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STUDY ON SEISMIC ECONOMIC LOSS RAPID ASSESSMENT METHOD OF TRANSFORMER SUBSTATION

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Abstract

Rapid estimation of earthquake economic loss is of great significance for emergency rescue, post-disaster restoration and reconstruction of earthquake-stricken areas. Transformer substation is composed of different types of buildings and outdoor and indoor high-voltage electrical equipment. Their seismic capabilities (vulnerability) usually differ greatly from each other. So estimation of the station's damaged condition and economic loss after the earthquake is difficult, and mostly, only an empirical rough estimation could be given. In this paper, equipment and facilities in the substation were classified into three major types of assets: buildings, outdoor high-voltage electrical equipment, and indoor monitoring equipment. Based on the information of the damaged condition and the economic loss of the substations in Wenchuan earthquake, loss ratios of these three types of assets in different earthquake intensity areas were summarized, proportional coefficients of these three types of assets of the substations were calculated, and then an economic loss estimation model of the substations was created, and tentative calculations were given. This work provides a reference for the emergency rescue, loss estimation, restoration and reconstruction of power facilities after an earthquake.

Key words: *transformer substation; electrical equipment; building; earthquake; loss estimation*

1. Introduction

The seismic capacity of power systems is relatively weak. Earthquakes usually cause a wide range of damages. The strong chain effects can result in great direct and indirect economic losses. The functioning condition of power systems during earthquakes not only affects the production and living of people in the disaster areas, but also has significant impact on the execution of emergency rescue and earthquake relief works. Therefore, faster and more accurate estimation of the damaged condition and economic loss of power facilities right after disastrous earthquakes has an important reference meaning for emergency rescue of power facilities and the planning of post-disaster reconstruction.

In recent decades, a lot of researches have been carried out on the rapid estimation of earthquake damage, casualties and economic loss by foreign countries. Since 1980s, Federal Emergency Management Agency (FEMA) has developed HAZUS97, HAZUS99, HAZUS-MH software systems based on GIS technology[1] , which have been used to provide references for all levels of government to deal with disasters; in 1996, Japan researched and developed the EES system (Early Estimation System) to assess early damages, which was then developed and integrated to the DIS system (Disaster Information System) for the estimation of the scope and degree of earthquake damages as well as to provide support for carrying out emergency measures more rapidly

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and accurately[2]; many European countries have also carried out researches on rapid estimation methods and developed a number of corresponding estimation software[3,4]. Besides, on the basis of earthquake loss estimation HAZUS system developed by Federal Emergency Management Agency (FEMA), Taiwan (China) has upgraded the existing earthquake loss estimation system – HAZ-Taiwan and completed the development of Taiwan Earthquake Loss Estimation System (TELES). Its functions include earthquake simulation, earthquake early estimation and earthquake risk estimation etc[5]. The above software make loss estimation of power facilities on the basis of the vulnerability of power facilities, as well as the estimated damage and function failure conditions according to the field strength affected by earthquake motion (intensity or peak acceleration)[1], in which the vulnerability model of some power facilities is based on earthquake damage investigation and expert experience.

Since the Xingtai earthquake in 1966, many scholars in mainland China have carried out analysis on the earthquake damage of buildings, which has become the starting point of the research work about earthquake disaster prediction and estimation. Since the end of 1980s, China has begun to study the earthquake disaster prediction and disaster prevention measures in large and medium-sized cities, focusing on the research of earthquake damage prediction and decision-supporting methods of urban monomer and group buildings. In late 1990s, through carrying out earthquake disaster prediction in more than 30 demonstration cities, many scholars had accelerated the research on rapid estimation and prediction methods of earthquake damage, and have so far developed a series of earthquake damage estimation software systems in the development process, such as the earthquake damage estimation program (EDEP) [6] and the lifeline engineering earthquake damage and loss fast estimation software system (LEEDLFES 1.0)[7] in the early times and the current China-HAZUS[8]. Initially, the rapid estimation of LEEDLFES used in China basically relied on the extremely simple and rough preliminary judgments of experts. In view of the complexity and diversity of various lifeline systems, in recent years, during earthquake loss estimation, some scholars studied the proportional relation between the lifeline system earthquake damage loss and the building damage under different intensities, established lifeline system rapid estimation method of overall economic loss, calculated the proportional coefficients of the lifeline engineering to building structural damage under 6 to 10 seismic intensities in large, medium-sized and small cities, and therefore primarily embodied the overall loss of all the lifeline systems[9]. In addition, some scholars had also calculated the loss ratio of lifeline system to overall economic loss after an earthquake on the basis of all the earthquakes occurred in China in the past 30 years, which can be used as a statistical method to macroscopically estimate the overall lifeline system loss after an earthquake[10]. The above earthquake loss estimation methods can only make rough and macroscopic estimation of the overall loss of multiple lifeline systems. However, there are various facilities of lifeline systems accounting for different proportions in different regions and with very different vulnerabilities. Therefore, loss estimation model of each type of lifeline systems are needed for making more accurate estimation of economic loss.

