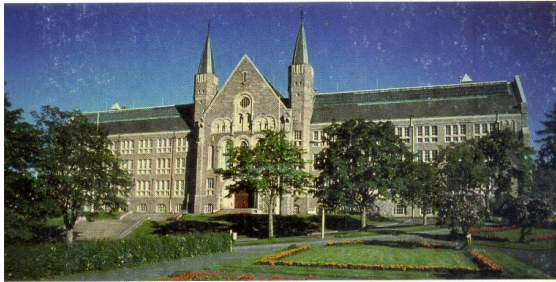




**Third International Conference on  
MATHEMATICAL METHODS  
IN RELIABILITY  
Methodology and Practice**

June 17-20, 2002  
Trondheim, Norway



COMMUNICATIONS



**Application of non parametric reliability distributions and tests for analyzing MV  
energy distribution network's failures : case of Niamey's 20 Mv network**

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**Abstract**

In this communication, we applied non parametric reliability distributions and tests in order to evaluate the "age" of energy distribution network's departures. These departures are affected by different kind of failures. Here, we restricted the study by analysing the failures which occasioned important indisponibility time to the damaged departures. On other hands, we developped the software "FiaElectricité" specially adapted to the specificity of collected datas. An application on analysis of different departures of Niamey's 20 Mv energy distribution network is realized.

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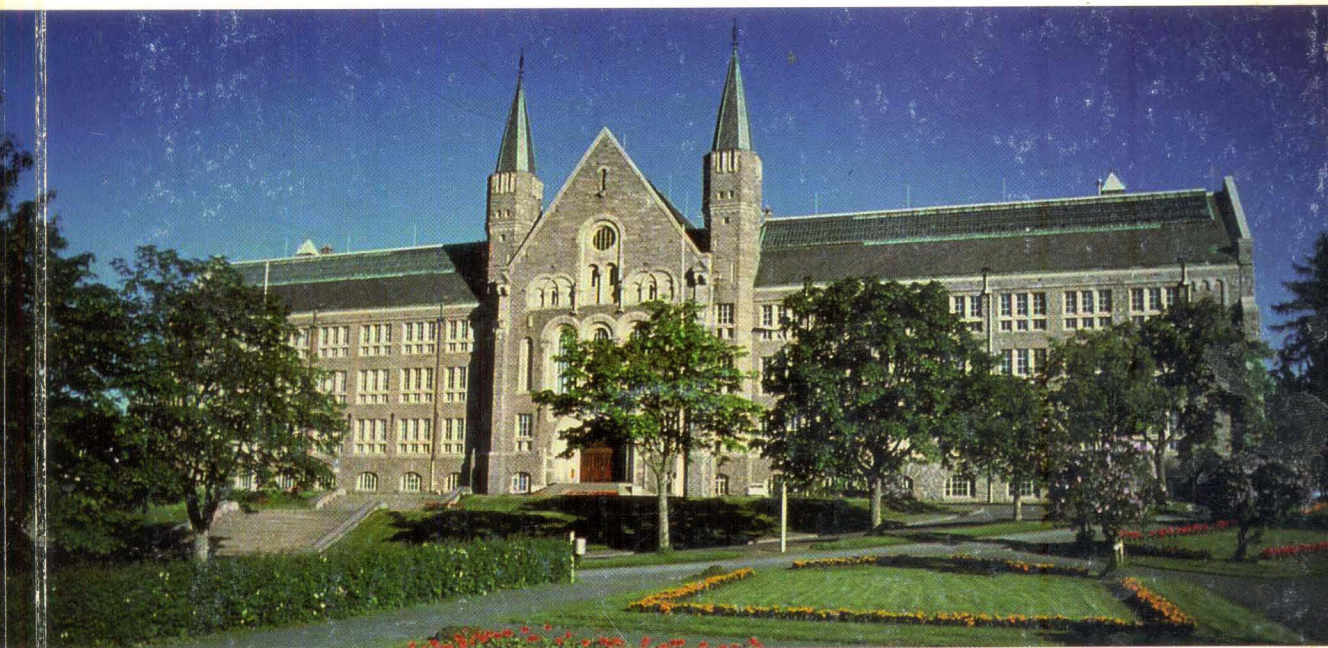


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## **Introduction**

Nowadays, in the theory of electric and energetic systems' functioning, reliability notions occupied a wide domain and constituted a determinant factor. Particularly, more than 60% of failures collected on these systems appear on energy distribution networks. Therefore, we recommanded reliability analysis for energy distribution network. It detected failures which deteriorated the system and determined the measures to take in view to improve the system's functioning.

This present work is included in FSE<sub>2</sub>'s aim (reliability of electric and energetic system). This aim consist to have care for studies about reliability of energy networks in specified conditions (lack of datas, ...).

