STUDY ON THE ECONOMIC LOSS AND ITS EVALUATION METHODS OF SHORT INTERRUPTION

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ABSTRACT

Short interruption means that the outage lasts less than 3 minutes. With social development and digital high-tech equipments widely applied, the economic losses caused by short interruption are serious and lead to significant social influences. Thus, it is necessary to make research on the losses caused by short interruption. In order to show the features and serious social impacts of short interruption, based on the concept and loss structure of short interruption , the quantify method of short interruption losses and evaluation index were proposed. According to losses and occurring frequencies of short interruption, the danger of short interruption was analyzed.

1. INTRODUCTION

By the NO.DL/T836 document, published in 2010. -- "Reliability Evaluation Regulations of Power Supply in Power System", short interruption is an interruption whose time duration is within 3 minutes. According to the power quality investigation made by Leonardo Energy, there were 15 billion pounds losses that occurred in industry every year, among them, 60% were caused by Voltage sag or Short Interruption [1].

Thus, this study is helpful to understand short interruption features and learn the serious made by short interruption .The frequencies of short interruption is higher, the losses of users is larger [2]. Meanwhile, owning to the interruptible load price and high reliability price depending on users' losses, study on the losses of short interruption could make a contribution to decision-making of these kinds of prices and to city grid improving.

Short interruption was common phenomenon in city grid, but studies on it were only appeared in few literatures. Contrary, there were many studies and achievements on general interruption. Reviewing these studies, the estimation methods of interruption losses can be divided into direct one and indirect one. Direct estimation methods contain four types: (1) Building losses function by questionnaire survey [3,4]; (2) Estimating losses by IEAR index[5]; (3) Building losses function by simulation curve[6]; (4) Calculating losses by neural network and fuzzy logic model[7-9]. Also, indirect estimation method includes three measures: (1) Calculating losses by the quantity of power generation [10.11]; (2) Estimating losses by multiplying average electricity price [12.13]; (3) Estimating losses by input-output [14]. Generally, IEAR and ICPE were taken as the evaluation index of interruption losses [15].

These methods and achievements could provide important references for short interruption study. In this paper, short interruption losses function of power users will be built by questionnaire survey. Meanwhile, whether the IEAR, ICPE can be used to evaluate short interruption will be discussed.

2. SENSITIVE USERS AND SHORT INTERRUPTION INFLUENCES

The losses caused by power interruption depended on features of users' devices. For example, programmable controller and frequency conversion speeder will be damaged by power interruption of several frequencies or voltage sag; production line of integrated circuit chip, computer system of bank and stock centre will be broken seriously by power interruption or voltage sag, which time duration was over one frequency current. Actually, these sensitive instruments were widely applied in various

industries, such as, auto-mobile manufacture, bank, IT, rubber, plastic, textile, metallurgy, chemical fibre, pharmaceutical, electronic industries etc. Meanwhile, some public utilities, government and military agencies, for example, hospital, international conference and key lab, were also sensitive to short interruption [16]. Thus, these power users, who will suffer large economic, political and social losses in short interruption, were called sensitive users. And sensitive users were divided into four groups in this paper; they were industry, business, government and public. By taking investigation on users, the structure of short interruption losses was showed in Table1.

Tab.1 Structure of different users' short interruption losses

Type	Short interruption losses	
	Direct losses	Indirect losses
Industry	Product line interrupted Production discarded Product equipment broken	Cost of equipment maintenance Compensation for dangerous byproducts Damage on enterprise reputation
Business	Instruments broken Business operation disturbed Important data lost	Service quality low Enterprise reputation lost Compensation for customers
Government	Devices damaged Government affairs interrupted Key literature and data lost	Work efficiency low Government reputation damaged Cost of stable society
Public	Equipment broken Losses on public activities Losses on social normal income	Cost of reality measures Compensation for customers Institution reputation damaged

3. SHORT INTERRUPTION LOSSES FUNCTION OF SENSITIVE USERS

3.1 Building function

Drawing on the experiences of questionnaires estimation method, we will develop the users' losses functions for different sensitive users by statistics of questionnaire. In order to establish the functions, three messages were required, i.e. users' electric load, interruption and users' expense, among them, electric information can get from power company; expense data should be estimated by function. The specific method was showed as follows:

(1)Classify sensitive users and design questionnaires of different sensitive users

(2)Take investigation on users' short interruption losses by questionnaires

Assuming that short interruption occurred in peak load, and users' losses increased in direct ratio with users' power load. The value of short interruption losses for different users in different units, 0.05s, 3s、30s、1 min、2 min、3min, can get from the user's reports or estimate by statistics. Then, each Customer Damage Function in different units can be gotten as follows:

$$CDF(t) = \frac{COST(t)}{P_{\max}} \quad (1)$$

In function（1）, CDF (t) is each user's losses in peak load, Yuan/kW; COST (t) is each user's losses in different units, Yuan; P_{max} is each user's peak load, kW.

(3)According to formula (1), Sector Customer Damage Function could be built as follows:

$$SCDF(t)_i = \frac{\sum_{x=1}^{n_i} CDF(t)_x}{n_i} \quad (2)$$

In function（2）, it shows the relationship between sector users 'losses and short interruption time duration. $SCDF(t)_i$ meant i sector users' losses in peak load, Yuan/kW; n_i meant numbers of i sector users.