Substations are important function nodes of the power grid. They have large economic value and are liable to be damaged during earthquakes. To estimate the loss of power systems, we must first estimate the economic loss of the substations. A substation contains a variety of indoor and outdoor electrical equipment and civil facilities, whose seismic capacities (vulnerability) are usually quite different. Currently, China has not carried out much researches on the vulnerability of various indoor and outdoor equipment, except for researches on the vulnerability of few electrical equipment such as transformer and bus bar etc[11,12,13]. Due to inconsistent seismic capacities of domestic and foreign electrical equipment, the vulnerability curves of electrical equipment produced by other countries cannot be adopted. Therefore, the rapid estimation method of economic loss by using their vulnerability results of power equipment is restrained. In view of this, in this article, substation assets are categorized into three major types: outdoor high-voltage electrical equipment, indoor monitoring equipment, and building. According to the survey data of substation equipment damage and economic loss of civil facilities during Wenchuan earthquake, loss ratios of these three types of assets under different earthquake intensities are calculated respectively, proportional coefficients of these three types of assets in substations with different voltage grades are calculated, and eventually the substation economic loss estimation model is created.

2. Estimation of substation economic loss

2.1 Investigation of substation economic loss in Wenchuan earthquake

In Wenchuan earthquake, 60 counties and cities in Sichuan province, as well as 4,050,700 users' electricity supply were affected. The power grid in 10 counties including counties of Pengzhou and Dujiangyan in Chengdu city, counties of Mianzhu, Shifang and Zhongjiang in Deyang city, counties of Beichuan, Jiangyou and Anxian in Mianyang city, counties of Qingchuan and Jiange in Guangyuan city etc. were seriously damaged. The direct earthquake economic loss of power facilities was 7.1 billion Yuan and the net loss of assets was about 5.64 billion Yuan. Of which, Sichuan Electric Power Company suffered a loss of 5.43 billion Yuan[1].

Based on the statistical data of Sichuan Electric Power Company, numbers and conditions of the damaged substations and lines are shown in table 1.

Table 1 – Number of damaged substations and lines in Wenchuan Earthquake

Voltage grade /kV	**Number of damaged substations**	**Number of substations that needs reconstruction**	**Number of damaged lines**
500	1		4
220-330	14	3	64
110	75	5	136
35	156	7	187
10			1252
Total	246	15	1643

The power supply system of Sichuan province consists of the power grids hosted by the State Grid Corporation and some local power companies. They are mostly 35kV – 220kV substations. Fig1 is the distribution map of substations hosted by the State Grid Corporation and some local power companies in the intensity 7 and above areas. Substations marked in red are hosted by the State Grid Corporation, in which those marked in blue are outage substations and yellow are non-outage substations. The seismogenic fault of Wenchuan earthquake lies on the edge of the basin, in the southeast direction of which is the plain area of the basin. This area is densely populated with large amount of commercial power usage, and so, substations are mostly built here. A Questionnaire survey focusing on three types of assets: outdoor high-voltage equipment, building and indoor equipment was carried out on the earthquake loss of the 35kV -220kV substations hosted by the State Grid in Chengdu, Mianyang, Guangyuan and Aba areas. According to the returned 121 questionnaire of substations, the sample names of the substations, located areas, voltage grades and the local seismic intensities are shown in table 2. For reasons of business secret, specific economic losses and the specific data of original assets are not revealed in this article. The earthquake fortification levels of above substation samples were mostly intensities 6 and 7. Data of these substations are the base of this paper.

