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EVALUATION OF RELIABILITY OF ON-SITE A.C. POWER SYSTEMS BASED ON MAINTENANCE RECORDS

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Abstract

To the end of ascertain in what extent the evaluation of reliability of emergency diesel generators (D.G.) can be improved by means of a deeper knowledge of their operating history a study has been carried-out on 21 D.G. sets: 4 D.G. of the Caorso nuclear plant (BWR, 870 MWe) and 17 D.G. in service at 6 steam-electric fossil-fuelled plants.

The major points of interest resulting from this study are:

1) reliability assessments of A.C. on-site power systems, made on the basis of outcomes of surveillance tests, may lead to results which overestimate the real performance.
2) the unreliability of a redundant system of stand-by components is determined in large extent by unavailabilities due to scheduled and unscheduled maintenance, latent failures, tests.

Resumé

Pour vérifier dans quelle mésure l'évaluation de la fiabilité des diesel-électrogènes de sécours peut être amelioreé au moyen d'une connaissance plus étendue et detailleé de leurs histoire de fonctionnement, on a effectué un étude concernant 21 diesel électrogènes: 4 appartenants à la centrale nucléaire de Caorso (BWR, 870 MWe) et 17 en service auprès de 6 centrales électriques à huile combustible ou charbon.

Les indications les plus significatives fournies par cet étude sont les suivantes:

1) Les évaluatons de fiabilité effectueés surtout sur la base des issues des essais de fonctionnement peuvent conduire à des résultats qui surestiment la performance reélle.
2) La fiabilité des systèmes redondants des composants en stand-by est affecteé en large mésure par les indisponibilités dues aux opérations d'entretien systématiques, aux interventions d'urgence, aux defaillances latentes, aux essais de fonctionnement, etc...

1. PRELIMINARY CONSIDERATIONS

Difficulties encountered when assessing reliability/availability of stand-by components and systems are well known. On the other hand-these components and systems should assure the main machinery protection in a nuclear plant as well as the prevention of accidents that could have dangerous effects on the population. Such difficulties are due chiefly to two different factors:

— insufficient quantity of information about the operating experience of components and systems similar to those to be assessed.

— incompleteness of information: single events are notified in an excessively synthetic way; this does not allow the analyst to make sound assessments.

In order to ascertain in what extent the evaluation of reliability of these components can be improved by means of a deeper and detailed knowledge of their operating history, a study has been carried out on 21 emergency diesel generators: four ot them in a modern nuclear power plant and seventeen in six Italian fossil-fuelled electric plants.
In the following paragraphs the documents analysed, the criteria adopted and the results obtained are described.

2. — DOCUMENTATION

Information required by this study has been taken from:

— for the 4 diesel generator sets of the Caorso nuclear power plant (BWR, 870 MWe):

a) events notified by the licensee to the nuclear safety authority, according to the Technical Guide DISP/ ENEA n.11.

b) events stored in the licensee data bank: about 1500 reports referred to the interval 1978-1984

c) Diary of machine of the 4 diesel generators retrieved from the maintenence file of the licensee's data bank. Information given by the diary are: progressive number and date of issue of the work permits; start and end dates of maintenance works; type of intervention (planned, unplanned, system modifications); availability of diesel generators before the intervention and during the works; cause of failure; man-hours required by the works, short description of the works and of the component affected. Up to 31.8.84 452 work permits had been issued for the 4 diesel generators.

— for the 17 diesel generators of the 26 fossil-fuelled units of Tavazzano 1-6, Piacenza 1-4: Turbigo 1-4; Casella 1-4; Ostiglia 1-4; La Spezia 1-4: the diaries of diesel generators retrieved from the licensee's data bank. For about 123 units-year of operating experience the diaries of machine gave data of 1571 work permits.

Table 1 shows some data referred to the mentioned power plants and relative diesel generators.

The present study took advantage and inspiration from other previous reports about reliability of stand-by components in general and of Diesel generators in particular.
Some of these reports are cited in bibliography.

3 — SHORT DESCRIPTION OF MORE COMMON UNAVAILABILITIES AND OF DUTY CYCLE OF EMERGENCY GENERATORS.

Duty cycle: the normal duty cycle of a diesel generator follows generally the cycle of the plant. When the plant cycle is annual, then so is the cycle of its diesel generators.
During the annual planned outage of the plant also the diesel generators can undergo a complete overhauling followed by a functional test under load. For the rest of the year each diesel generator set is weekly or monthly subject to surveillace tests. Generally frequency and nature of maintenance are decided according to troubles or symptoms noticed during the tests.
Diesel generators are tested at full power for 1 hour. Therefore the negative tests are credible while positive ones do not fully demonstrate their capabilities of reliable operation for an extended period of time.

