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DEVELOPPEMENT D'UNE BASE DE DONNEES DE FIABILITE DES MATERIELS SPECIFIQUE A UNE CENTRALE NUCLEAIRE

NUCLEAR POWER PLANT RELIABILITY DATABASE MANAGEMENT

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SYNTHÈSE :

Dans le cadre du développement d'un projet d'études probabilistes de sûreté de site (notion d'EPS vivante), la centrale nucléaire de Saint Laurent des Eaux développe une base de données de fiabilité des matériels propre au site. Les principaux objectifs de ce projet sont les suivants :

- élargir l'analyse des risques, et constituer une base de réflexion locale efficace sur la sûreté opérationnelle, en sollicitant la participation de tous les services de la centrale, analyser tous les transitoires opérationnels possibles et leurs conséquences sur la disponibilité, ce qui implique de dépasser le stade de la simple application de règles d'exploitation,
- impliquer les exploitants dans l'analyse du retour d'expérience notamment en suivant le comportement des différents matériels et des fonctions de sûreté,
- permettre aux responsables de la sûreté de la centrale de justifier leurs décisions vis-à-vis des activités de sûreté dans l'évaluation des incidents d'exploitation, et l'élaboration des programmes de maintenance préventive.

Pour atteindre ces objectifs, il est nécessaire de disposer de données, d'outils, de techniques et de développer des compétences.

La première étape consiste à estimer les données de fiabilité des matériels propres au site.

Les données brutes proviennent du système de gestion de la maintenance de la centrale, qui gère toutes les activités de maintenance et conserve en mémoire la trace de toutes ces activités et des défaillances de matériels.

L'estimation des données de fiabilité propres à la centrale s'effectue à l'aide d'un modèle bayesien qui combine ces données brutes validées avec les données génériques de l'entreprise.

Cette approche permet d'obtenir des données de fiabilité, par les principaux composants, modélisés dans les EPS, en vue de vérifier la cohérence du programme de maintenance préventive (OMF) et de valider les hypothèses de conception à propos de la fiabilité des composants.

Plusieurs études ont été réalisées, portant sur la fiabilité des composants, ainsi que sur le processus de prise de décision dans l'évaluation des risques d'incidents spécifiques.

Cette note donne une vue d'ensemble du développement réalisé sur le site, partant des données brutes jusqu'à la base de données de fiabilité spécifique, et ce conformément aux objectifs établis par l'entreprise.

EXECUTIVE SUMMARY :

In the framework of the development of a probabilistic safety project on site (notion of living PSA), Saint Laurent des Eaux NPP implements a specific EDF reliability database. The main goals of this project at Saint Laurent des Eaux are :

- to expand risk analysis and to constitute an effective local basis of thinking about operating safety by requiring the participation of all departments of a power plant : analysis of all potential operating transients, unvailability consequences...that means to go further than a simple culture of applying operating rules,
- to involve nuclear power plant operators in experience feedback and its analysis, especially by following up behaviour of components and of safety functions,
- to allow plant safety managers to outline their decisions facing safety authorities for notwithstanding, preventive maintenance programme, operating incident evaluation,...

To hit these goals requires feedback data, tools, techniques and development of skills.

The first step is to obtain specific reliability data on the site.

Raw data come from plant maintenance management system which processes all maintenance activities and keeps in memory all the records of component failures and maintenance activities.

Plant specific reliability data are estimated with a bayesian model which combines these validated raw data with corporate generic data.

This approach allow to provide reliability data for main components modelled in PSA, to check the consistency of the maintenance program (RCM), to verify hypothesis made at the design about component reliability.

A number of studies, related to components reliability as well as decision making process of specific incident risk evaluation have been carried out.

This paper provides also an overview of the process management set up on site from raw database to specific reliability database in compliance with established corporate objectives.

NUCLEAR POWER PLANT RELIABILITY DATABASE MANAGEMENT

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1 - INTRODUCTION

In the context of development of a probabilistic safety project on site (notion of living PSA), the Saint Laurent des Eaux NPP has implemented a site-specific EDF reliability database. The main goals of this project at Saint Laurent des Eaux are:

- to expand risk analysis and to constitute an effective local basis for thinking about operating safety by requiring the participation of all departments of a power plant: analysis of all potential operating transients, consequences of unavailability, etc., which means going beyond a simple culture of applying operating rules,

- to involve nuclear power plant operators in operating feedback and its analysis, in particular by following up the behaviour of components and of safety functions,

- to help plant safety managers to defend their decisions concerning preventive maintenance programs, operating incident evaluation, etc., before the safety authorities.