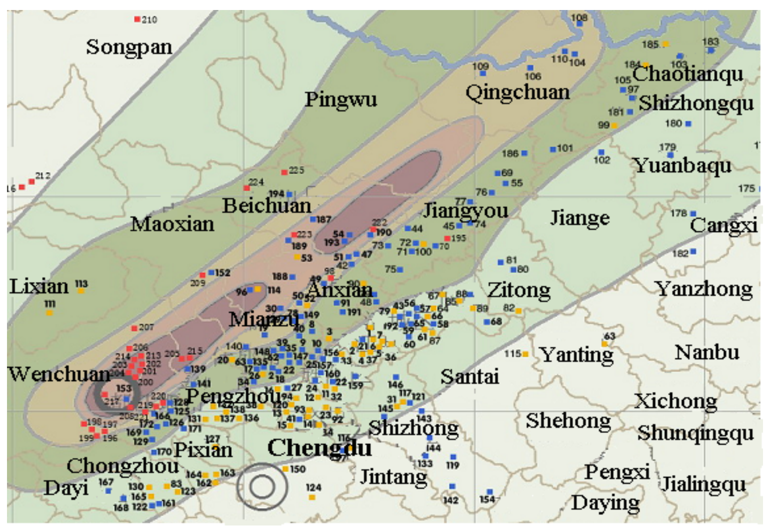

Fig.1 – Distribution map of substation
(Note: the red is the hosted substation of state grid corporation, the blue is the outage substation and the yellow is the non outage substation)

