Journal of Scientific Research & Reports
2(1): 145-172, 2013; Article no. JSRR.2013.012

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Cost Estimates and Study of the Characteristics of the Discontinuity of Electricity Supply of Industries in Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. The corresponding author BD designed the study, but the two authors BD and TTT work together at all stage of this manuscript. All authors read and approved the final manuscript.

Research Article

Received 21st December 2012
Accepted 23rd February 2013
Published 17th March 2013

ABSTRACT

This article treats the cost estimates and study of the characteristics of electricity supply interruptions in industries. The impact of the characteristics (duration, timing, warning time and frequency) on the cost of interruptions is put in evidence. The model described in this article uses data collected through a survey with questionnaire of a representative sample of industries and from previous statistical studies. The choice of the sample of industries was made thanks to a two degree sample survey method. The results obtained indicate that the average costs of interruptions are €1,050/h and of €815/h respectively for the scenarios without advance notice and with advance notice. The cost by interruption per industry is on average €6,300 for a supply interruption without advance notice and of €4,890 for a supply interruption with advance notice, thus a difference of 8.4%.The average cost varies from €2.58/kWh to €4.83/kWh lost for a 1-hour interruption and from €1.75/kWh to €3.75/kWh for a 4-hour outage. The trend of the interruptions' costs shows a decrease after the first hour, they are not proportional to the frequency of the outages. The supply interruptions are more frequent at the peak periods (6 pm -11pm); we record an increase of 10% in the costs compared to the costs at normal periods. However,

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disparities of 5 to 15% were observed between the costs of interruptions in industries according to the equipment and the measurements which exist in order to mitigate the effect of outages. A mastery of the electricity supply interruption cost structure would make it possible for industries to be better prepared to face them and the company in charge of electricity called Applied Energy System- SONEL (AES-SONEL) could easily improve the performances of the electricity network.

Keywords: Industries; electricity; cost; supply interruption.

1. INTRODUCTION

With an unstable electricity capacity of 19.83 GW of which less than 3% is exploited [1], Cameroun has the second hydro-electric potential in Africa after the Democratic Republic of Congo (DRC). The model of centralization of the production of electricity around the Sanaga River basin and the monopoly with regards to the transport and the distribution of the electrical energy had been adopted in the year 1970. In the year 2002, 94.79% of the hydro-electric production of electricity came from the Sanaga River basin through installations in the towns of Edea and Song-Loulou; the 5.21% left was produced from the Lagdo dam [1]. In 2012, the capacity installed was only 923 MW, very few changes were brought to the configuration of the electricity supply network, it comprises two inter-connected networks,the South Interconnected Network (SIN),the North Interconnected Network (NIN) and an autonomous network of electricity which feeds the EST region of the country. Electricity is conveyed from the point of production towards the distant industrial centres of more than 400 km for the majority of cases, through badly maintained transport lines functioning closest to their limits, this generates losses of energy of about 20 to 30% in the transport network [2]. In the reference [3], the pathways of these losses were identified by using the algorithm of Dijkstra. The electricity distribution network made up of air power lines also faces significant degradations and of many racking of electricity on behalf of the malevolent populations, it is the most vulnerable point of electrical installations. The quality of the electrical energy is degraded considerably by the appearance of harmonic currents, voltage hollow and flickers; otherwise, the continuity of the provisioning of the consumers with energy is not any more reliable. Continuity of supply is characterised by the number of electrical supply interruptions and their duration. The electricity network is the seat of many perturbations. These disturbances can be placed within the framework of operational research (OR) of uncertainties on the capacity of the sources of electricity, uncertainties on the loads, and in risks [4]. These disturbances are the cause of many electricity supply interruptions recorded by the consumer. In the literature, the devices to cope with overvoltage and voltage drops exist [5], the more worrying failures thus concerns supply interruption [6]. In Cameroon, industries recorded about 128 electricity interruptions of a 4 hours duration in the year 2010, the deficit of the supply compared to demand in electricity being estimated at 241GWh [7]. Supply interruption is a condition in which the voltage at the supply terminal is lower than 5% of the reference voltage (ENS 50160:2010). In the reference [8], the authors showed that the electricity interruptions in the electricity distribution network of the town of Yaoundé (Cameroon) follow a truncated and gamma distribution or truncated normal law in opposition to the exponential law and Poisson distribution encountered in the literature.

In a context marked by the requirements of competitiveness and performances in industrial milieu, a precise estimate of the costs of these electricity supply interruptions is a concern of great importance for industries for the improvement of their developmental programs. The European Union (EU) in its report C10-eqs-41-03 [9], specifies the framework and the methodologies of the studies related to cost estimate of the interruptions and fluctuations of voltage. In 2002, the Conference of the wide-area networks of electricity (CIGRE) in its report CIGRE TF 38.06.01 had already developed the basics and methods of control of the investigations intended for the cost estimate of interruptions in industries. Three main methods are used for the estimation costs of power interruptions to industrial companies, namely analytical methods, case studies of blackouts, and customer surveys methods. Bental and Ravid [10], developed an estimation model for power interruption costs based on the determination of marginal costs of electricity self-generation. According to this model, the marginal cost of power outage is equal to the cost of electricity self-generated assuming that firms operate essentially with the aim of maximizing their profits. This model was also used by Beenstock in 1997 for the estimation of the cost of power outage in business and public sectors in Israel; the value of US$7.20/kWh of unsupplied electricity was obtained [11]. Adenikinju combined the marginal cost (MC) method and the production function approach to estimate the power interruption costs to industries in Nigeria [12]. The result which comes from a survey sample of 800 industries in Thailand shows that unplanned outage cost negatively impacted industries [13]. Reviews on the power interruptions costs are presented in the references [14-16].

Two major insufficiencies are observed in a recurring way in the majority of studies, the absence of a rigorous method in the choice of the survey units which constitute the sample, moreover these articles are focused on the total costs estimate of the interruptions without being concerned with the study of the characteristics of these suspensions of electricity (frequency, timing, warning time, duration). The lack of rigour in the constitution of the sample is the cause of worse costs estimates of the interruptions, which has as consequences the catch of the bad decisions and the unrealistic choices in industries. The timing, the frequency, the warning time and the duration have a direct impact on the costs of the interruptions. The bad taking into account of these characteristics leads to the absence of mastery of the interruptions costs and constitutes a barrier to the search for the best solutions vis-a-vis the discontinuity of the electricity supply in industries.

The objective of this study is to evaluate the interruptions costs in industries by highlighting the incidences of the frequency, the timing, the warning time and the duration on these costs. To this effect, a rigorous method, the two degrees sample survey method (TDSSM) for the choice of the representative sample of industries is used; it implements a double sampling and makes it possible to obtain a better organization of the data-gathering than with the traditional methods [17]. The method of cost estimate as for it is based on the scenarios of electricity supply interruptions and combines the investigations and statements in industries. This combination of two approaches has a merit, indeed the investigation gives flexibility in the definition of the time beaches of the scenarios, and it must be supplemented by the data of consumption of energy coming from the statements and of the profile of the loads. The rest of the paper is organized as follows: In Section 2, we present the materials and methods used, while the results obtained are presented and discussed in Section 3.