Fig. 1 shows schematically the actual and theoretical diagrams of unavailability of a diesel generator under the hypothesis of an unavailability probability which is proportional to time.

Maintenance: in a nuclear plant the availability of diesel generators must be assured even when the reactor is shut-down, because core cooling capability must be maintained in case of loss of the outside power (L.O.O.P.). In conventional plants this problem is not encountered (★); therefore the intervals of planned outage of the plant allow a greater freedom in doing the diesel generator overhaul activities.

The licensee can perform maintenance according to one of the following models:

— symptomatic maintenance: the interventions on diesel generators take place only in cases of failure under test or on demand.

— preventive maintenance: the interventions on diesel generators take place at planned intervals of time for repetitive works; in addition interventions are performed as suggested by functional anomalies verified during surveillance tests even though a test failure did not occur.

Unavailability of diesel generators: for the purpose of the reliability evaluation it is convenient to distinguish the following conditions in which a diesel generator can be:

— unavailability due to a failure, awaiting for the repair work beginning.

— unavailability during maintenance: some kinds of intervention require preventive disconnection of actuation logics aud the diesel generator has to be considered as unavailable.

— latent unavailabilities: often surveillance tests ascertain an unavailability state preceding the start of the test. The beginning date of this unavailability cannot be determined. As a first approximation it can be assumed that in the period of time elapsed from the previous surveillance test the diesel generator has been unavailable during one half of such time.

— unavailability due to surveillance tests: during a surveillance test a diesel generator cannot respond automatically to an undervoltage signal of its bus-bar. The unavailability time is very short when the test is succesful. In case of failure or functional anomalies, unavailability is prolonged if the diesel generator is put out of service or submitted to maintenance.

Repair time: in the cases of failure to start or failure to run, the knowledge of the average time required for repairing the failure and putting again in service the diesel generator, has a particular importance. Even though technical specifications require a maximum time of about 30 seconds for start up and loading, it is evident that negative consequences of a plant black-out have their effect at least after 30 minutes-1 hour. Some simplest failures, therefore, can be repaired within this reasonable time. Many other failures, however, require longer times, generally more than 10 hours.

(★) excluding the cases where, during planned maintenance, the alternator left in a hydrogen atmosphere, is concerned. In this case the availability of the emergency power supply for the hydrogen seal systems is strictly required.

4 — INTERPRETATION OF OPERATING EXPERIENCE DATA

The instant probability of mission failure of a stand-by component is generally evaluated as the ratio between the number of negative outcomes and the number of operation demands:

$$p_0 = \frac{n_1 + n_2}{N_1 + N_2} \qquad 1)$$

where:

N_1 = number of start-up demands;
n_1 = negative outcomes of the N_1 demands;
N_2 = number of periodical surveillance tests;
n_2 = negative outcomes of the N_2 tests.

This evaluation criterion gives not much credible results, because of the following reasons:

a) the surveillance tests are not equivalent to a real operation under load.
In general

$$\frac{n_2}{N_2} \neq \frac{n_1}{N_1} \text{ with } N_2 \gg N_1$$

Therefore the probability p_0 is determined by the results of the surveillance tests (many but with a low degree of credibility) rather than by the few results of the real demands in case of need.

b) in order that the probability of failure on demand, p_0, has a physical meaning, its indipendence on the demand frequency should be demonstrated. In other words, if the hypothesis is made that the number of demands doubles or is reduced to a half, p_0 should have to remain constant:

$$p_0 = \frac{n'}{N'} = \frac{n''}{N''} = \text{const.}$$

On the contrary the operating experience shows that p_0 is not independent on the demand frequency. When N is low, p_0 decreases when N grows, then, grows when the frequency of demands is higher than a certain threshold value.
Two other criteria for evaluating the time-average probability of failure of a stand-by component are the following:

— **mixed criterion unavailability/failure on demand.** In the period tc when the component unavailability is ascertained, the probability of failure on demand is 1. In the periods of presumed availability the probability of failure is assumed as equal to the ratio between the number of negative outcomes and the total number of demands N. Therefore the average probability of failure during T is given by:

$$p_1 = \frac{tc}{T} + \left(1 - \frac{tc}{T}\right) \times \frac{n}{N} \qquad 2)$$

— **criterion of the availability factor.** Being t_c the total duration of the ascertained unavailabilities and t_l that of the latent unavailabilities in the period T under consideration, the average probability of failure on demand is:

$$p_2 = \frac{t_c + t_l}{T} \qquad 3)$$

In fact, each demand of operation is seen by the stand-by component as equivalent to a random occurence; thus the probability that the demand occurs during an unavailability (with a failure) is measured by the ratio $(t_c + t_l)/T$.

