SAFETY ASPECTS ON DEPENABILITY MANAGEMENT FOR A TRIGA RESEARCH REACTOR IN ROMANIA

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Abstract

Safety on the management for a nuclear research reactor involves a "***good dependability*** [*] ***management***" of the activities, such as: ***reliability, availability, maintainability and maintenance support***. In order to evaluate the safety management aspects intended to be applied at a research reactor management, the performance dependability indicators and their impact over the availability and reactor safety have to be established. The document ***ISO 9000-4/IEC 300 –1 "Dependability Management***" (1995), describes five internationally agreed indicators of the reactor equipment dependability, each of them can be used for ***corrective maintenance*** or for ***preventive maintenance***, such as: I_1 - equipment Maintenance Frequency; I_2 - equipment Maintenance Effort; I_3 - equipment Maintenance Downtime Factor; I_4 - equipment Maintenance Contribution to the System Function Downtime Factor; I_5 - equipment Maintenance Contribution to the reactor Capability Loss Factor. The paper presents an evaluation of those 5 mentioned indicators with referring only at the primary circuit of the INR's TRIGA research reactor and conclusion. The analyzed period was stated between 1994-1999. It is to be noted that this type of analyze is performed for the first time for a research reactor.

Introduction

Dependability involves the management of ***Reliability, Availability and Maintainability (RAM)*** and maintenance support to ensure that plan meets the RAM targets, which must be attained. ***([*] Dependability - the collective term used non-qualitatively to describe the availability performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance)***. Each of those five indicators can be applied separately both for preventive and corrective maintenance (*PM & CM*), giving rise to as many as ten indicator values for each item of equipment. Used in this way, the indicators provide a comprehensive picture of the maintenance strategy employed for key pieces of equipment and its effectiveness as well as a valuable managerial tool for maintenance activities improving at the reactor level and certain safety criteria to be taken into consideration for the safe management of the maintenance. It is recommended that the equipment dependability parameters should be used within reactor to improve equipment dependability and, hence, to reduce operating costs, particularly through the implementation of improved maintenance strategies and spare part policies.

Dependability Indicators Evaluation

As shown before, five indicators are to be calculated both for the Preventive Maintenance and for the Corrective Maintenance (***PM & CM***) and have the following interpretations: ***(I_1)*** - is related to maintenance frequency; ***(I_2)*** - represents maintenance effort; ***(I_3)*** - concerns equipment unavailability; **(I_4)** and ***(I_5)*** - are associated with the effects of equipment maintenance activities, at system function level and reactor level. **I_1** is linked to the reliability performances and **I_2** to the maintenance and support performance.

Method of Calculations:

I1= (No. of Maintenance actions per item of equipment)/(Reference time period);
I2 = (ΣMMh per item of equipment)/(Reference time period);
I3= [(Equipment maintenance downtime, in hrs)/(No of equipment items * no. of years* 8760h)]*100;
I4 = [(System function downtime per item of equipment, in hrs)/(Reference time period)]*100;
I5 = [(Unit capability loss per item equipment-in MW)/(Reference power generation, in MW)]*100. where:
Reference time period = 8760 hours (one year); ΣMMh = reflects the total effort needed for maintaining a given equipment and only that; Equipment Maintenance downtime = cumulative duration of maintenance actions (including all delay times) during the reference time period; System function downtime = cumulative durations over which the system function is lost due to maintenance activities (CM or PM); Reactor capability loss per item equipment = corresponds to the equipment unavailability because of maintenance activities.

All the determined calculations are referred only at the primarily circuit of the INR's Pitesti TRIGA Research Reactor, as shown in figure 1:

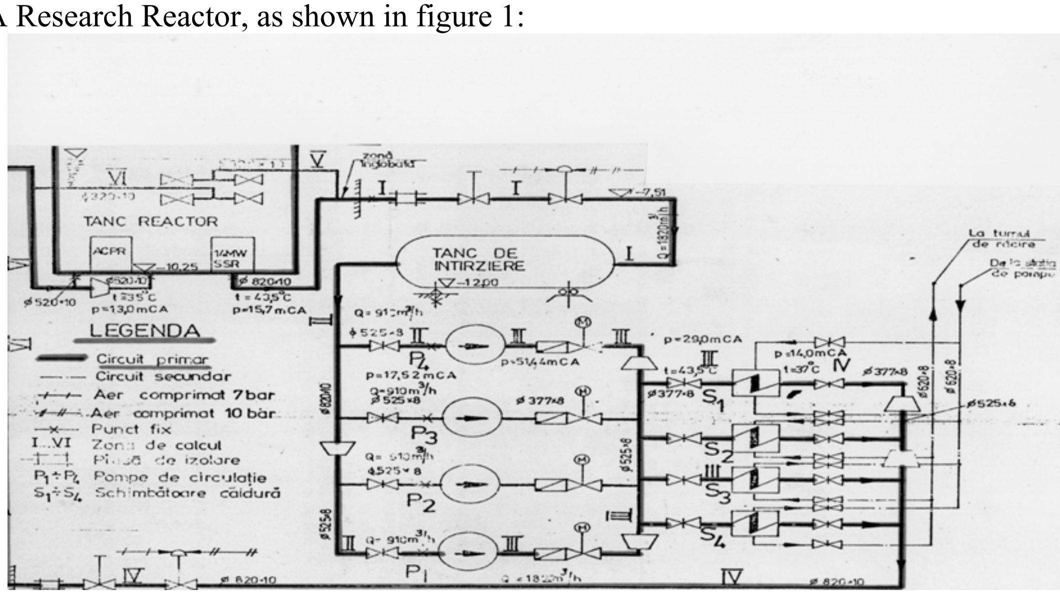

Figure 1 The primary circuit of INR 's Pitesti TRIGA Research Reactor

Reactor which includes the following main equipments:

- **4** ***circulation pumps*** - (***$P_1 \div P_4$) and*** **3** ***heat exchangers - ($S_1 \div S_3$);***
- **1** ***delay tank*** and **pipes** ***820x10 mm*** and **20** ***relief and safety valves*** (in operation or standby);
- **1** ***emergency pump***; ***instrumentation and control***;

It is to be noted that the equipment dependability indicators are linked to the maintenance activities and associated work (repair after a failure, preventive maintenance, inspection, tests, etc.). Modifications, however much part of the process of improving reactor dependability is not taken into consideration. This means that only preventive maintenance (PM) and corrective maintenance (CM) are involved.

Note: Corrective maintenance (CM) is carried out after recognition of a fault due to a failure, which can be partial or complete (i. e. either some or all of the required functions cannot be performed) according to the IEC 50 (191). Maintenance, which is not corrective, is termed preventive maintenance (PM). Component PM will only be taken into account in calculating dependability indicators if the availability of the equipment is affected by the PM activity. PM can be carried out on an opportunity basis during CM and vice-versa. CM carried out during PM on the same equipment is considered as a single PM action; PM carried out during CM on the same equipment is considered as a single CM action.

To facilitate the interpretation of dependability indicators, all equipments are classified according to its mode of operation. The dependability indicators will apply to all these different possibilities and the operational mode will be determined by the time equipment was in operating during the period of time under consideration (reactor operating time per year). For the equipment operation a factor, C_o is used to identify the equipment operational mode. This factor is defined as the ratio of the time that the equipment was in operation to the overall duration of the period of time under consideration: $Co = \frac{t_o}{t_p}$ where t_o = total time the equipment was in operation during the overall period of time under consideration; t_p= overall period of time under consideration (reactor operating time per year, in hrs). To facilitate a comparison between different equipment with similar operational modes, the values of the equipment operation factor are grouped into four different categories, such as:

a). based category (C_{o1}): $C_o \geq 0.5$; b). two shifting category (C_{o2}): $0.1 \leq C_o < 0.5$; c). Peaking category: (C_{o3}): $0.01 \leq C_o < 0.1$; d). Standby category (C_{o4}): $C_o < 0.01$. The INR TRIGA research reactor started operation in 1979. In this work, the period 1994 - 1999 has been taken into consideration and the following table summarizes data for the calculation of the dependability indicators, as follows:

Table No. 1 ***Data for calculation of the dependability parameters***

Year	Reactor operation time (Hours)	Unavailable time (hours)	Reference time period (Hours)	Failures (Numbers)	Maintenance Man-hours for repair (MMh)
1994	1689	22.75	8760	16	350
1995	1724	118.75	8760	12	230
1996	1762	162.6	8760	27	456
1997	1834	175.0	8760	26	412
1998	1925	213.0	8760	19	275
1999	2134	169.5	8760	25	436