2. MATERIALS AND METHODS

2.1 Sample Survey and Construction of A π- Estimator

In most studies related to the estimate of the electricity supply interruptions costs, very little attention is given to the methods used in choosing the statistical units constituting the sample [2]. Most often, the estimators generally used lead to values which deviate from reality. The sample choosing and the generalization methods used is TDSSM. The interest of the method of TDSSM lies in its capacity to facilitate the realization of an investigation even if one does not have a base of survey supplements; moreover it makes it possible to reduce the costs of investigation when this is done in a large territory, which is not the case with other frequently used methods.

This method perfectly applies to our study which covers the entire country and which relates to industries with several field activities.

Assuming that the population $U = \{1, \dots\dots\dots, k, \dots\dots, N\}$ of industries be made up of M sub-population $U_i, i = 1, \dots\dots\dots, M$, called primary statistical units. Each primary statistical unit is made up of N_i secondary statistical units, N being the population size U, we have

$$\sum_{i=1}^{M} N_i = N \quad (1)$$

A primary unit sample is chosen with respect to the sample survey $p_I(s_i)$ such that $P_r(S_I = s_I) = p_I(s_I)$ and$= \#S_I$. If a primary statistical unit U_i is chosen at first draw, we chose a sample S_i of secondary statistical units using $p_i(s_i)$, we note the chosen secondary statistical units such that $P_r(S_i = s_i) = p_i(s_i)$ and $n_i = \#S_i$. The two degree sample surveys are invariable and independent, signifying that the sample survey $p_i(s_i)$ depends not on what happened at the first degree, more so the two degree sample surveys draws are independent of one another. The complete sample S is given by relation (2)

$$S = \cup_{i \in S_I} S_i \quad (2)$$

Let X be a studied variable, the total calculated t_x within the statistical population can be written using the relation (3):

$$t_x = \sum_{k \in U} X_k = \sum_{i=1}^{M} \sum_{k \in U_i} X_k = \sum_{i=1}^{M} t_{xi} \quad (3)$$

Where t_{xi} is the total calculated within the primary unit i and X_k the value of variable X related to the industry k.

$$t_{xi} = \sum_{k \in U_i} X_k \qquad i = 1, \dots\dots, M \quad (4)$$

The mean $\bar{X}$ calculated within the population of industries is given by the relation (5):

$$\bar{X} = \frac{1}{N} \sum_{k \in U} X_k = \frac{1}{N} \sum_{i=1}^{M} \sum_{k \in U_i} X_k = \frac{1}{N} \sum_{i=1}^{M} N_i \bar{X}_i \quad (5)$$

$\bar{X}i$ represents the mean value calculatedwithin the primary unit $i$is given by the relation (6)

$$\bar{X}_i = \frac{1}{N} \sum_{k \in Ui} X_k, \qquad i = 1, \dots\dots, M \quad (6)$$

σ_{xi}^2 and $S_{xi}^2$are respectively the variance and the corrected variance within the primary unit U_i, these two terms are calculated using the relations (7) and (8).

$$\sigma_{xi}^2 = \frac{1}{N_i}\sum_{k\in U_i}(X_k - \bar{X}_i) \tag{7}$$
$$S_{xi}^2 = \frac{N_i}{N_i-1}\sigma_{xi}^2 \tag{8}$$

Let us note π_{Ii} the probability of inclusion for the first pulling, i.e. the probability of choosing the primary unit U_i. Let π_{Iij} be the probability of inclusion of second degree, actually the probability of choosing both the primary unit U_i and the primary unit U_j.These probabilities come from the sample survey $p_I(S_I)$.

$$\Delta_{Iij}= \begin{cases} \pi_{Iij} - \pi_{Ii}\pi_{Ij} & si\ \ i \neq j \\ \pi_{Ii}(1-\pi_{Ii}) & si\ \ i = j \end{cases} \tag{9}$$

Let $\pi_{k/i}$ be the probability of choosing the secondary unit k given that the primary unit of index i has been selected and let $\pi_{kl/i}$ be the probability of jointly choosing the secondary units k and l given that the unit i has been selected.

$$\Delta_{kl/i}= \begin{cases} \pi_{kl/i} - \pi_{k/i}\pi_{l/i} & si\ \ i \neq j \\ \pi_{k/i}\left(1-\pi_{k/i}\right) & si\ \ i = j \end{cases} \tag{10}$$

The probability of first order inclusion of a secondary unit for the entire sample survey is the probability of selecting the primary unit containing this unit multiplied by the probability of selecting the secondary unit in the primary unit, we have:

$$\pi_k = \pi_{Ii}\pi_{k/i} \quad k \in U_i \tag{11}$$

For probabilities of second order inclusion, while taking into account the invariance and independence properties, we would distinguish two cases:

- If two secondary units k and $l$belong to the same primary unit U_i , then the probability of second order inclusion is worth;

$$\pi_{kl} = \pi_{Ii}\pi_{kl/i} \tag{12}$$

-If two secondary units k and l belong to two distinct secondary units U_i and U_j, then the probability of second order inclusion is worth;

$$\pi_{kl} = \pi_{Iij}\pi_{k/i}\pi_{l/j} \tag{13}$$

Let $\hat{t}_{x\pi}$ and $\hat{X}_\pi$ respectively represent the total π- estimator and the π- estimator of the mean $\hat{t}_{xi}$ is the π- estimator of t_{xi}.

$$\hat{t}_{x\pi} = \sum_{i\in S_I}\sum_{k\in S_i}\frac{x_k}{\pi_{Ii}\pi_{k/i}} = \sum_{i\in S_I}\frac{\hat{t}_{xi}}{\pi_{Ii}} \tag{14}$$

$$\hat{t}_{xi} = \sum_{k\in S_I}\frac{x_k}{\pi_{k/i}} \tag{15}$$

$$\hat{\bar{X}}_\pi = \frac{1}{N}\sum_{i\in S_i}\sum_{k\in S_i}\frac{x_k}{\pi_{Ii}\pi_{k/i}} \quad (16)$$