Table 2 – Economic loss samples of substations in Wenchuan Earthquake

Area	Sample Name	Voltage Grade	Seismic Intensity	Area	Sample Name	Voltage Grade	Seismic Intensity
Chengdu	Juyuan station	220	8	Mianyang	Nanta station	110	7
Chengdu	Xujia station	110	8	Mianyang	Gaoshui station	110	7
Chengdu	Guanxian station	110	8	Mianyang	Santai station	110	7
Chengdu	Jinjiang station	110	8	Mianyang	Puming station	110	7
Chengdu	Chongzhou station	110	8	Mianyang	Tieniu station	110	7
Chengdu	Wangchang station	110	8	Mianyang	Xinzao station	110	7
Chengdu	Yongkang station	110	8	Mianyang	Shiqiaopu station	110	7
Chengdu	Pengxian station	35	7	Mianyang	Tangxun station	110	7
Chengdu	Pingqiaozhan station	35	6	Mianyang	Yuanyi station	110	7
Chengdu	Cifeng station	35	8	Mianyang	Xianrenqiao station	110	7
Chengdu	Stone beef station	35	8	Mianyang	Youxian station	110	7
Chengdu	Double Jade station	35	8	Mianyang	Weicheng station	110	7
Chengdu	Tanggong station	35	8	Mianyang	Xiaoxian station	110	7
Chengdu	Qingshan station	35	8	Mianyang	Changqing station	110	7
Chengdu	Tianba station	35	8	Mianyang	Hongren station	110	7
Chengdu	Zhangjiawan station	35	8	Mianyang	Huagai station	110	8
Chengdu	Cuiyue Lake station	35	8	Mianyang	Jiepai station	110	8
Chengdu	Guankou station	35	9	Mianyang	Majiaoba station	110	8
Chengdu	Xingfu station	35	9	Mianyang	Erlangmiao station	110	8
Chengdu	Xiaoyudong station	35	10	Mianyang	Taibai station	110	8
Chengdu	Whitewater river station	35	9	Mianyang	Ganxi station	110	8
Chengdu	Dabao station	35	8	Mianyang	Shawo station	110	8
Guangyuan	Hongjiang station	220	7	Mianyang	Sanhe station	110	8
Guangyuan	Chihua station	220	6	Mianyang	Zhongba station	110	8
Guangyuan	Yuanjiaba station	220	8	Mianyang	Yongan station	110	9
Guangyuan	Cangxilingjiang station	110	6	Mianyang	Jushui station	110	9
Guangyuan	Shaxiba station	110	7	Mianyang	Leigu station	110	9
Guangyuan	Shangxi station	110	7	Mianyang	Yuanmenba station	110	9
Guangyuan	Lantupo station	110	7	Mianyang	Xiaoba station	110	9
Guangyuan	Chengjiao station	110	7	Mianyang	Wudu station	110	8
Guangyuan	Songlinpo station	110	7	Mianyang	Longfeng station	110	8
Guangyuan	Jiuhua station	110	7	Mianyang	Xiaoting station	110	7
Guangyuan	Baolun station	110	8	Mianyang	Shiling station	110	6
Guangyuan	Chaotian station	110	8	Mianyang	Xinqiao station	35	7
Guangyuan	Zhuyuan station	110	8	Mianyang	Yuhe station	35	7
Guangyuan	Sandui station	110	8	Mianyang	Zhongxing station	35	7
Guangyuan	Qiaozhuang station	110	9	Mianyang	Shiban station	35	7
Guangyuan	Muyu station	110	9	Mianyang	Xiaoba station	35	8
Guangyuan	Jinxi station	35	6	Mianyang	Guanshan station	35	8
Guangyuan	Cangxichengjiao station	35	6	Mianyang	Xinan station	35	8
Guangyuan	Cangxi longshan station	35	6	Mianyang	Jiuling station	35	8
Guangyuan	Cangxi dongxi station	35	6	Mianyang	Houba station	35	8
Guangyuan	Cangxi Wulong station	35	6	Mianyang	Chonghua station	35	8
Guangyuan	Yuanba station	35	7	Mianyang	Yanmen station	35	8
Guangyuan	Linqing station	35	7	Mianyang	Dunshang station	35	10
Guangyuan	Jiachuan station	35	7	Mianyang	Tongkou station	35	10
Guangyuan	Dashi station	35	7	Mianyang	Yuli station	35	10
Guangyuan	Zhongzi station	35	8	Mianyang	Longwei station	35	11
Guangyuan	Yangmu station	35	8	Mianyang	Leigu station	35	11
Guangyuan	Chenjia station	35	8	Mianyang	Jade dragon station	35	6
Guangyuan	Sanguoshi station	35	9	Mianyang	Gaodeng station	35	6
Guangyuan	Goujiaya station	35	9	Mianyang	Jinkong station	35	6
Mianyang	Fenggu station	220	6	Mianyang	Fivedragon station	35	6
Mianyang	Yongxing station	220	7	Mianyang	Fuyi station	35	6
Mianyang	Jiaqiao station	220	7	Mianyang	Heiping station	35	6
Mianyang	Baisheng station	220	8	Mianyang	Baizi station	35	6
Mianyang	Tianming station	220	8	Mianyang	Chengguan station	35	6
Mianyang	Dakang station	220	9	Mianyang	Zhinan station	35	6
Mianyang	An county station	220	8	Mianyang	Huangdian station	35	6
Mianyang	Three yuan station	110	6	Mianyang	Chenkang station	35	7
Mianyang	Mianyang station (old)	110	7				

2.2 Economic loss estimation of damaged substations under different seismic intensities

Substation assets are categorized into 3 types: outdoor high-voltage electrical equipment, indoor electrical equipment and buildings. Outdoor high-voltage electrical equipment mainly contain main transformer, circuit breaker, disconnecting switch, potential transformer, current transformer, lightning arresters, bus bar, as well as impeder and capacitor etc. Indoor equipment contain control panel, DC power supply (storage battery), some switch cabinets in lower voltage grades etc. Buildings of substations refer to the master control room, office and living rooms.

If the total number of substation samples is N_i under the earthquake intensity of i (i =6, 7, 8, 9, 10, 11) and the value of k-type equipment or facility in the No. n substation is $V_{k,n,i}$, (k=1, 2, 3, which refers to outdoor high-voltage electrical equipment, indoor electrical equipment or civil facility respectively), the actual economic loss under the seismic intensity of i is $L_{i,k,n}$, then the loss ratio ($RL_{i,k,n}$) of k-type asset in No. n sample under the seismic intensity of i is:

$$RL_{i,k,n} = L_{i,k,n} / V_{i,k,n} \tag{1}$$

The average loss ratio of substation k-type asset under the seismic intensity of i is:

$$\overline{RL}_{i,k} = \frac{1}{N_i}\sum_{n=1}^{N_i} RL_{i,k,n} \tag{2}$$

Where $\overline{RL}_{i,k}$ is the average loss ratio of substation k-type asset under the seismic intensity of i (i is the seismic intensity; N_i is the total number of substations under the seismic intensity of i).