This cannot be said in the case of the surveillance tests that are performed only when the component is assumed as available. The duration of the latent unavailability, t_l, can be evaluated on the basis of the number and modalities of failure under test and on demand. The failure causes and the works performed to eliminate them allow in general to ascertain whether the unavailability existed before the test or occurred as a consequence of the test. In the first case the supposed duration of the latent unavailability can be assumed as equal to the half of the time elapsed from the previous test.

The selection of one of the 1). 2), 3) criteria depends on the quality and quantity of the available information.

In the case of a diesel generator subject to symptomatic maintenance (small unavailability) the application of the criterion 1) can give reliable results when the frequency of actual demands is high. in the opposite case the ratio between failures and demands does not allow a credible evaluation.

Criterion 3) considers only the times of ascertained and latent unavailability. For diesel generators subject to preventive maintenance and to few actual demands it gives results more reliable than those given by criterion 1). However it can introduce noticeable errors when the probability of failure under test has the same order of magnitude as, or higher than , the unavailability factor.

Criterion 2) appears to give results less affected by errors, as a consequence of the possible unbalance between unavailability and frequency of demands.

In the framwork of the present study the evaluation of the failure probabilities have been made with the 3 mentioned criteria.

The recovery time of a D.G. after a mission failure has been evaluated, as well as the probability that after 1,2..., n hours subsequently to the failure the diesel generator is returned to service.
The recovery times after a failure under test (the only data available) have to be considered longer than those strictly required, because in these cases there is not a real need to regain at any cost the D.G. operability. An other factor capable to affect the time to repair of one D.G. is the reliability of the on-site emergency power system as well as the reliability of the off-site power-grid. For instance the Caorso nuclear power plant has four diesel generator sets; only one of them is required. In addition the plant is connected to two indipendent transmission lines, respectively 380 and 110 KV. Caorso is connected also to a small hydroelectric power plant, about 5 km away.

5. ESTIMATION OF THE FAILURE PROBABILITY FOR THE 4 DIESEL GENERATORS OF CAORSO NUCLEAR POWER PLANT

Among about 1500 operational events analysed, 58 concerned the diesel generators. 51 of them are referred to individual sets and the remaining events to two or more sets, namely:

- 4 events common (or potentially common) to 4 sets.
- 2 events common to 2 sets.
- 1 automatic start of a set couple on spurious signal.

The analysis of the diaries of machine allowed to find other unavailabilities of the 4 sets (due mainly to planned maintenances). By means of both data sources it has been possible to reproduce the time sequence of unavailabilities and of failed tests.

The number of maintenance operations listed in the diaries of machine during the period 1/7/1978 - 31/8/84 are 452.

332 of them concern failure repair while 120 are referred to other maintenance works without component failures (sampling, instrument recalibration, etc.).

243 interventions have been performed on D.G. sets available before and during maintenance works;

191 interventions have been performed on D.G. sets available before the start of works but disconnected (and then unavailable) during works. Finally in 18 instance D.G. sets were unavailable before the maintenance and during the works.

Table 2 contain data required by the evaluation of the mission failure probability according to the previously mentioned criteria 1), 2) and 3). The examination of data contained in this table suggests that:

— the mission failure probability is about 0,06. This value can ben considered as normal when maintenance unavailabilies are taken into account;

— the latent unavailability of diesel generators subject to monthly surveillance tests has the same order of magnitude as the ascertained unavailability.

Fig. 2 shows the trend of probability p that a diesel generator fails to be recovered after 1,2,3,... n hours elapsed from a mission failure.

It can be seen that the probability to recover a diesel generator within few hours is very low. This can be related to the frequency and quality of the maintenance interventions: the more trivial failure causes are eliminated and the D.G. rarely fails on demand. However these rare events require more than 24 hours of repair time. It can ben predicted that the diesel generator performance could be different, if maintenance interventions were less frequent.