At the first stage we chose primary units with proportional probabilities of inclusion to the size of the primary units. The probabilities of choosing primary units are given by the relation (17):

$$\pi_{Ii} = \frac{N_i}{N}m \quad (17)$$

At the second stage, secondary units are chosen with respect to the random sampling without putting back with a sample size of $n_i = n_0$, we have:

$$\pi_{k/i} = \frac{n_0}{N_i} \quad (18)$$

The probability of second order inclusion is given by the relation (19):

$$\pi_k = \pi_{Ii}\pi_{k/i} = \frac{mn_0}{N} \qquad k \in U_i \quad (19)$$

The primary units are chosen at unequal probabilities and the secondary units are chosen at equal probabilities, the total π-estimator and the π- estimator of the mean are expressed by the relation (20):

$$\hat{t}_{x\pi} = \frac{N}{n}\sum_{k\in S} x_k \quad (20)$$

$$\hat{\bar{X}}_\pi = \frac{1}{n}\sum_{k\in S} X_k \quad (21)$$

The variance is given by:

$$Var(\hat{t}_{x\pi}) = \sum_{i=1}^{M}\sum_{j=1}^{M}\frac{t_{xi}t_{xj}}{\pi_{Ii}\pi_{Ij}}\Delta_{Iij} + \frac{N}{n}\sum_{i\in U_i}(N_i - n_0)S_i^2 \quad (22)$$

Where

$$S_i^2 = \frac{1}{N_i - 1}\sum_{k\in U_i}(X_k - \frac{t_{xi}}{N_i}) \quad (23)$$

The minimum sample size required of industries was calculated using the approach of Yamane [18] with 10% of precision, 95% level of confidence and 0.5 proportion of variability. This approach makes an assumption that there is a normal distribution of the sample error. If population sizes (N) are known, the minimum sample size required can be computed as follows:

$$n = \frac{n_0}{1+\frac{(n_0-1)}{N}} \quad (24)$$

$$n_0 = \frac{N}{1+Ne^2} \quad (25)$$

Where: n_0 is the first approximation of n, N represents the population size, e is the level of precision and n is the minimum sample size required.

A sample of 70 industries was considered for this investigation over a statistical population of 250 industries sensitized in diverse industrialised sectors. Table 1 presents the sample of industrial companies. Initially, companies were contacted by phone to ascertain whether they would take part. Concerning the location of these industries, most are found in the towns of Douala, Yaoundé, Edea, Kribi and Limbe which together harbour 80% of the industrial production of Cameroon [19]. The distribution of this questionnaire was done from February to March 2010; survey forms were given directly to the various officials and production manager in charge of electricity supply in the targeted industrial companies. Available data were written on those forms and supplementary information was obtained during the various meetings held with officials of those industries. The questionnaire was preferred to other data collection instruments because its flexibility made it possible to design it in a way as to get very specific information regarding the cost of power interruptions. A sample of the questionnaire is presented in the Annex 1. Before its final administration, the questionnaire was pre-tested in 10 industrial companies; the following aspects have been tested 1) scenarios understood and accepted, 2) question formulated in a clear way,3) range of answer values are representative,4) length of questionnaires. In order to mitigate the effect of biased answers, the calibration of obtained responses was done. When the obtained results differ with a higher threshold from the results obtained from similar industries (with approximate size and same domain of activities), the results were put under review. Additional information enables us to find errors or mistakes in the damages reported. Cases of partial non-responses in the questionnaires were treated using the *hot deck* imputation method. The *hot deck* imputation consists of randomly selecting a unit in the sample and to impute the value of this unit to the unit which did not respond [17]. The *hot deck* imputation method has the disadvantage of adding the estimated values but nevertheless it does good approximations a whenever applied in the neighbourhood of industries for example. This neighbourhood is a set of industries which can be grouped in a homogenous stratum. In this study, this neighbourhood was constituted of industries belonging to the same domain of activities, similar size and structure. In order to choose this *hot deck* method, we admitted the implicit hypothesis according to which in the neighbourhood of industries, there is dependence between the non-response and the interest variable of interest. Given that there are little of disparities between industries belonging to the same domain of activities in Cameroon [2], the *hot deck* seems to be better indicated than the *imputation method* by prediction whose parameters are difficult to be determined in a country where the reach for information remains a hard task. A reader who wishes to have more explanation on the treatment of non-responses by *hot deck* imputation method could consult the references [17] and [20].

Table 1. Distribution of the sample of industries

Industrial sectors	Number of industrial companies within the survey sample	Number of industrial companies within the sample base
Food products and drinks	15	82
Textile	5	12
Manufacturing of wood articles	8	25
Paper, cardboard articles	6	20
Refinery	1	1
Chemical products	8	35
Rubber and plastic products	4	10
Glass, construction materials	5	25
Metallurgy, Smelting works	7	23
Metal articles	4	12
Electricity, water and gas	3	5
Total	70	250

2.2 Costs Estimation Methods

2.2.1 Normalization of cost per hour of interruption

This method is based on the principle that each time there is outage, be it of short or long duration, it has a negative impact on the production units' functioning. We would consider that this cost has two essential components, i.e the fix cost (CF) and the variable cost of the interruption duration(CV). The interruption cost(CI) can be calculated using the relation (26):

$$CI = CF + CV \tag{26}$$

The variable cost of outage according to the reference [21] constitutes the value of lost production (VLP), the outage related cost (ORC) and the savings (ORS). VLP is the financial value of the production deficit corresponding to the duration of the power interruption. Outage related costs are those directly incurred because of the outage. ORC includes overtime production cost (OPC), starting equipment cost (SEC), material damage costs, physical plant damage cost, materials reprocessing cost, and cost to operate backup generation equipment. ORS have to do with expenses not incurred because production equipment remained non-functional during the power interruption. Among these, there are the costs of wages unpaid to workers during the interruption, the cost of raw materials not used, the cost of fuel not used and the scrap value of damaged materials.

CV is the sum of VLP, ORC and ORS expressed by the relation (27):

$$CV = VLP + ORC - ORS \tag{27}$$

The interruption costs are determined following some scenarios whose duration r is variable. For an interruption of duration$r$, the interruption cost for any industry k noted $CI_{k(r)}$ is given by the relation (28):

$$CI_{k(r)} = CF_k + CV_{k(r)} \tag{28}$$

$$CV_{k(r)} = VLP_{k(r)} + ORC_{k(r)} - ORS_{k(r)} \tag{29}$$

Where $VLP_{k(r)}$,$ORC_{k(r)}$ and $ORS_{k(r)}$respectively represent the lost production value, the cost relative to interruptions and the profit realised in the industry k for an interruption of duration r. $VLP_{k(r)}$ is determined by the relation (30) :

$$VLP_{k(r)} = S(r).(\frac{V}{h}) \tag{30}$$

Where:
V defines the total value added, h the number of hours of the process and $S(r)$ the value of the spoiled product for a supply interruption duration r as a fraction of $\frac{V}{h}$. Amongst the cost which represent theORC, there are ORC and SEC which are not easily estimated by industries. These costs have been calculated using the relations (12) and (13). In order to respect the production engagement and constraints, most industries have resorts to work at supplementary hours in view of recovering the lost production. For an industry k and for an interruption of duration r and considering an overtime period h_0, $OPC_{k(r)}$ is calculated using the relation (31):

$$OPC_{k(r)} = h_0\left(\frac{V}{h}\right) + \lambda.CF \tag{31}$$

Where:λ= Fraction of CF that is recovered
$SEC_{k(r)}$ is determined while considering the starting-up time of a supply interruption $\beta(r)$ using the relation(32):

$$SEC_{k(r)} = \beta(r).(\frac{V}{h}) \tag{32}$$

Where $\beta(r)$ is the start-up time for an interruption duration of r

The interruption costs have been normalized using the relation (33):

$$NCI_{k(r)} = \frac{CI_{k(r)}}{r.CI_{k(1)}} \tag{33}$$

$NCI_{k(r)}$: Normalized cost of interruptions cost for an industry$k$
$CI_{k(r)}$: Cost for an interruption of duration$r$for an industry$k$
$CI_{k(1)}$: Cost for an interruption of 1hour duration for industry$k$

