a constant and optimum sealing level.

The f_3 function is report to the valve roll like safety turbine-hydro generator element, which assure the normal functioning of equipments, respectively there operatively insulation in case of failures or repairs

For all these functions it's obligatory the integrity of protection subsystem (PSS).

The functions conditioning by the state (integrity) of BV subsystems it is presented in table 1.

Table 1 The functions conditioning by the state of BV subsystems

Function	Subsystems
f_1	PSS
f_2	CSS Λ SSS
f_3	SS(f_2) Λ NSS Λ OSS

Taking into account the BV functions it can represent the states graph of BV related to them (figure 4).

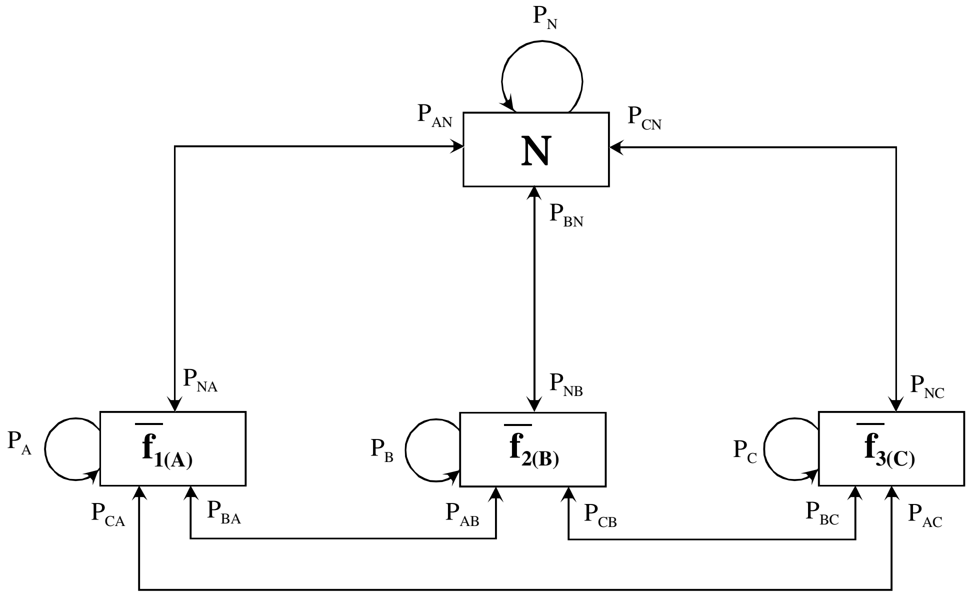

Fig. 4 The states graph of BV in view of her functions using as indicators the state and transition probabilities (N – normal state, $\overline{f}_i$ - failure state relating to f_i functions)

The states and transitions probabilities from figure 4 are represented using the typical expressions [6]:

$$\Pr ob(E_1 \cap E_2 \cap \ldots \cap E_m) = \Pr ob(E_1) \cdot \Pr ob(E_2) \cdot \ldots \cdot \Pr ob(E_m) \tag{1}$$

$$\Pr ob(E_1 \cap E_2 \cap \ldots \cap E_m) = \sum_{j=1}^{m} \Pr ob E_j - \sum_{j=2}^{m} \sum_{i=1}^{j-1} \Pr ob(E_i E_j) + \sum_{j=3}^{m} \sum_{i=2}^{j-1} \sum_{k=1}^{i-1} (E_i E_j E_k) + \ldots + (-1)^{m-1} \Pr ob(E_1 E_2 \ldots E_m) \tag{2}$$

The elementary events (E_i) are reported to functioning or failure of the butterfly valve (i) subsystems.