## **1. Niamey's 20 Mv distribution network**

This system extracts energy through two posts. We named: Niamey III repartition's post and Goudel 66/ 20 Mv post of transformation. The network is constituted to 16 departures. Among them 7 are underground. Equipements are found on the departures with different functions:

- protection and isolation components ( circuit - breakers,...)
- measure and command components
- power components (power's transforming)

The departures are affected by different kind of failures. Here, we restricted the study by analyzing permanent failures . There occasioned important indisponibility time to the damaged departures.

## **2. Statistics tests for non parametric reliability distribution:**

Generally, it's not easy to detect the adequate distribution on the base of statistic datas: many distributions can be proposed to the same equipment . So, it's preferable to characterize life distribution by a qualitative property which express the "age" of the equipment (Aïssani and Saidi, 1997). This reason explained why we used the non parametric reliability distributions and tests.

A usual format for testing is:

$$H_0: \langle \bar{F} = \exp(-\alpha x) \rangle \text{ against } H_1: \langle F \in C, \text{ not exponential } \rangle,$$

Here, C is a class of non parametric distribution. It exists various statistic tests for the same class of non parametric distribution. In this case, we used the test  $T_n$  of Kochar and  $D_n$  of Koul. Their statistics are given respectively by (Kochar 1985, Koul 1977)

$$T_n = \frac{\tilde{T}_n}{\bar{X}} = \frac{\sum_{i=1}^n J\left(\frac{i}{n+1}\right) X_{(i)}}{n\bar{X}}$$

where  $J(u) = 2(1-u)[1-\log(1-u)]-1$  and  $\bar{X}$  is the sample mean of  $X_1, X_2, \dots, X_n$ . The  $T_n$  test reject  $H_0$  in favour of  $H_1$  for large values of  $T_n$ . The critical values are given in (Kocher 1985)

$$D_n = \frac{1}{n^2} \min_{1 \leq i \leq j \leq n} [nS_{ij} - (n-i)(n-j)] = \frac{1}{n^2} \min_{1 \leq i \leq j \leq n} T_{ij}$$

with  $S_{ij} = \sum_{k=1}^n I(X_{(k)} > X_{(i)} + X_{(j)})$  and  $T_{ij} = [nS_{ij} - (n-i)(n-j)]$  pour  $1 \leq i \leq j \leq n$ .

This test reject  $H_0$  for small values of  $n^2 D_n$ . The critical values of  $D_n$  test are given in (Koul 1997).

### 3. Application of statistic tests for non parametric distribution on Niamey's 20 Mv network

We have to note that for computations, we appeal to the software named "FiaElectricité". We'll present it in the following pages.

#### 3.1 Modelisation

In view to simplify the model, we codify the different departures. Among the 16 departures, we considered only 13 for the study. Quite so, Koubya and Medina are departures which are created recently.

We assimilated  $X_i$ , the random variable denoting the lifetime of equipment  $i$  in reliability theory, to "the number of permanent failures collected each year on the departure  $i$  ( $i = 1, \dots, 13$ )". The  $X_i$ 's values are given in the table 3.1 (see document of the Nigerien Compagny *Nigelec*).

At each  $X_i$ , we associated a distribution  $F_i$  ( $F_i$  characterized a qualitative property which expressed the "age" of the departure  $i$ ). The fundamental problem consists to determinate the  $F_i$  ( $i = 1, \dots, 13$ ). This reason explained our choice for non parametric tests.

Before determinating the  $F_i$ , we did a previsions study. We considered that the values of each  $X_i$  constituted a chronological series. By applying "exponential lissage" method, we obtained the results of the following table:

Table 3.2 : forecasts' values for 2001's year by departure

	1997	1998	1999	2000	Forecast 2001	Constant of Smoothing ( $\alpha$ )
Departure 1	10	13	15	14	14	0,1
Departure 2	12	12	18	8	12	0,9
Departure 3	8	12	8	4	8	0,9
Departure 4	8	10	6	8	8	0,9
Departure 5	5	1	4	9	5	0,9
Departure 6	2	8	10	7	7	0,1
Departure 7	17	10	6	9	9	0,1
Departure 8	5	21	14	11	12	0,5
Departure 9	3	4	2	3	3	0,9
Departure 10	1	1	0	1	1	0,9
Departure 11	4	3	1	2	2	0,1
Departure 12	1	5	4	4	4	0,2
Departure 13	4	2	6	6	4	0,9

### 3.2 Determination of the $F_i$ ( $i = 1, \dots, 13$ )

#### a) Test $T_n$ of Kochar

This test is consistent, its application on Niamey's network gave the following results:

**Table 3.3 : statistics' values and  $F_i$ 's nature by departure**

Departures	1	2	3	4	5	6	7	8	9	10	11	12	13
Val( $T_n$ )	0,543	0,492	0,472	0,530	0,382	0,456	0,455	0,433	0,511	0,463	0,468	0,468	0,479
$F_i$	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp

It resulted to this test that all the  $F_i$  are exponential with a level  $\alpha = 0.05$ . In referring to the classification of non parametric reliability distributions, we proposed to do a test for NBU's property.