The retained outage scenarios are the following:
-a 1 hour outage starting at 2 pm without advance notice
-a 1 hour outage starting at 8 pm without advance notice
-a 1 hour outage starting at 9 am without advance notice
-a 2 hours outage starting at 2 pm without advance notice
-a 2 hours outage starting at 8 pm without advance notice
-a 2 hours outage starting at 9 am without advance notice
-a 4 hours outage starting at 2 pm without advance notice
-a 4 hours outage starting at 8 pm without advance notice
-a 4 hours outage starting at 9 am without advance notice

In view of acknowledging the importance of the warning time, each of the cited scenarios was repeated while considering an advanced notice of 3hours before apparition of the interruption. To assure a proper collection of information, the liable persons in charge of energy in industries were briefed a year before on the objectives of this study. For an industry k, admitting as assumption that the variable cost $CV_{k(r)}$ is proportional to the interruption duration r and defining $CV_{k(1)}$ as the variable cost for an interruption of 1 hour duration. The relation (34) becomes

$$NCI_{k(r)} = \frac{CF_k + r.CV_{k(1)}}{r(CF_k + CV_{k(1)})} \tag{34}$$

Considering that $V_k = \frac{CV_{k(1)}}{CF_k + CV_{k(1)}}$, the relation (34) becomes

$$NCI_{k(r)} = V_k + (1 - V_k)r^{-1} \tag{35}$$

For all industries, the normalized cost of interruptions for duration r is calculated using the relation (36):

$$\widehat{NCI}_{(r)\pi} = \frac{1}{n}\sum_{k \in S}[V_k + (1 - V_k).r^{-1}] \tag{36}$$

2.2.2 Normalization of cost by energy not supplied factor

Energy not supplied energy is one of the most used criteria for normalisation of costs of interruption [22-23]. The values of $CI_{k(r)}$ for each power interruption scenario must be normalized in order to produce data that helps to show the variations of interruption costs according to the duration of outages. The normalization parameter used is the energy not supplied (ENS) in (kWh) because our study focuses on long interruptions in the various scenarios. The energy not supplied during an interruption with duration r from T_1 until T_2 for each industry k is calculated following relation (37) hereafter.

$$ENS_{k(r)} = \int_{T_1}^{T_2} P_k(t)dt \tag{37}$$

Where $P_k(t)$ is the hourly load in kWh/h. The normalized cost $NC_{k(r)}$ for an industry k for a scenario of interruption of duration r is therefore given by

$$NC_{k(r)} = \frac{CI_{k(r)}}{ENS_{k(r)}} \tag{38}$$

Where $NC_{k(r)}$ is the normalized direct cost of power interruption of a duration r for an industry k in (€ /kWh) and $ENS_{k(r)}$ is the energy not supplied during an interruption of duration r for an industry k (kWh).

For all industries, the normalized cost of interruptions for duration r is calculated using the relation (39):

$$\widehat{NC}_{(r)\pi} = \frac{1}{n}\sum_{k \in S}[NC_{k(r)}] \tag{39}$$

2.3 Characteristics of the Industries

A total of 63 industries over a sample of 70 industries effectively filled the questionnaire that was given to them, a response rate of 90% is satisfactory compared to that of 36% obtained for similar investigations realised by postal method [24]. The collaboration of industries in the realization of this study was satisfactory. Most industries have a staff of 60 full time workers and 55 part time workers. 90% of industries work from Monday to Saturday, 10% of industries work during the whole week, which implies that it is not possible to recover the production if an interruption occurs for this last class of industries. Industries which answered our questionnaire have production units which consume valuable quantities of electricity. *Aluminium of Cameroon* (ALUCAM) and *Cement factory of Cameroon* (CIMENCAM) are Industries of the high voltage (HV) customer's category; the 61 others are customers of the medium voltage (MV) category. The tariff grid of the company AES-SONEL which holds the monopoly of the production, the transport and the distribution of electricity in Cameroon is discriminatory, the small and medium industries (customers of MV) pay an average of €0.12/kWh consumed [25]. The large-scale industries (customers of HT) pay only €0.06/kW. ALUCAM which however consumes between 30 and 40% of distributed energy pays only €0.025/kWh because of a particular contract signed with the AES-SONEL company. All industries totally depend on electricity, ALUCAM whose annual production of aluminium is 210 ktons consumes between 12.8 and 17kWh/kg of produced aluminium. In order to make ALUCAM profitable, it must function with a load factor higher than 90% and a configuration of power ranging between 155 and 205MW [26].

During the 12 last months, all industries experienced supply interruption; 60.3% three interruptions/day; 14.2% five interruptions/day; 20.6% seven interruptions/day and 4.9% eight interruptions/day. One of the weaknesses of the AES-SONEL company is the absence of an information system to the service of the consumers about the programmed interruptions or the time necessary to restore the provisioning of electricity following the accidents which might have occurred in the electricity supply network. 90% of industries experiencing supply interruptions received no advance notice, 10% of industries are informed occasionally after calling AES-SONEL. Lasting less than 1hour were 25% of interruptions (inclusive of one to two seconds (momentary) which accounted for 15% of interruptions). The average duration time of a power interruption is 6 hours [27], while across all distributions areas, 88.3% of faults were restored in 3 hours in Britain [28]. Some measurements done in industries units revealed that the power factor is between 0.6 and 0.7, the consequences are high consumption of reactive energy and the heavy penalties recorded in the electricity bills.

2.4 Reliability of Electricity Supply

Reliability can be defined as the ability of the power system components to deliver electricity to all points of consumption in the quantity and with the quality demanded by customers [29]. The importance of incorporating reliability of supply criteria when studying the performance of an electricity distribution system has been highlighted in the reference [30]. The authors found that an annual average interruption duration per installed capacity of a specific grid increases ceteris paribus by 1.36 minutes if the grid tariff of this specific grid is decreased in the previous year by 1€/MWh. The Institute of Electrical and Electronic Engineers (IEEE) defines the generally accepted reliability indices in it's ''Standard number P1366,''Guide for Electric Distribution reliability Indices'' list several indicators. For relative studies to the reliability in electricity distribution networks, three power quality indicators which are indices at the grid interface points are used, these are 1) customer average interruption duration index (CAIDI), 2) system average interruption frequency index (SAIFI) and 3) system average interruption duration index (SAIDI). In the reference [31], the authors describe indices relative to customers poorly served; this refers to Maximum Individual Customer Interruption Frequency (MICIF) and the Maximum Individual Customer Interruption Duration (MICID). In Cameroon, SIN is the most solicited interconnected network and the post vulnerable, SIN deserting about 60 to 75% of AES-SONEL customers. The transportation network records important energy losses and voltage drop, for example the west-Cameroon electric transport line experienced a voltage drop of 16% in 2006 [25]. Very little research works treated the power quality indicators measure of the Cameroonian electric network, in the reference [2], the values of MICIF for the Biyem- Assi and Mbankomo localities indicate that these zones are not supplied with electricity respectively during 2000hrs/year and 4000hrs/year and the MICIF value fluctuates between 3 to 4 hrs/customer per year.