To attain these goals requires feedback data, tools, techniques, and the development of skills.

The first step is to obtain site-specific reliability data.

Raw data come from the plant maintenance management system, which processes all maintenance activities and stores complete records of component failures and maintenance activities.

Plant-specific reliability data are estimated using a Bayesian model that combines these validated raw data with corporate generic data.

This approach makes it possible to provide reliability data for the main components modelled in PSA, to check the consistency of the maintenance program (RCM), and to verify hypotheses made in the design stage about component reliability.

A number of studies, related to component reliability as well as the decision-making process for site-specific incident risk evaluation, have been carried out.

This paper gives an overview of everything done on site, from raw database to specific reliability database, to meet established corporate objectives.

2 - OBTAINING A RELIABILITY DATABASE ON SITE

Objectives

A high-quality reliability database specific to the Saint Laurent des Eaux site has been developed to meet the following requirements:

- track the reliability of safety equipment in the context of the plant safety re-evaluation requested by the safety authorities,
- optimize maintenance,
- carry out probabilistic evaluation of operating incidents using data specific to the site.

The system used to obtain these reliability data must:

- ensure exhaustive collection of observed failures,
- be highly automated to facilitate the analysts' work,
- be usable for both safety studies (PSA) and maintenance studies (RCM),
- be easy to use at all the skill levels of the site,
- be usable, in the longer term, at all of EDF's units.

Validated raw data

To meet these requirements, the raw data are taken from the maintenance management data-processing system for EDF PWR power plants. This system is identical on all of the units. All work on an item of equipment, however minor, is recorded in it, from the initial request to the closing of the file.

Based on a list of equipment families judged important for safety or maintenance studies, all requests for work associated with these items of equipment are extracted from the management file and automatically loaded into an analysis file using FIDEMIS© software. The information contained under the many headings of the management file is automatically assigned to the various fields of the failure record of the FIDEMIS© software. Each of the records is then analyzed by a site engineering expert. The set of analyzed records constitutes a validated raw reference data file that can be used to ascertain the reliability parameters of the equipment being investigated.

To facilitate the analysis, the expert can call on on-line help that allows the use of text or numerical information from other applications, such as the general operating rules, operating specifications, events, and operating statistics management applications.

Figure 1 shows one of the screens of the FIDEMIS© software used to validate a failure record.