6. EVALUATION OF THE MISSION FAILURE PROBABILITY OF 17 D.G. OF ITALIAN FOSSIL-FUELLED POWER PLANTS.

The analysis of 1571 work permits, performed by means of the same criteria as those adopted for the 4 Caorso diesel generators, gave the results shown in Table 3. On the average the maintenance occurrences have been 12.8 per unit per year... 5.6 of them have been performed being the diesel generator unavailable because of a previous failure or as a consequence of the nature of the works to be made. The average hours of ascertained unavailability are 228 h per unit per year while 58 are the hours of latent unavailability. The mission failures under test are not uniformly distributed among the 17 generators. This can be due to two factors:

— the non uniformity of criteria in use at the 6 conventional plants in considering a test as a mission failure.

— the intervention of the operator in order to assure the success of the test, removing possible causes of failure.

No mission failure results to be occurred in the case of loss of connection to the grid (L.O.O.P.).

The average probability of failure, about 0.04, is lower and better of that resulting for the 4 Caorso diesel generators. This can be at least partially explained by the different size of the sets: the Caorso diesel-generators have a 5400 KW unit power, while the power of the 17 sets of the conventional plants ranges between 500 and 700 KW. Furthermore it must be noticed that statistics concerning Caorso and conventional plants can be used for predictive purposes very cautiously. In fact:

a) the significance of the "nuclear" sample is, statistically, low; this can reflect negatively on the average values found;

b) the safety functions of the "nuclear" diesel generators require a higher maintenance standard. This implies more frequent interventions, then longer unavailability times;

c) the technical specifications for operations of "nuclear" diesel-generators are undoubtedly more stringent; this contribute to define as failures events that in the context of fossil-fuelled plants would not be classified as anomalies.

Fig. 3 shows that the non recovery probability after a mission failure exhibits a trend similar to that of Caorso D.G.

7. COMMON CAUSES OF FAILURE AND UNAVAILABILITY

The analysis of anomalous operation events and work permits concerning the 21 diesel generators under study has shown few cases of multiple and contemporary unavailabilities. The cases where it has been verified that the failure in a D.G. was due to causes existing also in the other D.G. are more frequent.

The following cases are a sample of the multiple unavailabilities verified:

Caorso, February 1979 - In-leakage of water from man-way in to the common fuel storage tank. 2500 liters of water discharged. Unavailability: 170 hours. If the 4 diesel generators had to operate in those conditions, they probably had tripped because of the fuel pollution.

Caorso, June 1979 - While the diesel generator-2 was running, a decrease of the power output occurred. It has been found out that the load set-point of the governor drifted because of the engine vibrations. A test immediately performed on diesel generators 1,3 and 4 revealed the exixtence of the same problem.

Caorso, January 1985 - Because of the particularly low weather temperature (−22°C) and of the insufficient concentration of antifreeze in the diesel engine cooling water loop, the water freezed inducing the unavailability of all diesel generators during 48 hours. According to technical specifications the plant was shut-down for the same time.

Tavazzano 1-2, September - Because of leakages from the fuel storage tank, the diesel generators remained unavailable during 120 hours.

Casella August 1979 - The D.G.-4 has been unavailable during 564 hours because of maintenance works. During the same period works have been done on D.G. 1,2,3. Along 36 hours only 2 D.G. have been available.

Common cause failures occurring in a redundant system of diesel generators depend on their design characteristics and on the maintenance model adopted.

All the 21 diesel generators taken into consideration have indipendent auxiliary systems. Only the fuel cycle has components common to all the diesel generators of the same plant; in some plants each D.G. has a daily tank fed by one storage tank. The failures of the storage tank (piping, level meter, etc.) can, thus, determine contemporary unavailabilities for all diesel generators.

The probability that a potential cause determines contemporary multiple failures can be considered mainly as a function of the maintenance model. The operation history and the diaries of machine of the 21 generators show that preventive maintenance is often able to find out in advance the potential causes of common failure allowing to intervene by means of suitable actions.

During the about 140 units × year of operating esperienze of the diesel generators, as analysed in this study, never a mission failure single or multiple accurred following a real demand. Furthermore the execution of surveillance tests in different days for the diesel generators of the same plant, does not allow to verify whether the potential causes of common failures could have been really evidenced. Nevertheless a detailed analysis of data recorded in the diaries of machine induces to think about the credibility of evaluations based exlusively upon logic-mathematical criteria.