In 1998, law No 98/022 of the 4 December 1998 governing the electricity sector was adopted. This law was to mark the liberalization of the sector of electricity with for corollaries the fall in the prices of the electric power and an improvement of the electricity supply. Two regulation agencies of the electricity sector were created, these were; the electricity sector regulation agency (ARSEL) and the rural electricity agency (AER). The AES-SONEL company was seen entrusted the monopoly of the production, the transport and the distribution of the electric power in Cameroun. In 2013, the acknowledgement of failure is overpowering, nearly 40% of Cameroonians do not have access to electricity, the prices of electricity have almost triple in ten years, moreover the electricity offer is poor from the quantitative and qualitative point of view. In the literature, several research tasks estimated the cost for improving quality in electricity distribution, in the reference [32], the authors used a parametric distance function approach to estimate the cost of preventing an interruption in France from €1.8 to €69.2 for the year 2005.In order to carry out similar studies in Cameroun, it is necessary to have the reliable data on the costs of the interruptions.

3. RESULTS AND DISCUSSION

3.1 Components of Supply Interruption Costs

Table 2 and Table 3 present the fixed costs and variable costs estimates relating the interruptions. These estimates concern the maximum, minimum and mean values of the costs according to the scenarios of the interruptions. The cost of sudden supply interruption undergo deep variations with the duration, it is of €1,872 in average per industry for 1h of interruption without warning time starting at 2 pm. For interruptions of 2hrs and of 4hrs without warning time, these costs respectively reach the thresholds of €2,505 and €2,972. For similar scenarios but with warning time, these costs are respectively of €1,260, €1,716 and €2,716. These costs of the supply interruptions are significant for industries in developing country like Cameroon. The average costs per hour of interruptions are €1,050/h and €815/hr respectively for the scenarios without advance notice and with advance notice. When it is known that the average duration of an interruption is of 6h [27], the cost by interruption/industry is in average of €6,300 for a supply interruption without advance note and of €4,890 for a supply interruption with advance notice. Table 4 present the cost per kWh of energy not supplied in order to facilitate comparisons with the results encountered in the literature. The average costs of electricity lost decrease with the duration of outages. The average cost varies from €2.58/kWh to €4.83/kWh lost for a 1-hour interruption and from

€1.75/kWh to €3.75/kWh for a 4-hour outage. In the case of the interruptions of short durations, 65% of industries estimate that they cause a fall from 5 to 10% of their production. 18% of industries affirm to undergo a fall of production from 2 to 4%, while the remainder (17%) locates their fall of production between 13 and 15%. In the case of the long interruptions, 40 to 50% of industries locate their fall of production between 15 and 21%, the remainder of industries affirm to undergo a fall of production from approximately 12%. These differences take account of the structural characteristics and the branches of industry in which the action of these industries fits. The impacts of these interruptions extend from industries right up to the whole economy. These impacts are the fall of the industrial production and its corollaries which are the fall of the financial incomings from 5 to 10% and the deceleration of the investments. At the scale of the economy of the country, the secondary sector of industries from which the near total of the industries comes from contributed for 32.4% of gross domestic product (GDP) of Cameroon in 2007 [2], suffered a deceleration of its activities because of the interruptions of electricity. The inter-employers' group of Cameroon (GICAM), an organization which gathers industries, estimated at €16.7millions the financial losses undergone by its members in 2007. In the reference [33], the author estimates between 1 and 2% the deceleration of growth undergone by Cameroon in the year 2002 because of the electricity supply interruptions. In spite of the significant energy resources and significant natural assets (climate), the annual economic growth of Cameroon stagnates. Between 2001 and 2007, the real average growth rate of the GDP is established to 3.4% [34], and does not allow reaching the rate of 7% of economic growth necessary to carry out the objectives of Millennium Development Goals (MDG) on the 2015 horizon. Cameroon is classified 171st over183 countries according to *the Doing Business index,* and is below 25 percentiles of all the indicators *of the index of governance of Kaufman and Kraay,* this statute considerably discourages investment [35].

Table 2. Supply interruption cost without advance notice (in €)

Scenarios	Fixed costs	Value of lost production			Outage related cost			saving		
	Mean	Maximum	Minimum	Mean	Mean	Maximum	Minimum	Mean	Maximum	Minimum
1-hr starting at 9 am	314	858	929	784	1,045	1,175	1,013	215	245	220
1-hr starting at 2 pm	347	950	1,150	756	1,165	1,274	1,065	243	258	226
1-hr starting at 8 pm	352	1,158	1,224	965	1.250	1,435	1,103	253	298	235
2-hr starting at 9 am	415	1,248	1,416	1,115	1,210	1,310	1,117	312	397	302
2-hr starting at 2 pm	435	1,635	1,754	1,652	1,346	1,369	1,239	473	495	462
2-hr starting at 8 pm	465	1,725	1,943	1,703	1,408	1,535	1,354	497	505	481
4-hr starting at 9 am	503	1,918	2,077	1,803	1,522	1,615	1,503	688	720	685
4-hr starting at 2 pm	515	2,054	2,243	1,875	1,674	1,776	1,589	756	768	725
4-hr starting at 8 pm	535	2,168	2,545	1,945	1,845	1,822	1,648	821	865	805

Table 3. Supply interruption cost with advance notice (in €)

Scenarios	Fixed costs	Value of lost production			Outage related cost			saving		
	Mean	Maximum	Minimum	Mean	Mean	Maximum	Minimum	Mean	Maximum	Minimum
1-hr starting at 9 am	225	725	745	708	730	815	701	205	219	195
1-hr starting at 2 pm	245	756	785	732	789	825	763	285	305	274
1-hr starting at 8 pm	287	818	891	804	798	830	795	302	318	298
2-hr starting at 9 am	329	1,127	1,283	1,042	945	1,023	918	612	635	594
2-hr starting at 2 pm	365	1,345	1,376	1,298	1,025	1,143	996	654	667	649
2-hr starting at 8 pm	382	1,415	1,498	1,395	1,190	1,215	1,025	709	720	699
4-hr starting at 9 am	405	1,709	1,903	1,695	1,350	1,427	1,338	617	652	609
4-hr starting at 2 pm	423	1,946	2,054	1,895	1,457	1,575	1,405	687	698	672
4-hr starting at 8 pm	435	2,151	2,208	1,919	1,520	1,618	1,496	705	730	692

