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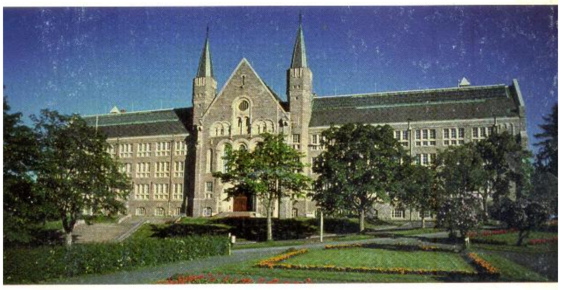

COMMUNICATIONS

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Economic Aspects of Distribution Power System Reliability. Application to a 30KV network of Béjaia, Algeria

Rabah MEDJOUDJ
LAMOS
Laboratory of Modeling
and Optimization of Systems
University of Bejaia, 06000 Algeria
E-mail: lamos_ bejaia@hotmail.com

Djamil AISSANI
LAMOS
Laboratory of Modeling
and Optimization of Systems
University of Bejaia, 06000 Algeria
E-mail: lamos_ bejaia@hotmail.com

Abstract

Distribution systems are the part of power systems that deliver energy from the area supply to the customers. The reliability indices sought-after are frequency and mean duration of interruptions and the non-delivered energy (NDE). To improve these indices, technical and organizational measures are considered. When decisions are made about the level of reliability to be achieved in a system, an attention must be paid to the economic factors, such as the incremental costs of reliability, the benefits expected from a change in reliability, and the allocation of the reliability investment among the system. However, an objective function is defined with the goal to determine an optimal balance between the gains realized from higher reliability and the cost of providing it. This function, minimizes the sum of costs of investments, operation expenses (losses) and economic inconvenience (damage caused to customers).

In this paper, an application is done for an Algerian electric distribution system by simulation . The actual state of the system is undertaken, and its reliability indices are compared with those computed under the measures already described. The results acquired, show major advances and contribute further on the understanding the relative importance of the economic aspects of reliability.

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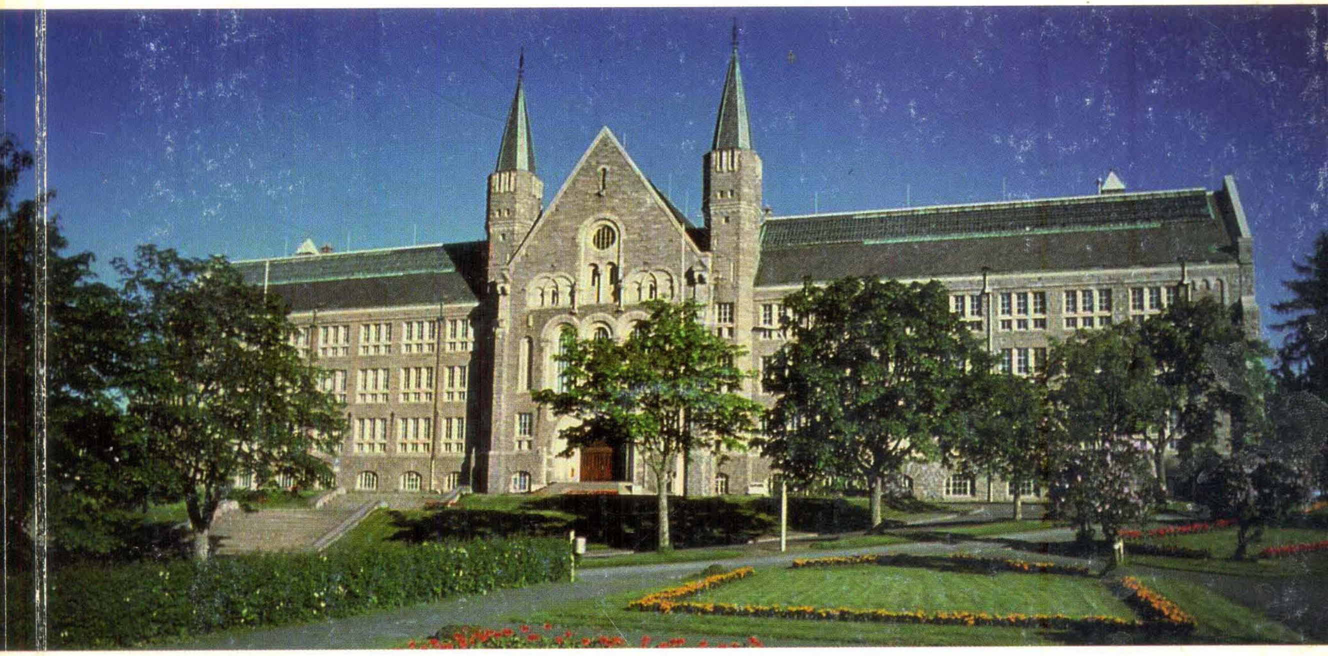