For example, the state and transition probabilities in a few cases are:

- The all satisfying functions probability (state N probability):

$$P_N(t) = \operatorname{Prob}(1 \cap 2 \cap \ldots \cap 5) = \prod_{i=1}^{5} R_i(t) = R_{BV}(t) \tag{3}$$

- The unsatisfying function f_3 probability (state C probability)

$$P_C(t) = \operatorname{Prob}\left(\bigcup_{i=1}^{4} E_i\right) \tag{4}$$

$$P_C = \operatorname{Prob}\left[\left(\bar{1} \bigcap_{i=\overline{2,4}} i\right) \bigcup \left(1 \bigcap \bar{2} \bigcap_{i=\overline{3,4}} i\right) \bigcup \left(1 \bigcap 2 \bigcap \bar{3} \bigcap 4\right) \bigcup \left(\bar{4} \bigcap_{i=\overline{1,3}} i\right)\right] \tag{5}$$

$$\begin{aligned} P_C(t) = {} & F_1(t)R_2(t)R_3(t)R_4(t) + R_1(t)F_2(t)R_3(t)R_4(t) + \\ & + R_1(t)R_2(t)F_3(t)R_4(t) + R_1(t)R_2(t)R_3(t)F_4(t) \end{aligned} \tag{6}$$

Depend on results obtained from the operational reliability studies [3,4], it can estimate the subsystems reliability indicators [R_i, Fi, μ_i, M_i]. The calculus relations are:

$$F_{BV} = \frac{\lambda}{\lambda + \mu};\ F_i = \frac{\nu_i[\%]}{100} \cdot F_{BV};\ \mu_i = \frac{\nu_i[\%]}{\beta_i[\%]} \cdot \mu;\ M_i = 1 - e^{-\mu_i \cdot t_r} \tag{7}$$

λ, μ - the BV reliability indicators;

F_{BV} – failure probability of BV;

v_i, β_i – the weight of number failures and failures time, of the (i) subsystems from the total value of these indicators at the level of BV.

The maintainability values (M_i) are determined using condition that the maintenance corrective operations must finished in $t_r = 27$ h.

The values are represented in table 2.

Table 2 The reliability indicators values for the BV subsystems

Subsystem	CSS	SSS	NSS	OSS	PSS
$F_i \times 10^4$	9,1017	243,647	18,9063	391,376	37,1072
$\mu_i\left[h^{1}\right]$	0,006927	0,01155	0,01188	0,009354	0,01117
M_i	0,17058	0,34196	0,2745	0,2232	0,2605
R_i	0,9990898	0,9756352	0,9981095	0,9608624	0,996289

The values of states and transitions probability are represented in table 3. The graph of BV states in view of her functions, are represented in figure 5.

Table 3 – The values of states and transitions probabilities between BV states

Indicator	The calculus expression (simplified)	Result
P_N	$\prod_{i=1}^{5} R_i = R_{VS}$	0,931358
P_A	$F_5 \prod_{i=1}^{4} R_i$	0,003468
P_B	$R_3R_4R_5(F_1R_2 + R_1F_2)$	0,024109
P_C	$F_1R_2R_3R_4 + R_1F_2R_3R_4 +$ $+ R_1R_2F_3R_4 + R_1R_2R_3F_4$	0,079979
P_{NA}	F_5	0,003710
P_{NB}	F_1+F_2	0,025274
P_{NC}	$F_1+F_2+F_3+F_4$	0,083316
P_{AB}	F_1+F_2	0,003710
P_{BC}	F_3+F_4	0,058041
P_{AC}	$F_1+F_2+F_3+F_4$	0,083316
P_{AN}	M_5	0,2605
P_{BN}	$med(M_1; M_2)$	0,256272
P_{CN}	$med(M_i;\ i = \overline{1,4})$	0,252561
P_{BA}	$med(M_1; M_2)$	0,256272
P_{CA}	$med(M_i;\ i = \overline{1,4})$	0,252561
P_{CB}	$med(M_3; M_4)$	0,24885