Table 4. Normalized interruption cost (in €/kWh)

Duration	Scenario of interruption with advance notice			Scenario of interruption without advance notice		
	Starting at 9 am	Starting at 2 pm	Starting at 8 pm	Starting at 9 am	Starting at 2 pm	Starting at 8 pm
1-hour	2.58	3.21	3.97	3.45	4.16	4.83
2-hour	2.16	2.95	3.27	3.04	3.85	4.31
4-hour	1.75	2.38	2.65	2.75	3.19	3.75

Source: Authors' computations

Many studies were undertaken in order to evaluate the costs of interruptions in industries. In the reference [36], the production-function approach was used to estimate the supply interruption costs. On a weekday during daytime, the value of lost load (VOLL) varies from €8.0/kWh to €7.9/kWh, on evening; this value is €8.9/kWh. The total damages caused by a 1-hr supply interruptions decrease on a weekday from €156 to €146 million. In the reference [23], a model from assessing economics losses caused by electricity cuts is presents. The economics effects for simulated power cuts from 1 to 48hrs in Austria are estimated. The average value of lost load for industries in the case of a power cut of a 1-hr on a summer workday morning was calculated at €17.1/kWh of electricity not supplied. In the reference [37], a practical approach that can be used to estimate reliability worth focusing on the evaluation of the expected energy not served is presented. The calculations indicates that for a supply interruption for a duration of (1-hr), (4-hrs) and 8-hrs, the supply interruption costs are respectively (450), (1000) and SR2900/kWh of electricity not served in the industries in Saudi Arabia. In the reference [38], the authors assessed the cost incurred by industrial sectors as a result of supply interruption. The study estimates the total cost to reach about US$20 billion/year. In the reference [21], on the basis of a survey on 299 industries, the authors estimated that the average total costs are US$74.835 for a 4-hrs outage without advance notice and US$11.027 for a momentary outage. The average total costs are respectively US$22.973 and US$39.459 for a 1-hr outage with advance notice and for a 1-hr outage without advance notice. A study was carried out in Finland [24], the results obtained indicated that the supply interruption costs for a 1-hr outage was US$5.92/kWh of electricity not served, this value failed to US$2.08/kWh for a 24-hrs outage in industries. In the reference [22], the authors estimated supply interruption costs in Norway. The values of supply interruption costs obtained fall between US$6.62/kWh to US$13.14/kWh of electricity not served whose duration stand between 1 hour and 4 hours. The approach used in that study presents some limitations. Firstly, the choice between the willingness to pay(WTP) and willingness to accept (WTA) compensation in case of supply interruption remains controversial, secondly the supply interruption costs estimations depends significantly upon the presentation and the wording of the questionnaire[16]. A comparison of the supply interruptions costs which we obtained and those met in the studies undertaken in industrialized countries shows significant variations, which is explained by the differences at the levels of the size of sales and turnover of industries. In United States of America (USA), for an industry having a sales turnover of US$1billion, loss production works out to US$133 000/hr [21], and while in Cameroon only five industries can realise a turnover bordering €10million/year.

3.2 Impact of Characteristics of the Electricity Supply Interruptions

3.2.1 Duration

For a one hour interruption, the percentage of the fixed costs is in average of about 32%, the variable costs being of 68% in industries. Fig. 1 presents the normalized costs according to the duration of interruptions.

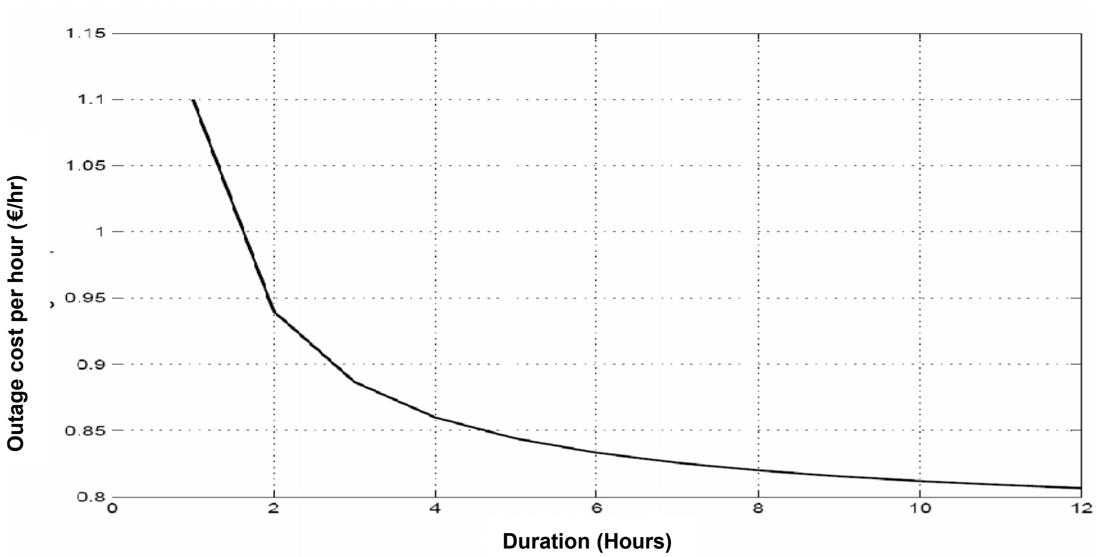

Fig. 1. Normalized cost of interruptions

For the second hour of interruption, the normalized cost is €0.93/hr, which is high for industries. These costs decrease quickly with time to stabilize itself after 5hrs time with approximately 60% of their value of the first hour. This reduction takes account of the duration of the cycles of production and measures established to mitigate the effect of the electricity interruptions. For industries having cycles of production of duration higher than 4hrs, the essence of the production is lost or the quality of the products is deteriorated. The metallurgy and smelting works industries are hardest hit by supply interruption; ALUCAM reported the output losses of about 35% in the year 2010. Industries which are less affected by supply interruption are those that operate with shorter manufacturing processes (drying). The investigation outlined three industrial categories 1) the small and medium size industries which have self-production equipment of electricity of sufficient capacity, 2) the small and medium size industries do not have power generating units of sufficient capacity, 3) large-scale industries. The costs of the interruptions in the first category of industries are roughly 58% lower than the costs of the interruptions of the second category of industries for an hour of supply interruption.

In the reference [39], the authors find that for industrial firms with battery operated standby systems, the supply cost are 60% lower for a 1 hour interruption when compared to firms with no standby equipment. The large-scale industries have high supply interruption costs, the capacity of the power generating units being largely lower than the minimum capacity necessary for the correct operation of the production units. The starting up of the power generating units makes it possible to compensate only part of energy not provided, initially intended for the majority of them used like auxiliary unit, these machines saw their operating time to pass from 3 to 17hrs/day. Most of the industries had invested in precautionary measures against power interruptions by acquiring back-up equipment mainly generators, but the cost of one kWh of electricity self-produced is €0.63 (US$ 0.525) which is five time of that sold by the company AES-SONEL [25]. These costs of a kWh of electricity in Cameroun are 7 to 8 times the costs of kWh required on a worldwide scale (USS0.05/kWh to USS0.07/kWh) for the competitiveness of industries [40].