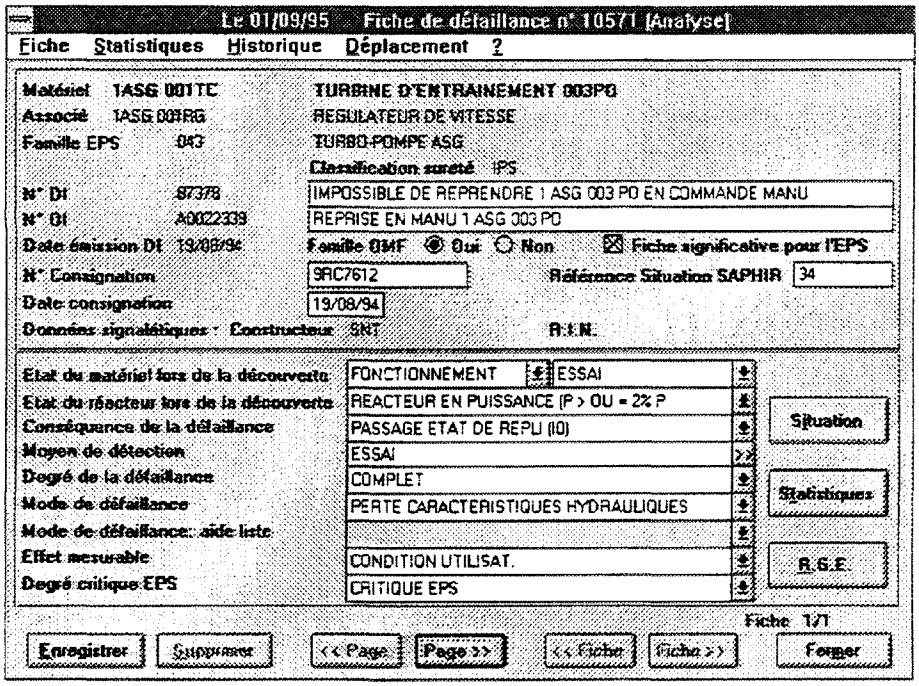

Figure n°1 : an example of FIDEMIS screen

Processing of validated raw data

From the file of validated raw data and the operating data for each equipment family, the reliability parameters (failure rate on demand, in operation, etc.) are estimated to constitute a reliability database specific to the Saint Laurent des Eaux site.

For this purpose, RDFS© (Site Reliability Data Collection) software has been developed; it automatically:

- extracts the validated failure records for a given equipment family from the FIDEMIS application,
- extracts, or generates using logical equations, the operating data associated with the equipment,
- estimates the reliability parameters of the selected equipment family using the Bayesian approach.

In effect, the main module of the RDFS© software is the FIABAYES© software, which uses the Bayesian approach briefly described below:

- the generic reliability data of all EDF PWR units, grouped by family, constitute the prior,
- the site reliability data for period N constitute the likelihood
- the posterior distribution calculated by combining the prior and the likelihood is used to estimate the reliability parameters specific to a particular equipment, site, and period N.

In addition, Bayesian inference makes it possible to follow the evolution of the reliability of the equipment continuously by re-using the posterior probability density of period N as prior for period N+1.

Figure 2 shows one the screens of the RDFS© software, used to estimate the reliability parameters of the equipment.

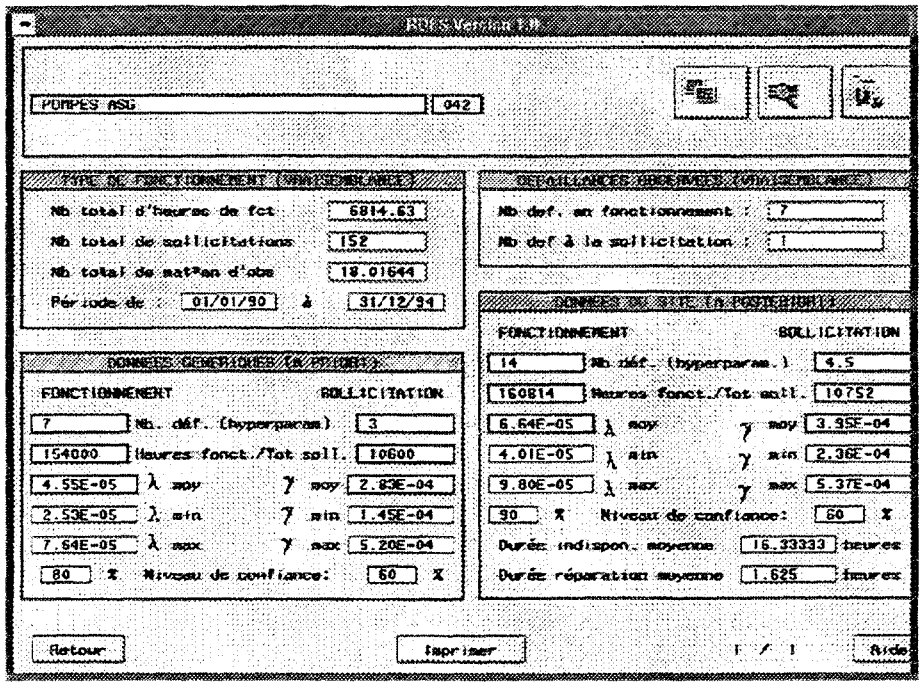

Figure n°2 : an example of RDFS screen

3 - RESULTS AND PROSPECTS

The objective of obtaining a high-quality reliability database specific to the Saint Laurent des Eaux site by the end of 1995 has been reached for the main safety equipment.

This concerns 80 mechanical and electrical equipment families, or approximately 4,500 elementary components from the primary pump to the level sensor.