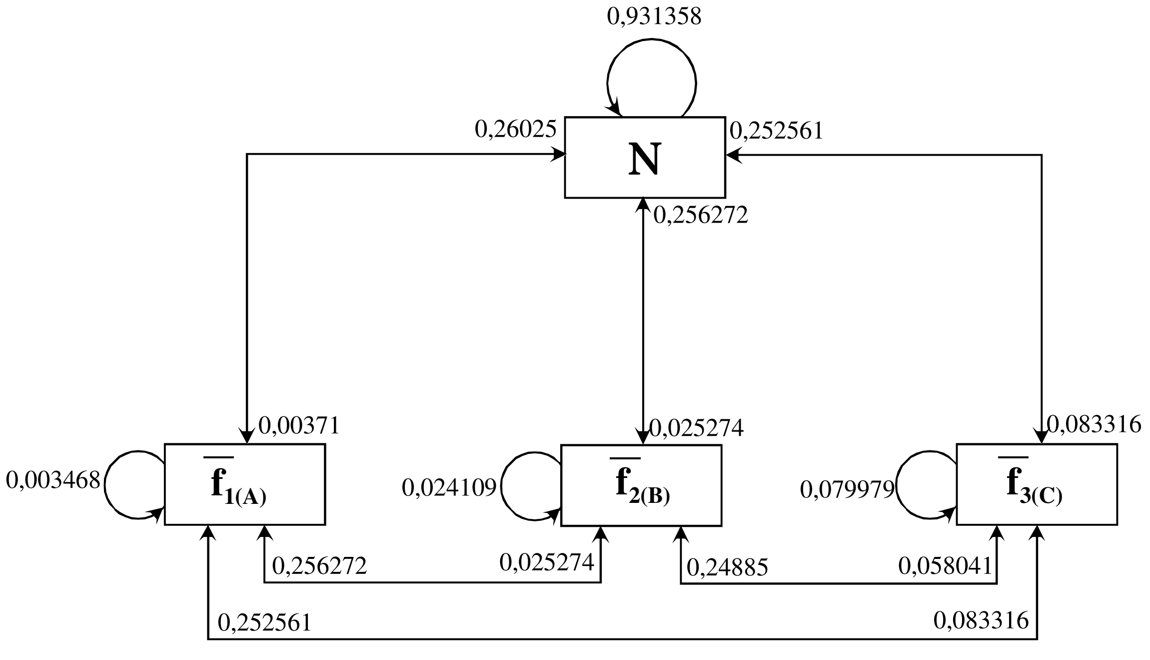

Fig. 5 The states graph of BV in view of her functions using as indicators the state and transition probabilities (N – normal state, $\overline{f}_i$ - failure state relating to f_i functions)

4. Conclusions

As a result of analysis and studies achieved it obtained the following conclusions:

1. Analyzing the BV structure from HPP Remeti, it has been ascertained that BV is a complex system formed of five subsystems serially bound.
2. For detailed the reliability analysis of BV, it has been defined her functions and it can report the reliability analysis at these functions.
3. The BV reliability indicators evaluation it make using the reliability indicators of subsystems, the equivalent diagram method, binomial method or the Markov method, after it represented the states graph.
4. Using the numerical results obtained, it have been represented the subsystems impact on the hydromechanical equipment non reliability, as in figure 6:

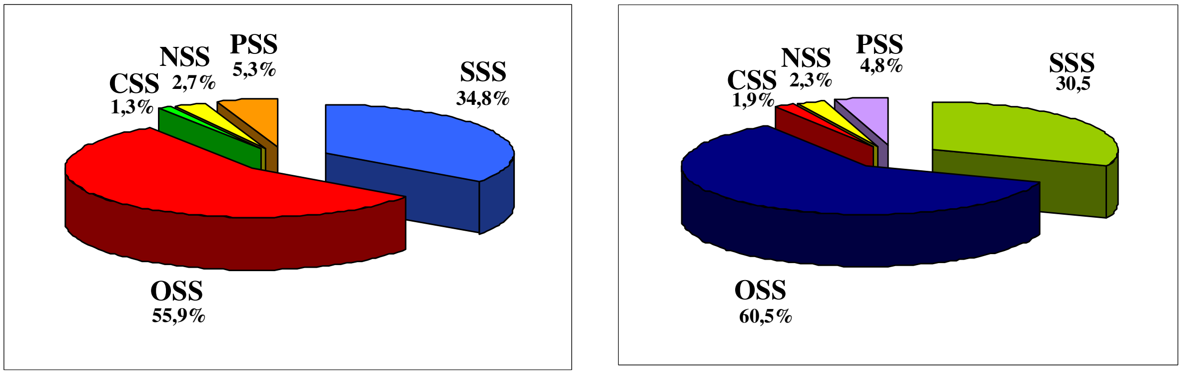

Fig. 6 The number and duration failures distribution on BV subsystems

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