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Introduction

At present, the reliability technics are successfully applied on the electrical supply networks field (Medjoudj, 1994). Indeed, much efforts are developed to ensure the reliability of the systems and the quality of service to customers. This mission depends of planning and the exploitation of these networks. More then 60% of interruptions appear in the distribution level. For this, a particular interest is granted to this part of networks. The frequency of appearance of the interruptions and their duration characterize the indices of reliability of an electrical network.

1 Technical aspects of reliability

The paramount interest of any study of reliability is to ensure a good quality of service to customer (Medjoudj and D.Aissani, 1994) defined as a combinaison of availability of the

energy supply and the quality of the energy available at customers (Medjoudj, 1994).
The availability of the energy supply for a customer is characterized by (Endrenyi, 1978):

- The annual average frequency of failures : $f_c = \sum_{k=1}^{n} \lambda_k$ (fault/year).
- The average duration of failures : $t_c = \frac{\sum_{k=1}^{n} \lambda_k T_k}{f_c}$ (hour).
- The annuel average duration of failures : $t_{ca} = \sum_{k=1}^{n} \lambda_k T_k$ (hour/year).
- The non delivered energy to the customer :$NDE = P_c t_{ca}$ (kwh/year).

Where : λ_k and T_k are respectively the failure rate and the down-time of the component k in a system of n elements and P_c is the power offered for a customer cut.
The quality of power offered to a customer is characterized by the deviations of the voltage level, the voltage curve and the frequency. To improve the reliability level, technical and organizational measures are considered during the planning and the exploitation of electrical distribution network. The actions currently carried out at the time are:

a) reorganization of the networks by:
    1. the looping or grid of these networks, for more flexibility in failure conditions.
    2. the reduction lengths of the departures, by the creation of new source stations.

b) automation of networks by installing the interlocking in lines and the fault detectors.

c) realization of work under tension.

2 Economic aspects of reliability

An attention is paid to the economic factors. The economic criterion considered is that which minimizes the expectation of the objective function given by the equation 1.

$$\min \mathbb{E}\left[\sum_{t=1}^{T} \frac{I_t + R_t + F_t}{(1+i)^t} - \frac{V_{T+1}}{(1+i)^{T+1}}\right] \quad (1)$$

Where:
T: horizon of planning; t: index of time step; I_t: cost of investments; R_t: cost of operation expenses (losses); F_t: cost of economic inconvenience; V_{T+1}: practical value of the system at the period of planning; i: up-dating rate characterizing the financial policy of the company. $\mathbb{E}$: operator of expectation, taking in account the random variables which affect the system.

2.1 Cost of investments

Let:
I_k: unit capital cost of a work, k ;
I_{ka}: annual capital cost brought up to date of work k: $I_{ka} = I_k \frac{\gamma^n(\gamma-1)}{(\gamma^n-1)}$.
with $\gamma = i + 1$ and n = year of use.
If there are k' works, the annual cost updated becomes : $I'_{ka} = \sum_{k=1}^{k'} I_{ka}$.
The total cost of investments over the period of planning is: $I_t = \sum_{t=t_1}^{t_2} I'_{ka} \gamma^{-t}$.

2.2 Cost of operation losses

The maximum losses are given by : $P_{max} = 3r' I_{max}^2 l$.
The annual cost of losses for a length of cable (line) k is: $R_k = (K_p + K_w \theta T_a) P_{max} \nu$.
with :
r': the linear electrical resistor in Ω/Km; I_{max}: the maximal loading in Amperes; l: the length of the line (cable) in Km; K_w: the tariff of kwh; K_p: the tariff of kw; θ: the ratio defining the use of the network; ν: the variation factor of demand; T_a = 8760 h. If, the network contains k' sections, the total annual cost is : $R_k' = \sum_{k=1}^{k'} R_k$.
The total cost of losses is thus : $R_t = \sum_{t=t_1}^{t_2} R_k' \gamma^{-t}$.