In the literature, most studies have attempted to measure the variation of supply interruption costs in relation with the duration in the industrial companies. In the reference [2], the fixed and variable costs in food industries were respectively estimated to 23 and 77%. In the reference [41], the proportions of the fixed and variable costs of the interruptions in industries are respectively 27% and 73%. According to the authors of that study, the normalized cost for supply interruption are consistent and the average hourly cost, diminish rapidly, levelling of about 50% of the cost of a 1 hour interruption. The authors highlight the disparities of costs of interruptions between the various sectors of industrial activities. For instance, one hour of supply interruption cost range from under US$2.00/(average kWh) for mineral fuels and Paper and Allied Industries to over US$60 average kWh) for leather Industries. The differences between the results of our study and those seen in the literature are inferior by 5%, they are in the same range of values. However, our study has the merit to relate to a broad sample of industries, which is not the case in several similar studies where only 10 industries were surveyed [41-42].According to our investigation, 80% of industries affirm being in the embarrassment about decision taking and actions in the cases of supply interruption because of the absence of the advance notice or the ignorance of time necessary to restore the continuity of the supply of electricity. Sub-section 3.2.2 treats the impact of warning time on the costs of interruptions.

3.2.2 Warning time

The impact of this characteristic is measured by comparing the costs of interruptions for which the scenarios differ only by non-existence or the existence of 3 hours duration of warning time. Due to the higher cost of operating, engine driven standby equipment are only used in a few industries, this exposes the manufacturing units to the nuisances of supply interruption. The value of the lost production decreases by 17.73 to 18.2% for a 2 hours interruption in the case of an advance notice of 3h. Beyond 4h, the impact of the warning time is less, the reduction in the lost production costs being only of 5.2% in industries. In fact, when the supply interruption lasts more than one hour, industries become reluctant to engage new production cycles, which decrease the quantities of lost raw materials. For industries which do not have power generating units of sufficient capacity, when the suspension of energy occurs without advance notice, all the raw material introduced into the cycle of production is almost lost. A difference of 30 to 35% is recorded in the costs of interruptions concerning industries due to the existence electricity self-production units able to ensure the continuity of the electric power supply. The raw materials constitute the second most significant point of the losses in the event of interruptions in industries. The costs due to the restarting of the machines and the auto production of electricity fluctuate between 10 and 15% according to whether the interruptions were announced or not. After 4 hours of interruption, the cost (ORC) represents about 2/5 of the registered cost after the first hour. The reduction potential of the costs of the ORC due to the advance notice is about 32.3%, 23.84%, and of 12.95% respectively for the durations of 1hr, 2hrs and 4hrs of interruptions.

Many research works have treated the impact which the warning time could have on the costs of interruptions. In the reference [43], the authors estimate a 0.0012% decline in supply interruption cost with a 1% increase in warning time. The weakness of that work is that, supply interruption cost estimate for different outage scenarios were pooled in the same regression, without controlling for similarities in responses by the same customer for different outage scenarios [16]. In the paper [43], the authors find that a 1% increase in advance warning reduces supply interruption costs by 0.006% in the industrial sector. In the reference [41], the authors reported reductions of 68% in the industrial sector for 3 days advance notice. In the references [44-46], the authors found that the effect of advance notice to reduce supply interruption cost is not statistically significant. In the reference [21], the difference of US$16.486 was observed between a 1-hr outage with advance notice and a 1-hr outage without notice. In the reference [12],the authors indicates that in Nigeria, 20-30% of initial investment of industries is on the acquisition of facilities to enhance electricity supply, the advance notice could reduce by 16% the supply interruption costs. The results obtained in our study show a significant variation with those recorded in similar researches carried out in developed countries, but they are in the same range as those recorded in industries of developing countries such as Nigeria. These variations observed in the reduction percentages of interruptions costs due to the warning time are explained by the low industrialization of Cameroon and the insufficiency of the equipment making it possible to reduce the effect of the interruptions. In developing countries, following the example of Cameroon, these percentages of reduction of costs are significant and the alarm systems (Internet, mails, telephones) consequently should be set up to better inform industries on the fluctuations of electricity supply.

3.2.3 Timing

In Cameroon, generally the production units function in full-time (24hr/24hr) per working day, consequently, the variations of the costs of interruptions are closely related to the daily periods of occurrences of interruptions. Electricity supply interruptions take place mainly during the periods of high demand in electricity (6pm-11pm).The cost of electricity supply interruptions vary with the timing of outages, the percentage above daily average varies from -15 to 35 %. The supply interruption costs during the first morning hours are inferior to their daily average. These supply interruption costs are higher at afternoon and at night (hours of high electricity demand). A better planning of the functioning of the production units will help to reduce the impact of timing on the supply interruption costs; this is possible by moving the full production periods together with that of high electricity demands. This solution is applicable only in industries of small load factor which do not function at full time and whose activities do not go throughout the working week.

Two approaches are mainly used in the literature to study the impact of the timing on the cost of interruptions. First, survey questions have been used to directly assess the impact of timing on supply interruptions costs. Second, revealed supply interruption costs for outages occurring at different time have been compared [16]. In the reference [41], the variation of supply interruption costs by month around the annual average supply interruption cost was analysed. The authors indicated that little variability in estimated supply interruption cost was observed for large industrial firms, while small industrial firms exhibit a definite seasonal pattern in supply interruption costs, with higher estimates during the winter season. Over a day, large industrial firms continue to have stable supply interruptions costs, while small industrial firm's costs estimates vary substantially. Many studies [43-46], used the second approach by comparing the revealed cost for different times. In the reference [44-46], the authors find that supply interruption costs are significantly higher during evening hours, while in the reference [43], it is stated that higher supply interruption costs for industrial customers are observed during morning hours. The differences in appreciation of the impact of the timing on the supply interruption costs observed in the research work show the complexity of this subject, and require good information on the variations of the marginal costs of operation over long working periods of production.