(4)Depending on SCDF, each kinds of users' load rate per year and power consuming proportion, composite customer damage function is built, it shows the relationship about composite customers' losses in different units of outage.

$$CCDF(t) = \sum_{i=1}^{m} \frac{C_i \times SCDF(t)_i}{L_i} \quad (3)$$

In function（3）, m means the numbers of user 'type, Ci means i user' power consuming proportion; Li means i user' load rate.

This paper made a numerical study based on X city, A coast city in Southern China .The related losses functions (2), (3) were built by statistics. The losses results were showed in table 2.

Tab.2 Short interruption losses function of X city

Time duration (s)	SCDF(t) of Industry （yuan/kw）	CCDF(t) （yuan/kw）
0.05s	1.17	1.24
3s	4.28	4.25
30s	10.89	13.85
60s	20.02	31.01
120s	28.79	45.39
180s	35.27	52.54

3.2 Analysis on short interruption losses

In order to study the growth states of losses in different units of outage, the serious of short interruption losses in industry was showed. Dealing with related statistics, losses distribution and simulation curve can be seen in figure1, SCDF represented unit losses of industry users, yuan/kW; t represented time duration of short interruption.

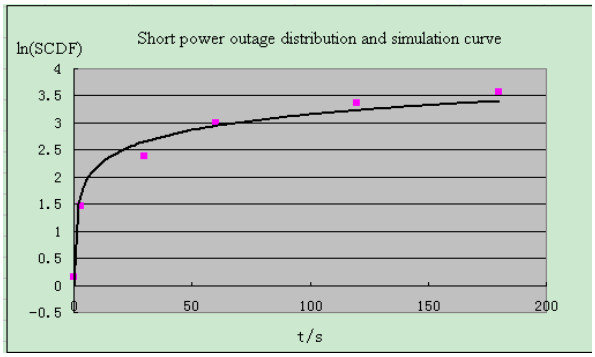

Fig.1 Short interruption distribution and simulation curve

SCDF(t) of industry users can be gotten as follows:

$$SCDF(t) = 18.98994 \times t^{0.4156} \quad (5)$$

Function (5) derivation,

$$SCDF(t)' = 7.8922 \times t^{-0.5814} \quad (6)$$

From function (6), the value was always bigger than 0, it meant that the losses of short interruption would become more serious with the time continuing. Because of (6) was decreasing function, marginal interruption losses of industry were decreased. In other word, the addition of short interruption cost will gradually reduce with the duration time increasing. In figure1, the point of 60s was demarcation. When the time duration was less than 60s, the losses grew faster; growth became slowing down when it was more than 60s. Therefore, if short interruption can be stopped in 60s, large losses can be avoided effectively.

Losses in unit time, called LSCDF, as follows:

$$LSCDF(t) = \frac{SCDF(t)}{t} = 18.98994 * t^{-0.5814} \quad (7)$$

From function (7), it showed that losses in unit time were smaller, when total losses of industry user were bigger. It could be concluded that frequent short interruption will bring larger losses to industry sensitive users[2].

4. EVALUATION OF SHORT INTERRUPTION

4.1 Evaluation Index

The severity of short interruption mainly appears in high-frequency and high losses, they can be taken as evaluation index of short interruption. Frequency of short interruption, IEAR and ICPE can be used to evaluate the severity of short interruption, the functions were as follows:

$$IEAR = \frac{\sum COST}{\sum LEP} \quad (8)$$

$$ICPE = \frac{\sum COST}{N} \quad (9)$$

Among that, Σ COST meant total losses of society interruption, yuan; Σ LEP meant total power quantity losses of society interruption, kWh; N meant the happen times of society interruption, ci.

4.2 Empirical analysis

According to related statistics, we taken an evaluation on short interruption of X city. Compared short interruption with general interruption by related indexes, such as IEAR, ICPE and so on, the severity of short interruption and general interruption could be seen in table3.

Tab. 3 Evaluation index between short interruption and general interruption

Type	Times（ci）	Total time duration（min）	Total power quantity losses（kWh）	Total interruption losses（yuan）	IEAR (yuan/kW）	ICPE（yuan/ci）
General interruption	73	1972	79783.88	12452542.21	156.08	170582.77
Short interruption	50	9.3185	1308	2537419.66	1939.92	50748.39
Proportion of Short interruption	0.41	0.0047	0.016	0.169	/	/

From tab.3, there were several rates about short interruption VS general interruption. For instance, rate of times was 41%,rate of time duration was 0.47%, rate of power quantity losses was 1.6%, rate of interruption losses was16.9% .Among them, IEAR of short interruptionwas12.4 times bigger than general interruption, reach 1939 yuan/kWh. Thus, the losses of short interruption were very serious. And also, it can be seen that these evaluation indexes are available to remark severity of short interruption. IEAR was more effective than ICPE in evaluated on short interruption.

5. CONCLUSIONS

In this paper, we summarized the various sensitive users' economic losses structure of short interruption and estimated short interruption losses of X city. Based on the related analysis, features of short interruption were found, namely that "high-frequency, high-losses, fast-happen" Compared with general interruption, the severity of short interruption was appeared. Meanwhile, by contrast with ICPE, it was known that IEAR was useful to evaluation of short interruption.

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