For instance the failure probability of the redundant system of 4 Caorso diesel generators, as computed under the hypothesis of independence of failure probabilities of the 4 sets, should be equal to:

$$P' = p^4 \cong 1.3 \times 10^{-5}$$

The common unavailabilities, ascertained or latent, account for 240 hours in 51.500 service hours. Even assuming that only 1/3 of this unavailability should be considered in evaluating the system unreliability, we have:

$$P'' = 1/3 \frac{240}{51500} + p^4 = 0.00155 + 0.000013 \cong 1.56 \times 10^{-3}$$

In practice the probability of system failure is determined by the few hours/year of contemporary unavailabilities. This must not surprise since the probabilities of failure of single diesel generators are not independent as a hasty analysis of available data could suggest. In fact:

— surveillance tests are performed in different times for the diesel generators of a plant and when there are no reason to think that a set is unavailable.

— not all the maintenance operations are preceded by a functional test. So some latent unavailabilities cannot be reavealed.

It is reasonable to think that:

— if surveillance tests were performed at the same time for all the diesel generators of one plant the potential common cause failures should determine contemporary unavailabilities with a frequency higher than that presently found.

— if surveillance tests were performed rigidly at fixed times (for instance at 10 a.m. of each wednesday) without taking into account che diesel generator operability conditions and the state of the plant, it can ben predicted that some failures presently unrevealed could occur.

— if each maintenance, planned or unplanned, with the plant shutdown or at power, were preceded by a functional test, it can be expected that some latent unavailabilities presently unknown could be put into evidence.

This should not be interpreted as a reccomendation to modify present criteria for D.G. testing and maintenance, only for the purpose of improving the quality of data to be used for reliability analysis. We want only to point out that incompleteness and unreliability of information presently available, even though useful and significant, do not allow to obtain credible results from sophisticated logic-mathematical models as offered by the reliability theory.

An empiric evaluation taking into consideration non statistical parameters (e.g. the maintenance quality, the on-site stock of spare parts and consumable materials) appears more appropriate considering the complex nature of the problem and the limited reliability of data at hand.

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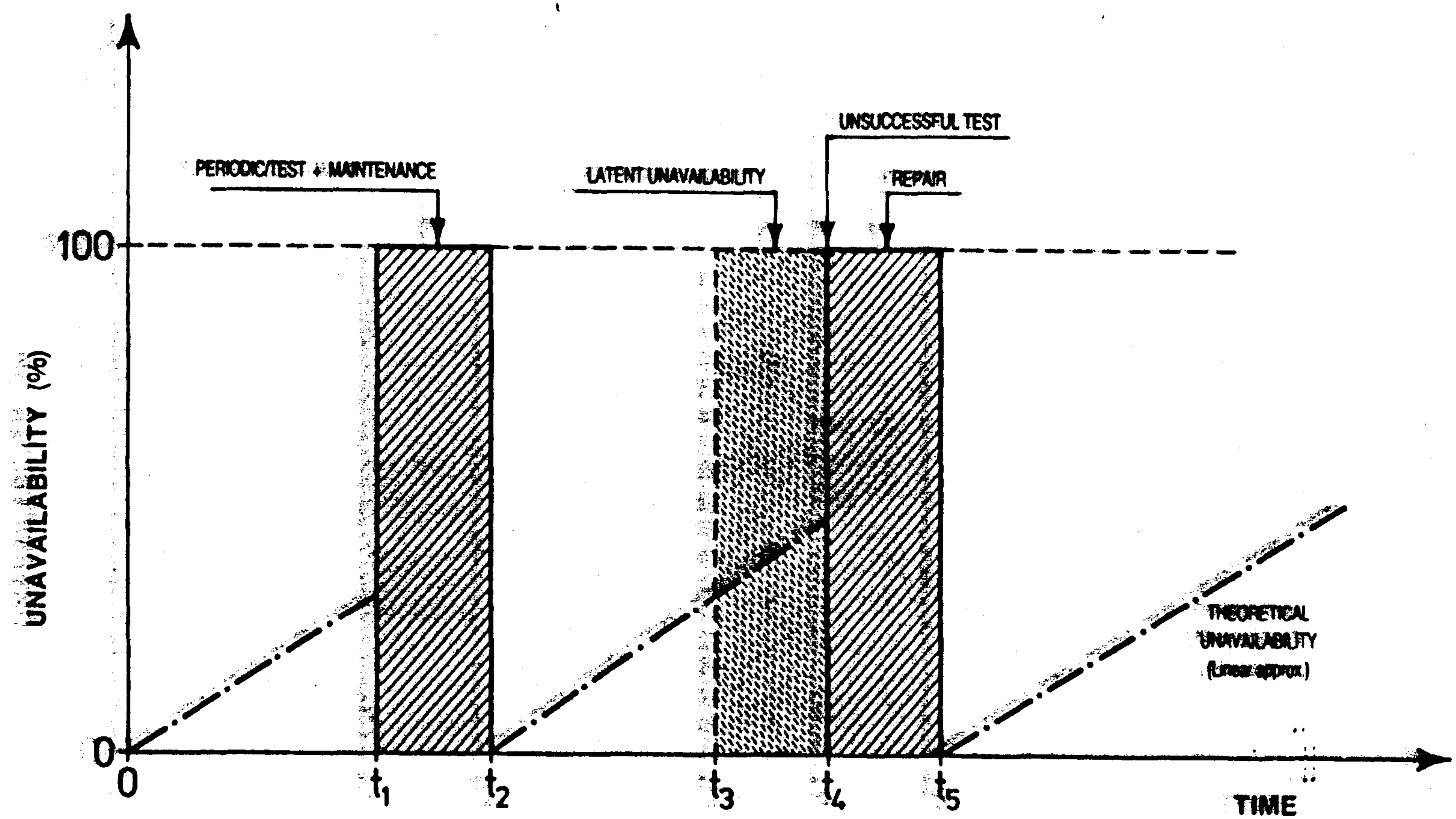