2.3 Cost of economic inconvenience

It is felt mainly by the user of the network. The valorisation of economic gene varies from country to another. Two examples are quoted.

a) Case of Norway : the cost of the failure is : $C_d = P_c(K_p + K_w t_c) = P_c K_p + NDE.K_w$.

b) Case of France : The cost of the failure is : $C_d = P_c(K_p f_c^2 + K_w t_c) = P_c K_p f_c^2 + NDE.K_w$.

It is noticed that in the second case, the economic embarrassment is a quadratic function of the number of failures. This valorisation directs the investments in priority on the most disturbed zones.
The updated cost of economic gene is then : $F_t = K_w \sum_{t=t_1}^{t_2} NDE.\gamma^{-t} + K_p \sum_{t=t_1}^{t_2} P_c f_c^2 \gamma^{-t}$.
Finally, the economic criterion to optimize is written

$$\text{Minimize } I_t + R_t + F_t \qquad (2)$$

3 Application to the 30kv network of BEJAIA

Having collected the necessary data relating to times of failures, failure rates of the the network components and other electrical characteristics, we perform the calculation of reliability indices. Simulation was carried out on soft ware ZV, developed in PASCAL 6.0 (Jungnckel and Haim., 1992).

3.1 Technical calculation

The reliability indices (R.I) are calculated for three alternatives defined as below:

Alternative 1: Current state of the network

Alternative 2: Automation of the network by

a) Installation of faults indicators .

b) Installation of faults indicators an reclosers in line.

Alternative 3: Reorganization of the network, by changing cables. This correspondes to the failure rate of cable in accordance with the international data.

The results are recapitulated in the table below .

Table 1: The results of reliability indices for different alternatives

Alternative / (R.I)	1	2a	2b	3
f_c(fault/year)	2.7160	2.7160	2.7160	0.4648
NDE (kwh/year)	8032	5865	3138	1602
t_{ca} (hour/year)	82.6	60.4	32.2	16.4
t_{fault} (hour/year)	4.1	2.8	1.8	0.8

3.2 Economic calculation

It is carried out for alternative 1 (no investments) and alternative 2a (with $I_k = 60477.0$DA (cost of fault indicators in Algerian money)).
With: $\nu = 1.03$, $T = 5$ years and $i = 3\%$: the losses pass from 123.6kw to 169.19kw.
With : $K_p = 23.86$ (DA / kw) , Kw = 66.10 (DA/ kwh)and $\theta = 30\%$.
The cost of alternative 1 given by the equation (2) is equal to : $C_1 = 138.08 \times 10^6$ DA.
The cost of alternative $2a$ given by the equation (2) is equal to : $C_2 = 137.46 \times 106$ DA.
From where, one retains the alternative 2a.

Conclusion

The search for an economy of scale on the planning and the exploitation of the electrical distribution networks, must be today founded on new techniques to ensure their reliability and place at the disposal of the customer a product of optimal quality. The new technics are wanted to be easily feasible and applicable by reliability models to achieve the goals aimed at by any company of electricity.

References

Endrenyi, J. (1978). *Reliability modeling in electrical power systems.* John Wiley and Sons ltd, Toronto.

Jungnckel, V. and Haim., K. (1992). Zuverlassigkeitanalyse vo mittelspnnungsneten (zv). *Fakultat electrotechnik, Zittau, Allemagne.*

Laturnus, G. (1993). Politique d'EDF GDF services en matière de qualité de fourniture dans le domaine rural. *Acte du CIRED, Bermingham.*

Medjoudj, R. (1994). *Analyse de la fiabilité d'un réseau électrique urbain - cas du réseau 10 KV de la ville d'Alger -.* Thèse de magister, Université de Béjaia.

Medjoudj, R. and Aissani, D. (1994). Méthodes de recherche de défauts et calcul des valeurs caractéristiques de fiabilité d'un réseau électrique mt. *Rapport interne, LAMOS , Béjaia.*

Medjoudj, R. and D.Aissani (1994). Calcul des indices de fiabilité d'un réseau électrique urbain. *Actes du CMES'94, Skikda,* pages 7–12.

Contents

NTNU

Norwegian University of
Science and Technology

Department of Mathematical Sciences

Alfred Getz vei 1
NO-7491 Trondheim
Norway

ISI Committee on
Statistics in Business and Industry

The Research Council
of Norway

SINTEF

Vesta

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