Based on the statistical data in table 2, the average asset loss ratios of the substations under different intensities are shown in table 3. The average loss ratios of these substation samples are shown in Fig2, 3, 4. The comparison of average loss ratio curves of the three types of assets are shown in Fig5.

Table 3 –The statistics of asset loss ratios of substation under different intensities

Intensity	**Average Asset Loss Ratio (%)**		
	Outdoor Equipment	**Indoor Equipment**	**Buildings**
6	0.5	0.3	3.6
7	1.5	3.1	13.6
8	16.9	12.9	20.7
9	52.0	42.9	34.3
10	71.6	58.6	57.7
11	81.3	81.7	78.3

As shown in Fig 2, 3, 4, the discreteness in the loss ratios of the 3 types of assets is quite large. In the intensity 7 and 8 areas, the loss ratio of most substations is not more than 0.2. Serious damage is seen in a few substation samples, and the loss ratio is close to 1.0. However, in the intensity 9 areas, some are basically intact, and some are seriously damaged. In intensity 10 and above areas, substations are mostly all damaged, which results in higher loss ratio. As shown in Fig 5, in areas of 6 – 8 intensities, damage of buildings is more serious than the damage of outdoor and indoor electrical equipment. In areas of 9 or above intensities, the damage of outdoor and indoor equipment is a little more serious than building damage, especially the damage of outdoor high-voltage electrical equipment.

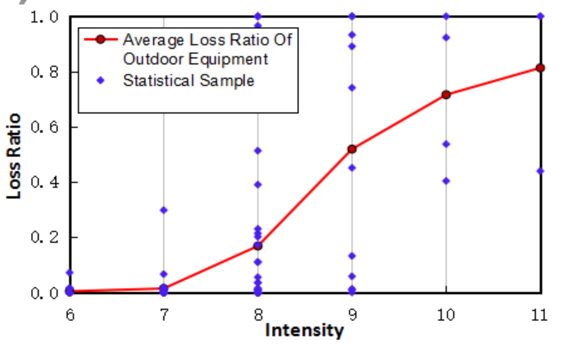

Fig.2 – Loss ratio of high-voltage power equipment outdoors under different intensity