Fig. 1 - Qualitative diagrams of real and theoretical unavailabilities for a stand-by Diesel Generator set

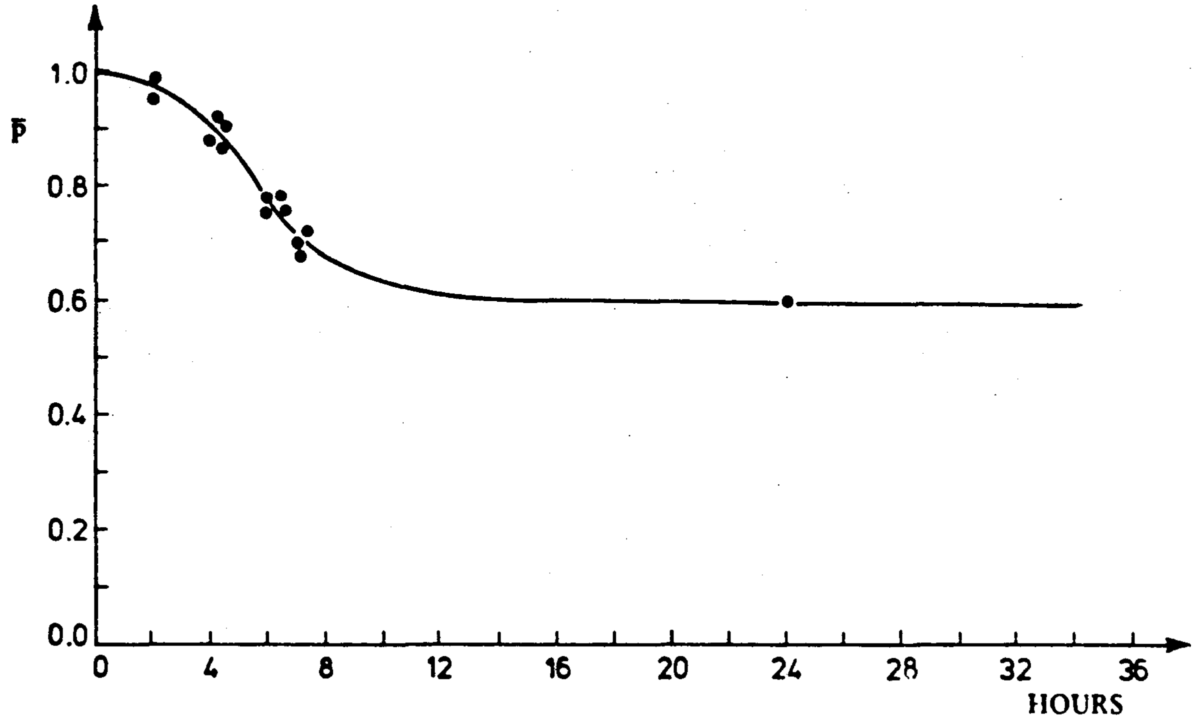

Fig. 2 - Non-recovery probability p̄ of a D.G. set 1,2,3, ... n hours after an unsuccessful periodic test (average data for 4 DG sets of CAORSO)