#### b) Test $D_n$ of Koul

We can notify that the critical values for  $n = 4$  exist ( $n$  is the size of the sample), and on the other hand  $D_n$  test is consistent. The applying of  $D_n$  test at 0.05's level gave the results of the following table

**Table 3.4 :  $F_i$  ( $i = 1, \dots, 13$ )'s nature for each departure**

Departures	Nature	Dist $\alpha = 0,05$	Dist $\alpha = 0,10$	Source station
1	Air	$F_1$ is NBU	//	Station of Ny III
2	Air	$F_2$ is Exp	$F_2$ is NBU	//
3	Air	$F_3$ is Exp	$F_3$ is NBU	//
4	Air	$F_4$ is NBU	//	//
5	Air	$F_5$ is Exp	$F_5$ is Exp	Station 66/20KV
6	Air	$F_6$ is Exp	$F_6$ is Exp	//
7	Underground	$F_7$ is Exp	$F_7$ is Exp.	Station of Ny III
8	Underground	$F_8$ is Exp	$F_8$ is Exp	//
9	Underground	$F_9$ is NBU	//	//
10	Underground	$F_{10}$ is Exp	$F_{10}$ is NBU	//
11	Underground	$F_{11}$ is Exp	$F_{11}$ is Exp	Station 66/20KV
12	Underground	$F_{12}$ is Exp	$F_{12}$ is NBU	//
13	Air	$F_{13}$ is Exp	$F_{13}$ is NBU	//

These results expressed that among all the departures, only three (3) presented NBU distributions. There are  $F_1$ ,  $F_4$  and  $F_5$ .

On other hand we would propose to test NBUE alternative, but the small size of the sample didn't allow us. Then, we resumed the  $D_n$  test of Koul with an increasing risk. We considered  $\alpha = 0.10$ . The results obtained are given in the table 3.4.

### 3.3 Interpretation of Results

It derived from the obtained results that only  $F_1$ ,  $F_4$ , and  $F_9$  are NBU's distribution. The other remained exponentials. However, NBU distribution placed in a prominent position the oldness of 1, 4 and 9's departures. Then, we affirmed that those departures are in reliability viewpoint, "old". For  $\alpha = 0.10$ , in addition of 1, 4, 9, the departures 2, 3, 10, 12, and 13 are "old" too.



#### 4. Optimization of different departures equipments maintenance

Here, we considered the departure 9. After the ABC analysis, for each considered equipment, we determined the failure cost  $C_{d9}$  and the maintenance cost (Lyonnet 1993). There are respectively given by the following formulas:

$$C_{d9} = K_w(1 + \theta) P_{c9} T_{c9}$$

$$C_{p9} = C_{m9} + C_{m09}$$

If  $r_9 = \frac{C_{d9}}{C_{p9}} > 1$ , this result justified our choice for a preventive maintenance policy.

At last, for optimizing the time of preventive replacement of equipments, we considered the preventive and corrective maintenance cost:

$$G_{c9} = \frac{C_{p9} + C_{d9}}{MTBF} ;$$

$$G_9(T) = \frac{C_{p9} + [1 - \bar{F}_9(T)]C_{d9}}{\int_0^T \bar{F}_9(t) dt}$$

with  $G_9(T) < G_{c9}$ . The optimal time of replacement is the time which minimizing the cost  $G_9(T)$ . For its evaluation, we had to resolve the following equation:  $\frac{dG_9(t)}{dt} = 0$ . Then, we could confirm the decision relative to the test of Koul.

#### 5. Presentation of "FiaElectricité" software:

This program is developed for previsions computations and determination of different distributions based on statistic datas collected from Niamey's 20 Mv distribution network.

"FiaElectricité" is been conceiving specifically to take into account the datas specificity. It is realized under Delphi 5 environment. "FiaElectricité" is constituted to 3 principal programs:

- computations of prevision. It gave  $\alpha$  (lissage's constant corresponded) which minimize the chosen criteria and the corresponded previsions' values.
- the appurtenance of a distribution to IFRA alternative
- the appurtenance of a distribution to NBU alternative

#### Conclusion

It derived from this application that three departures presented NBU distribution at 0.05's level. This reason allowed us to assert that corresponding departures are "old" in reliability viewpoint: NBU property belongs to the oldness models. In other hand we recommanded an applying on a preventive maintenance strategy. For the justification of this decision, we proposed an application which based on the "theory of equipment renovation".

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