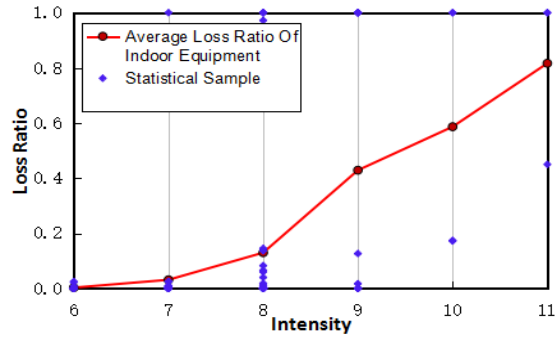

Fig.3 – Loss ratio of indoor equipent under different intensity

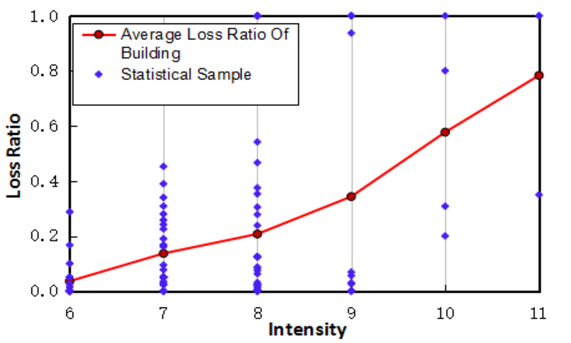

Fig.4 – Loss ratio of building under different intensity

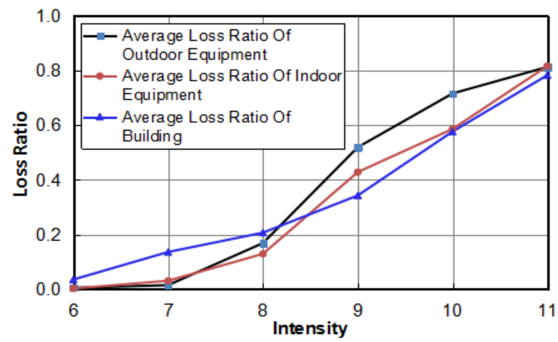

Fig5 – Average loss ratio of various assets under different intensity

The vulnerability of similar assets should be different for transformer substations with different voltage grades, and thus results in different loss ratios. However, due to the quantitative limitation of statistical samples, specific statistics was not conducted on different voltage grades of substations.

3. Total assets and the ratio of various assets in substations

With voltage grades of 35kV, 110kV and 220kV, substation samples are categorized into 3 types and are listed in table 2. The statistical results of the total assets (cost) and the ratio of the 3 types of assets (outdoor high voltage electrical equipment, indoor electrical equipment and buildings) in substations with different voltage grades are shown in table 4, Fig 6 and Fig 7.

Table 4 – Average total assets and the ratio of various assets in different voltage grade substation

Substation Voltage Grade	Ratio of Various Assets			Average Total Assets (10,000 Yuan)
	High-Voltage Electrical Equipment	Indoor Equipment	Building	
35kV	0.525	0.227	0.248	362
110kV	0.648	0.216	0.136	1865
220kV	0.679	0.195	0.125	4829

As shown in Fig 6, the costs of substations of different voltage grades vary a lot. The average cost of the 35kV substation is only close to 4 million Yuan, while the average costs of 110 kV and 220kV substations are close to 20 million and 50 million Yuan respectively.

As shown in Fig 7, for 110kV and 220kV substations, what occupies the highest asset ratio to the total assets is the outdoor high-voltage electrical equipment, which is more than 60%, followed by the indoor equipment, which accounts for more than 20%, while the building is relatively low, average ratio of which is usually less than 15%. Besides, ratios of similar assets in 110kV and 220kV substations are also similar. While for 35kV substations, the ratio of outdoor high-voltage electrical equipment is 50%, the highest compared with other assets, however, it is still lower than that of the high-voltage substations. The average ratios of indoor equipment and building of substations with different voltage grades are similar.

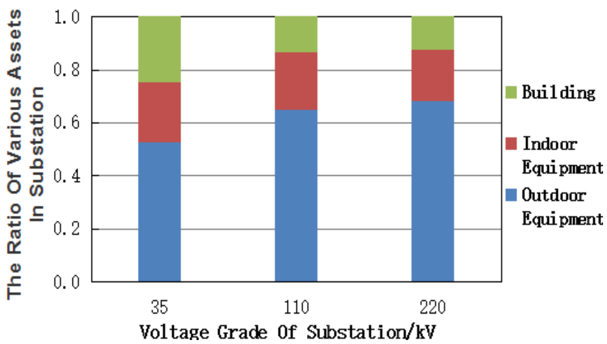

Fig.6 – Average total cost of substations with different voltage grades

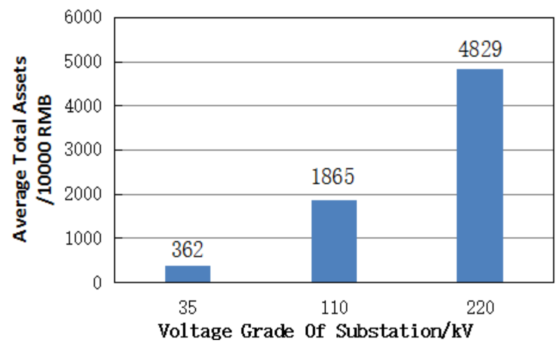

Fig.7 – Average ratio of various assets of substations with different voltage grades

4. Calculation method and procedure of substation economic loss

With reference to the statistical results of various assets loss ratios of substations with different voltage grades and under different intensities, once earthquakes occur, rapid estimation of earthquake economic loss of substations can be made according to the specific voltage grade and the local seismic intensity.