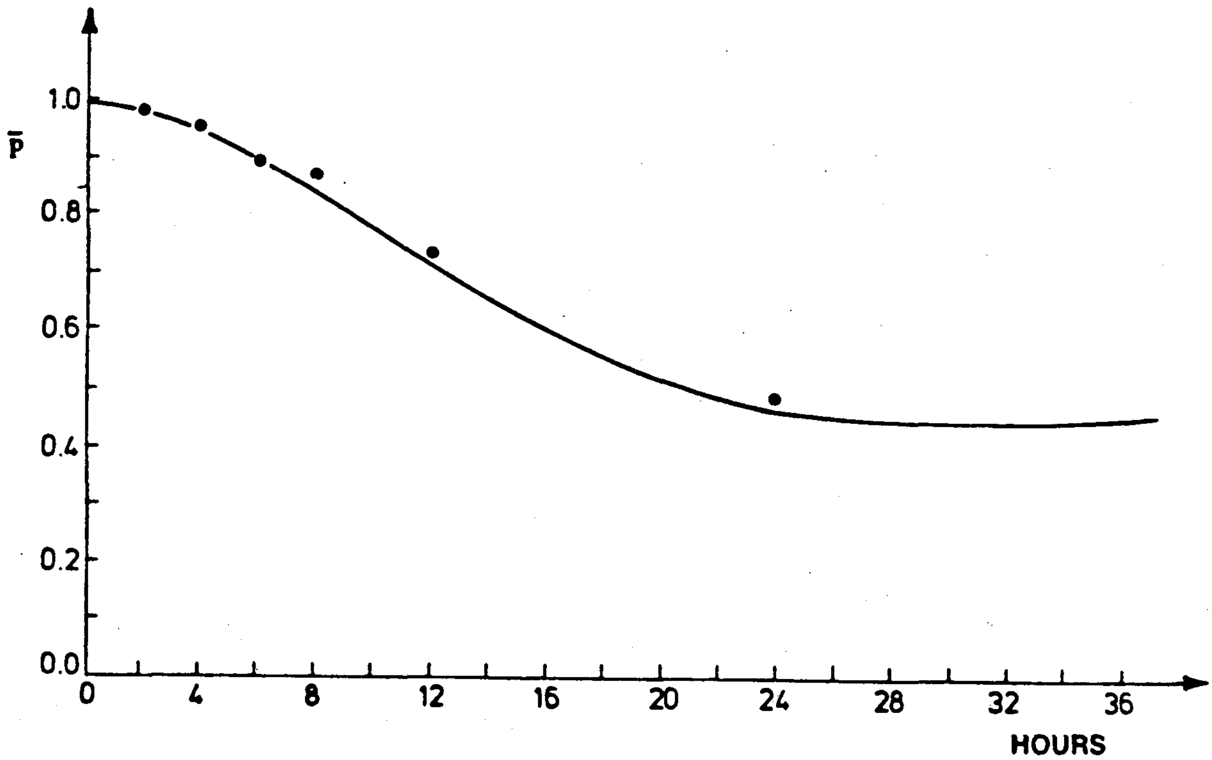

Fig. 3 - Non-recovery probability p̄ of a D.G. set 1,2,3,..... n hours after an unsuccessful periodic test (average data for 17 D.G. sets of fossil-fuelled plants).

Table 1 - General data on power plants and their emergency Diesel-Generators (D.G.) selected for the reliability analysis.

Name of the plant and units	Fuel	Gross capacity MW	Date of 1st Parallel	Number of D.G. sets
TAVAZZANO 1	OIL	70	4 - 1952	3
TAVAZZANO 2	OIL	70	9 - 1952	
TAVAZZANO 3	OIL	140	5 - 1959	
TAVAZZANO 4	OIL	140	12 - 1963	
TAVAZZANO 5	OIL	320	12 - 1981	
TAVAZZANO 6	OIL	320	9 - 1982	
PIACENZA 1	OIL	70	4 - 1953	2
PIACENZA 2	OIL	70	11 - 1953	
PIACENZA 3	OIL	320	9 - 1965	
PIACENZA 4	OIL	320	10 - 1967	
TURBIGO 1	OIL	260	5 - 1967	2
TURBIGO 2	OIL	260	4 - 1970	
TURBIGO 3	OIL	260	8 - 1970	
TURBIGO 4	OIL	260	11 - 1970	
OSTIGLIA 1	OIL	320	12 - 1967	3
OSTIGLIA 2	OIL	320	4 - 1973	
OSTIGLIA 3	OIL	320	1 - 1974	
OSTIGLIA 4	OIL	320	7 - 1974	
LA SPEZIA 1	COAL	320	8 - 1962	3
LA SPEZIA 2	COAL	320	5 - 1964	
LA SPEZIA 3	COAL	640	7 - 1967	
LA SPEZIA 4	COAL	640	7 - 1967	
CASELLA 1	OIL	320	7 - 1971	4
CASELLA 2	OIL	320	12 - 1971	
CASELLA 3	OIL	320	6 - 1972	
CASELLA 4	OIL	320	5 - 1973	
CAORSO 1	NUCLEAR	870	5 - 1978	4
			Total	21

Table 2 - CAORSO NPP. Performance of the 4 D.G. in the indicated observation periods.