3.2.4 Frequency

The investigation reveals that 85 to 92% of industries prefer long supply interruptions to be less frequent than frequent short supply interruptions. This preference is explained by the greatest adaptability to long supply interruptions by mobilizing the machines used for electricity self-production in order to mitigate the discontinuity of electricity. This momentary power interruption reduces the efficiencies of industrial processes and the life cycle of machines [2]. 27% of interruptions are lasting between one to four hours; and 48% of interruptions are lasting up to four hours. Frequent short supply interruptions increase the starting-equipment costs from 7 to 12% in small and medium industries; this percentage varies from 10 to 15% for high industrial consumers. Overvoltage and overload phenomena are observed during phases of sudden supply interruptions costs including when equipment restarts after supply interruptions. The major overvoltage and overload consequence is the deterioration of equipment components which are not usually powerful enough or were not made to withstand such frequent outages. During the year 2009, most industries recorded on average 275 to 353 short interruptions, this resulted in an increase of 13 to 20% of the expenditure linked to the repair of the equipment damage. The frequency of short supply interruption is more significant because the Cameroon industrial manufacturing units are old and obsolete. Most machines in service were bought 25 years ago. Maintenance is quasi-non-existent or at least poor, the outputs are below the standards and some parts of these machines were replaced by those obtained from counterfeit and smuggling. Frequent short interruptions contribute to increase the machines' unavailability rate, leading to higher supply interruptions costs. Devices following the example of Uninterruptible Power Supply (UPS) should be used to mitigate the effect of short supply interruptions for all equipment of low power.

No matter that the relationship between supply interruption costs and supply interruption frequency has received less attention in the literature to date [16], several studies were made in relation to this subject. In the reference [43], the available results indicate that the total supply interruptions costs are not proportional to supply interruption frequency. In the references [41-42], from 70% to 90% of large industrial electricity consumers interviewed were found to prefer infrequent long duration interruption (one 4 hour interruption) to frequent short interruption (four 1 hour interruptions). The weakness of those studies is that they mainly provide only qualitative information on the impact of supply interruption frequency on supply interruptions costs. The results which we obtained line up those encountered in previous studies, they indicate a whole decrease of the costs of interruptions while their frequency increase.

4. CONCLUSION

The aim of this work was to evaluate the supply interruption costs in industries whilst outlining the impacts of duration, frequency, timing and warning time on these costs. The obtained results indicate that the average cost per hour of interruption are €1.050/h and €815/h respectively for scenarios of with and without advance notice. The cost per interruption/industry is in average €6,300 for supply interruption without advance notice and

€4,890 for supply interruption with advance notice, thus a difference of 8.4%. This study showed that to have information in advance on the occurrence of electricity supply interruption considerably reduces the costs for industries. Consequently the installation of a system of information exchanges is imperative; industries must be informed in real time of the planning and exploitation parameters of the electricity network. A system of teledetection of the break downs must be set up in order to better locate the defects quickly and to reduce the duration and the frequency of the interruptions.

Disparities of 5 to 15% have been observed between the interruption cost in industries with respect to the equipment and the existing measures in view of attenuating outage effects. An optimisation of the functioning of electrical generators is imperative because of the exploitation costs of the equipment. A mastery of the cost structure will permit industries to be better prepared to face the situation and the company in charge of electricity (AES-SONEL) to ameliorate the efficiency of the electricity network. Efforts could be centred on the increase in the production of electricity, the rehabilitation of infrastructures (lines) of transportation and distribution network, and on good portion of flow load. A better consideration of the perturbations registered in the electricity network would lead to ameliorating the efficiencies of the system, the more efficient configuration algorithms could be developed to this effect.

ACKNOWLEDGEMENTS

We are grateful for all suggestions made by two anonymous reviewers. We are also grateful for comments made by Aurore Rapiat.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ANNEX

Annex 1. Example of Questionnaire

A Characteristics of the industry

Region

1 In which municipality is the industry located?

2 Is it located in a rural or urban area?

Information about the industry

- 3
  - What do you manufacture?
    - Food products
    - Beverages
    - Tobacco products
    - Textiles
    - Wearing apparel
    - Leather and related products
    - Products of wood, except furniture
      Paper products
    - Printing and reproduction of recorded medias
    - Refined petroleum products
    - Chemical products
    - Pharmaceutical products
    - Plastic products
    - Non-metallic mineral products
    - Basic metals
    - Fabricated metal products, except machinery and equipment
    - Computer, electronic and optical products
    - Electrical equipment
    - Machinery and equipment
    - Motor vehicles
    - Other transport equipment
    - Furniture
    - Repair and installation of machinery and equipment
      Other manufacturing

4 How many employees do you have?

5 What was the turnover in the last year [€]?

6 How many shifts do you have?

7 Has your company undertaken actions to reduce the consequences of interruptions?

- None
- Contacted grid company
- Installation of an emergency power unit
- Installation of overvoltage protection
- Installation of over harmonic filter
- Installation of phase compensating equipment
- Installation of UPS

	• Insurance (disaster, production)
8	What are the yearly expenses for these actions?
Electricity consumption	
9	Total electricity consumption in the last year [kWh]?
10	What was your electricity bill in the last year [€]?
Experiences with interruptions	
11	How many interruptions has your company experienced during the last year?
12	Electric motors disconnected from electricity network by the motor protection Short life time of light bulbs Electrical equipment gets hot
Customer satisfaction	
13	The number of interruptions experienced by your company in the last year is: very small •small •moderate •high • very high

B Cost estimation scenarios	
Reference scenario	
14	If an electricity interruption occurs with the following characteristics, what would be the costs for your industry? Duration: 1 hour Season: February Day of week: working day Time of day: 9am Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:
15	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 1 hour Season: February Day of week: working day Time of day: 2 pm Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]:

	C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:
16	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 1 hour Season: February Day of week: working day Time of day: 8 pm Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:
17	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 2 hour Season: February Day of week: working day Time of day: 9 am Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:
18	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 2 hours

	Season: February Day of week: working day Time of day: 9 am Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:

19	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 2 hours Season: February Day of week: working day Time of day: 2 pm Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:

20	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 2 hours Season: February Day of week: working day Time of day: 8 pm Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:

21	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 4 hours Season: February Day of week: working day Time of day: 9am Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]:
22	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 4 hours Season: February Day of week: working day Time of day: 2 pm Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]: E Damage to equipment [€] Sum of all costs [€]
23	If an electricity interruption occurs with the following characteristics, what would be the costs for your company? Duration: 4 hours Season: February Day of week: working day Time of day: 8 pm Warning: no advance warning A Lost production (minus savings) [€]: B Costs for making up production (overtime, etc.) [€]: C Costs for delayed delivery (fines, etc.) [€]: D Damage to raw materials and finished products [€]:

	E Damage to equipment [€] Sum of all costs [€]:

24	Has the interruption other non-monetary consequences? Danger for person safety Document safety Crimes/burglary Spill over effects to customers Inconvenience Pollution to the environment

25	Can you specify the total costs relative to The reference scenario
26	Can you specify the total costs relative to occurs at another day [%]? scenario if the interruption A Another working day: B Saturday: C Sunday/holiday:
27	Can you specify the total costs relative to the reference of scenario if the interruption occurs at another time [%]? A Day (7am- 5pm): B Evening (5pm- 12pm): C Night (0am - 7am):

Advance warning :

28	Estimate the required warning time that the company needs to reduce the cost of an interruption? • Less than 1 hour • 1-4 hours • 5-8 hours • 8-24 hours • 2 days • More than 2 days • Costs cannot be reduced

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=176&id=22&aid=957