Generally, if the voltage grade of a substation is *j* (*j*=1, 2, 3, which refers to 35kV, 110kV and 220kV respectively) under the seismic intensity of *i*, then the total economic loss of this substation is:

$$LA_{i,j} = \sum_{k=1}^{3} V_{j,k} RL_{i,k} \tag{3}$$

In formula (3), $LA_{i,j}$ is the total economic loss of substation with the voltage-grade of *j* and under the seismic intensity of *i*, $V_{j,k}$ is the cost of *k*-type asset in grade-*j* substation, $RL_{i,k}$ is the loss ratio of *k*-type asset under the seismic intensity of *i*.

This estimation method requires at least 2 parameters, the substation voltage grade and the seismic intensity in substation location. In addition to the 2 parameters, more information about various assets of the substations may also be required. Therefore, estimation with different accuracy can be made according to the completeness of the information of various assets.

(1) If only the substation voltage grade (*j*) and seismic intensity (*i*) are known, the total loss of substation $LA_{i,j}$ can be calculated using formula (4):

$$LA_{i,j} = \overline{V_j} \sum_{k=1}^{3} \overline{RA}_{j,k} \overline{RL}_{i,k} \tag{4}$$

where $\overline{V_j}$ is the average total cost of *j*-grade substation(see table 4); $\overline{RA}_{j,k}$ is the average ratio of *k*-type asset of the *j*-grade substation (see table 4); $\overline{RL}_{i,k}$ is the average loss ratio of *k*-type asset of substations under seismic intensity of *i*(see table 3).

The above parameters are known statistical values and can thus be directly pre-calculated with reference to table 3 and table 4. Please refer to table 5 for the pre-calculated results.

Table 5 – Average assessment of earthquake economic loss of substations under different intensities /10,000Yuan

Substation Voltage Grade	**Seismic Intensity**					
	6	**7**	**8**	**9**	**10**	**11**
35kV	4.38	17.7	61.42	164.96	236.41	292.38
110kV	16.16	65.23	308.83	887.81	1248.44	1510.79
220kV	40.53	161.17	801.62	2316.64	3252.37	3912.84

Thus, if only the voltage grade and the seismic intensity are known, the economic loss of substation can be directly looked up in table 5.

(2) If the substation voltage grade (*j*), seismic intensity of substation location (*i*) and the total cost of substation are known, but the ratios of various assets are unknown, rapid estimation value of earthquake loss of substations ($LA_{i,j}$) can be calculated using formula(5):

$$LA_{i,j} = V_j \sum_{k=1}^{3} \overline{RA}_{j,k} \overline{RL}_{i,k} \tag{5}$$

where V_j is the total cost of *j*-grade substation, which is a known condition value during loss rapid estimation. For values $\overline{RA}_{j,k}$ and $\overline{RL}_{i,k}$, refer to formula (4).

(3) If the substation voltage grade (*j*), the seismic intensity of substation location (*i*) and the cost of various assets $V_{j,k}$ are known, the earthquake loss of substations is:

$$LA_{i,j} = \sum_{k=1}^{3} V_{j,k} \overline{RL}_{i,k} \tag{6}$$

In formula (6), refer to table 3 for the value of substation average loss.

Flow chart for the calculation of substation economic loss is shown in Fig 8.

An calculation example: There are three substations (*A*, *B*, *C*), in which, the voltage grade of substation *A* is 35kV and its seismic intensity is 9 While its asset information is unknown; the voltage grade of substation *B* is 110kV, its seismic intensity is 10, and its total cost is 11 million Yuan; the voltage grade of substation *C* is 220kV, and its seismic intensity is 9. Also, the cost of its outdoor electrical equipment is 12 million Yuan, the cost of its indoor equipment is 6 million Yuan, and the cost of its buildings is 5 million Yuan. Thus, the economic losses of substation *A*, *B* and *C* are calculated as follows:

(1) The least two necessary conditions of substation *A* are known, therefore, according to the rapid estimation procedure shown in Fig 8, by directly looking up table 5, the total loss of this 35kV substation is 1,649,600 Yuan.