Event	From 1-8-1978 to 31-12-1980				From 1-1-1981 to 31-8-1984				
	DG1	DG2	DG3	DG4	DG1	DG2	DG3	DG4	Total for 4 D.G.
Period hours	21.192	21.192	21.192	21.192	29.952	29.952	29.952	29.952	119.808
Number of monthly tests	29	29	29	29	42	42	42	42	168
Real demands (loop)	1	1	—	—	—	—	—	—	—
Spurious demands	—	—	1	—	—	—	—	—	—
Failures on demand	0	0	0	—	—	—	—	—	—
Failure to start under test	2	3	1	—	1	1	2	—	4
Failure to operate under test	3	2	1	1	—	—	1	2	3
Hours of proven unavailab.	3525	1630	1364	786	664	685	1803	819	3971
Hours of latent unavailab.	1800	1800	720	360	360	360	1080	720	2520
N° of significant events (*)	26	23	21	14	8	13	19	12	52
p_0 (%)	0,167	0,167	0,0667	0,0345	0,0238	0,0238	0,0714	0,0472	0,0417
p_1 (%)	0,3052	0,2309	0,1268	0,0703	0,0454	0,0461	0,1273	0,0732	0,0735
p_2 (%)	0,2513	0,1618	0,0983	0,0541	0,0342	0,0349	0,0962	0,0514	0,0542

(*) Failures under test, unavailabilities due to unplanned or planned maintenance, modifications of subsystems, etc.

Table 3 - Performance data of 17 D.G. sets at 6 fossil-fuelled power plants

Event	Power plant																
	Tavazzano		Piacenza		Turbigo		La Spezia		Casella				Ostiglia			Totals
	1	2 e 3	1	2	1	2	1 e 2	3	1	2	3	4	1	2	3	Average
Maintenance works (N°)																
Unplanned	13	24	47	21	57	70	60	20	67	57	69	71	152	100	76	904
Preventive	3	3	6	10	6	6	54	56	32	27	22	22	75	84	80	486
Modifications	1	1	1	0	19	13	2	2	10	8	7	7	25	16	24	136
Others	10	16	2	1	0	0	0	0	0	0	0	0	5	7	4	45
Total	27	44	56	32	82	89	116	78	109	92	98	100	257	207	184	1571
Observation hours	23304	46.608	61.344	61.344	78912	78912	122688	61344	76680	76680	76680	76680	78912	78912	78912	1.077912
Weekly tests (N°)	156	312	364	364	469	469	728	364	456	456	456	456	469	469	469	6455
Failure under test. (N°)	6	8	15	5	5	12	10	1	0	0	2	0	15	4	2	85
D.G. outages (N°)	18	18	26	16	46	32	46	20	47	46	41	53	113	64	47	633
Proven unavailability (h.)	2112	2809	1008	336	2030	1516	1793	923	841	1294	1044	1769	6245	2041	2158	28019
Latent unavailab. (h.)	504	672	1260	420	420	1008	—	84	—	—	168	—	1260	336	168	7.140
Man-hours for maintenance (h.)	329	618	1111	618	1199	890	1474	934	1451	1323	1248	1360	←	12.555	→	25.110
Cost, 10⁶ it. lire	5,578	11,041	18,059	11,041	15,46	11,36	18,32	10,78	18,384	17,733	17,73	18,48	←	234,121	→	390,357
p_0 (%)	0,0385	0,0256	0,0412	0,0137	0,0107	0,0256	0,0137	0,0027	0	0	0,0044	0	0,012	0,0085	0,0043	0,0132
p_1 (%)	0,1256	0,0843	0,0570	0,0191	0,0361	0,0443	0,0281	0,0177	0,011	0,0169	0,0180	0,0231	0,1098	0,0341	0,0315	0,0389
p_2 (%)	0,1123	0,0747	0,0370	0,0123	0,0310	0,0320	0,0146	0,0164	0,0110	0,0169	0,0158	0,0231	0,0963	0,0301	0,0295	0,0326