The calculating numerical values for the equipment dependability indicators ($I_1 \div I_5$) are shown in Table no. 2, as follows:

Table No. 2 ***Numerical values for equipment dependability indicators***

Year	I_1 (y^{-1})	I_2 ($MMhy^{-1}$)	I_3 (%)	I_4 (%)	I_5 (%)	Factor C_o
1994	2.5	350	3.9	3.9	3.9	0.19
1995	2	230	2.6	2.6	2.6	0,21
1996	5	456	5.2	5.2	5.2	0. 22
1997	4	412	4.7	4.7	4.7	0.23
1998	3	275	2.85	2.85	2.85	0.25
1999	3	436	5.0	5.0	5.0	0.26

Note that there is no possibility of derating, $I_3 = I_4 = I_5$, whenever the repair on the equipment causes total unavailability of the reactor. These indicators can differ in a significant manner depending upon the maintenance practice and the degree of urgency associated with repair. Since there is clearly a trend with time, values averaged over a number of years must be treated with caution.

Equipment maintenance indicators:

A comparison concerns equipment dependability indicators for circulation pumps belonging to the reactor TRIGA's primary circuit are presented below:

I. Corrective maintenance indicators

Pump	I_1 (Maintenance frequency-Events/pump x year)	I_2 (Maintenance effort - Man-hours/pump x year)	I_3 (Equipment downtime-Downtime/Reference time period %)	I_4 (System Function downtime -Reference time period -%)	I_5 (Reactor capability loss factor (Unavailable power/Reference power - %)
P_1	1	50	0.25	0.03	$3.5x10^{-2}$
P_2	0.75	62	0.31	0.2	$2.3x10^{-2}$
P_3	1.5	69	0.72	0.13	$1.5x10^{-2}$
P_4	1.8	78	0.89	0.07	$2.1x10^{-2}$

II. Preventive maintenance indicators

Pump	I_1 (Maintenance frequency-Events/pump x year)	I_2 (Maintenance effort - Man-hours/pump x year)	I_3 (Equipment downtime-Downtime/Reference time period %)	I_4 (System Function downtime Reference time period -%)	I_5 (Reactor capability loss factor (Unavailable power/Reference power - %)
P_1	0.5	45	1.12	0	0
P_2	0.7	47	1.21	0.25	0
P_3	0.90	63	1.05	0.5	0
P_4	1	65	1.7	0.8	0

Comments and conclusion

From Table no.2 is easily to observe that the factor C_0 is very low, corresponding to the second category (b) which shows large fluctuations in operation both due to the unexpected shutdowns and to the long time of the maintenance operations as well as due to a inadequate spare part procurement policy (missing of the spare parts, longer time to buy, etc.)

The relative high values of the indicators I_1 and I_2 shows that the equipment used have low reliability parameters with significant influences to the reactor PSA analysis.
Also, the determination of dependability parameters may led to the establishment of programming aimed at protecting valuable research reactor, such as TRIGA, from High Impact, Low Probability (HILP) failures.
On the other hand, these indicators offer potential for wider application since:

- ***Provide valuable dependability characteristics to those responsible for the specification and procurement of equipment;***
- ***May be used to complement reactor level performance indicators in the field of operation, maintenance and improving of operating parameters;***
- ***Using the maintenance related indicators it is possible to follow trends with time and to compare different operating experience and maintenance strategies.***

The form of the indicators permits the exchange of data between different TRIGA users, with design decisions, availability predictions and operational assessment. Data exchange will facilitate the analysis of RAM as a function of time (trend analysis). Data exchange can also be used to verify RAM objectives or predictions.
Reactor equipment dependability indicators provide a quantitative indication of equipment RAM performance. These indicators can be applied separately to those corrective and preventive maintenance activities related to equipment unavailability. It is recommended that these indicators should be used within reactor unit to improve management of dependability. In particular, this can be of value in optimizing maintenance strategies and improving spare part policies. Provided that attention is paid to specifying equipment boundaries precisely and to record the size, type, level of redundancy and mode of operation of the particular equipment under consideration.

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