(2) For substation *B*, besides the voltage grade and seismic intensity, its total cost is also known, therefore, according to formula (5),

The total loss of substation *B* = 11,000,000×(0.648×0.716 + 0.216×0.586 + 0.136×0.577)

= 7,359,000 (Yuan)

(3) For substation *C*, in addition to the voltage grade and seismic intensity, the costs of three types of assets are known, therefore, according to formula (6),

The total loss of substation *C* = 12,000,000×52.0% + 6,000,000×42.9% + 5,000,000×34.3%

= 10,529,000 (Yuan)

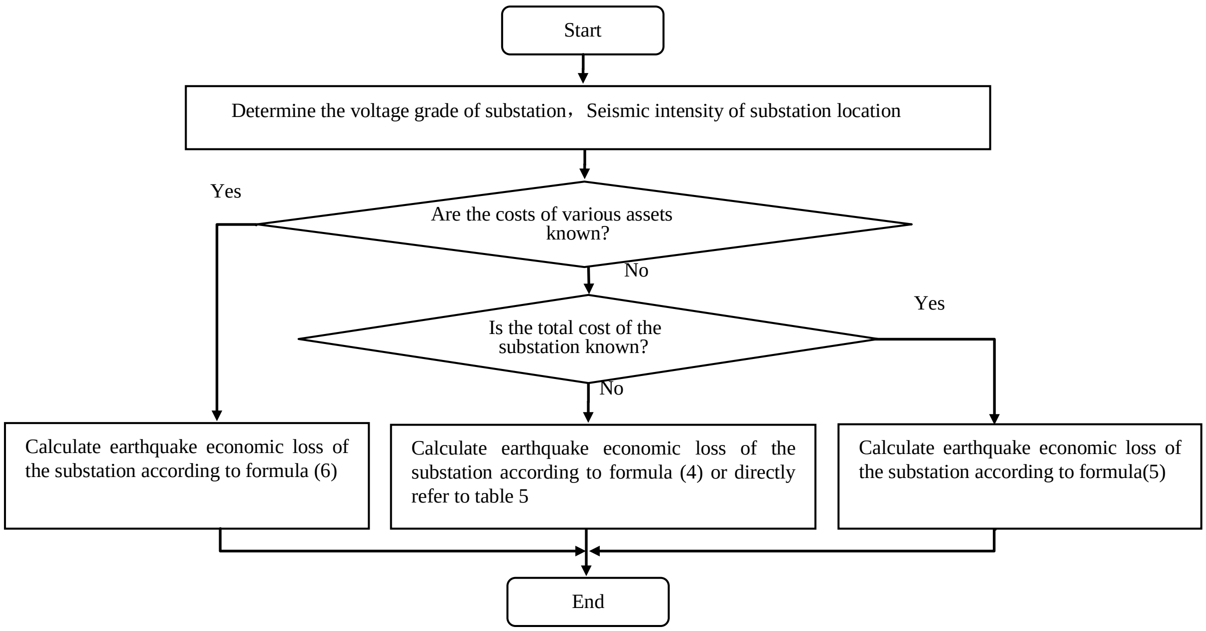

Fig.8 – Flow chart of the rapid assessment of earthquake economic loss

5. Conclusion

In this paper, substation facilities are categorized into 3 types: buildings, outdoor high-voltage electrical equipment, and indoor monitoring equipment. According to survey information about the economic losses of these three types of equipment and facilities in the Wenchuan earthquake, loss ratios of these three types of facilities under different seismic intensities are calculated respectively, percentages of these three types of assets in substations with different voltage grades are calculated. In the end, three types of economic loss rapid estimation models are given with the necessary conditions of voltage grade and seismic intensity and different completeness of substation assets information. After an earthquake, according to the proposed loss estimation method in this paper, each substation in the target area could be estimated, and then the total economic loss of all the substations in this area could be calculated.

It should be noted that, the survey samples of substation assets and losses are only part of the 220kV and less substations damaged in the Wenchuan earthquake, therefore, the estimation models proposed herein do not apply for 330kV and above substations. The substation reconstruction price varies in different regions. In more developed south China, substation reconstruction costs more, which means the economic loss with same damage would also be more in these regions. If this estimation model is adopted for earthquake economic loss rapid estimation, the estimation value of the economic loss should be increased accordingly. Besides, with the development of society, reinforce concrete structure has already been the main control room and other buildings of substations in many areas so far. To make estimation of such substations, the loss ratio of building asset should be reduced accordingly in consideration of different structural vulnerabilities.

6. References

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