The reliability studies conducted on site have concerned first of all:

-most of the pumps of the safety systems,
-the standby diesel generating sets,
-valves,
-circuit-breakers.

The samples of failure records cover a period of a ten of years and two 900-MW reactors, but data collection has really been exhaustive only since 1990.

These samples contain from a few tens to a few hundreds of failure or maintenance records.

The calculations of the failure rates in operation and on demand count only complete failures (total loss of the mission of the equipment). There are few such records, but enough for representative calculations using Bayesian theory.

As an illustration, the table below gives the results obtained for one type of pump, on demand and in operation.

	1990	1991	1992	1993	1994
failure rate in operation (generic value)	3.21 e-4/h	3.21 e-4/h	3.21 e-4/h	3.21 e-4/h	3.21 e-4/h
failure rate in operation (site value)	3.1 e-4/h	3.5 e-4/h	3.87 e-4/h	3.75 e-4/h	3.63 e-4/h
failure rate on demand (generic value)	2.96 e-4/d	2.96 e-4/d	2.96 e-4/d	2.96 e-4/d	2.96 e-4/d
failure rate on demand (site value)	2.89 e-4/d	2.82 e-4/d	2.75 e-4/d	2.67 e-4/d	2.63 e-4/d

More generally, we think that it is technically possible and relevant to obtain operating safety parameters at an industrial site provided that homogeneous generic distributions are available with the samples studied and that the Bayesian approach is used.

In particular, analysis of the differences in results between the observation and the generic distribution, and analysis of the evolution of the results versus time, yield indicators that are especially useful in ensuring the operating safety of the installation and the relevance of its maintenance.

The next step consists of performing probabilistic risk analyses using the failure and event trees provided by teams of specialists from the other divisions of EDF, together with the frequency of the initiating events and the mean operating profile of the units of the site.

For this purpose, a stage of learning with RISK-SPECTRUM© software is in progress, with as objectives:

- enhancing site engineering skills in probabilistic risk evaluation,
- performing, by 1996, probabilistic evaluations that are more representative of site realities, using the reliability database specific to the site.

Figure 4 sums up the approach applied at the Saint Laurent des Eaux site.

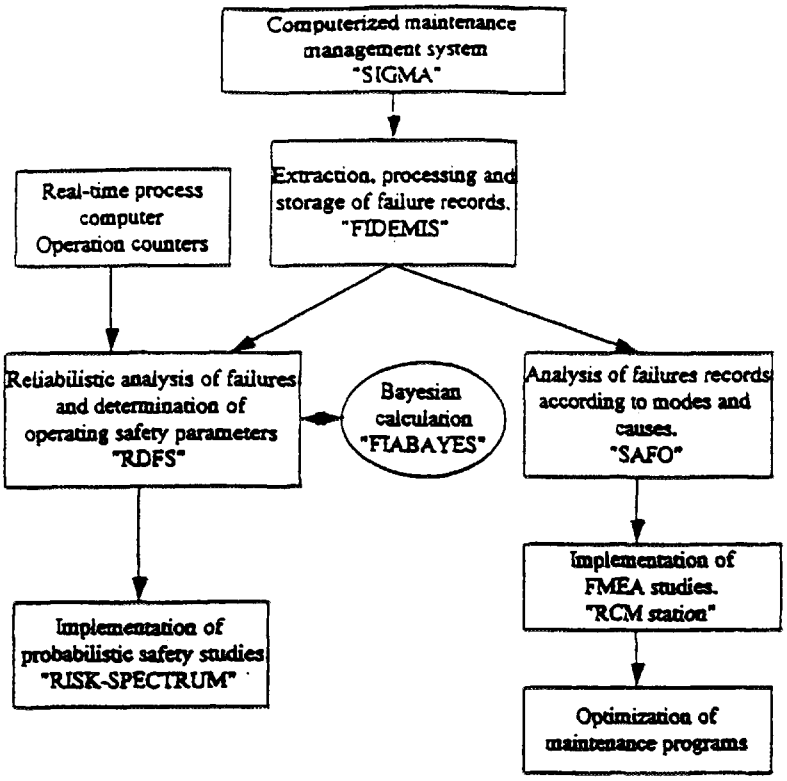

Figure n°4 : Schema of the approach applied at the Saint Laurent des Eaux site.