Summary of Seismic Reliability in Electric Power System

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ABSTRACT :

The earthquake disaster characteristics and reasons of electric power system including power supply networks, power transmission lines, substations and electrical equipments are researched and reviewed systematically. According to the facts of seismic damages, the authors present some measures on improving seismic capability of electric power system separately. Research state at home and abroad and developing trends of seismic capability are surveyed and some suggestions for further research are given.

KEYWORDS: Electric power system, aseismatic capability, earthquake disaster, developing trends

1. INTRODUCTION

With the rapid development of society productivity, as the part of lifeline system, electric power system has taken very important role in country economic and the needing of electric power becomes more and more great. There are many obvious characteristics in building, transportation, distribution and using of electric power such as undeposit, unreusing and having deep relationship with other country economic departments. Once the electric power system is destroied, it will take serious loss for country economic and people's living.
Earthquake is one reason of destoring electric power system, which usually leads to electric equipments breakage, even non-work of whole power system. The indirect loss of electric power system is even larger, which affects common life and reconducting. For example, the electric power system was destoried by Kobe Japan M7.2 earthquake in 1995 which leaded the water supply unwork, so the fire couldn't stop because of having no water. Taiwan chichi M7.6 earthquake resulted in 2103 people dead and loss of 24,000,000,000 taiwanese dollars. Forthermore, The computer CMOS chip factory was demolished strongly caused by wrose of electric power system which leaded the fluctuation of whole world computer price. All these examples show that the seismic security of electric power system must be strengthened and the seismic performance investigation of electric power system has become one of improtant topic in earthquake engineering.

2. REASONS AND CHARACTERISTICS OF ELECTRIC POWER SYSTEM

The research of earthquake disasters was begun in 1960s and there were so many concrete earthquake disasters recordings around world from that time. It is introduced the characteristics of electric power system as following.

2.1. Reasons and Characteristics of Electric equipments

The destroy style of switcher and high-voltage reactor is the break of sustain porcelain bushing, destroy of lighting arrester is the disjunction of element, destroy of isolator switch is the dehiscence between medical flange and porcelain. Earthquake may leads to the current transformer open circuit and produce high voltage, and then the equipments and transmission line are burn down. Accumulator can move, fall down and throw off as accumulator is not fixed well on base. The harm style of transformer is such as the foundation deviate from track, the shear failure of accessory equipments and anchor bolts, damage of pump tubing and burning out of transformer.

All these equipments has the traits such as thin shape, small damping ratio, brittleness material, low seismic ability and feasible to resonance with site in natural frequency between 1-10hz. These traits also are the main causes of electric system failure in strong earthquakes which bring difficult for relief work and life. In fact, there are so many real examples shown that power cut after earthquake can make factory not work, hospital not operate, mine stop and so on.

2.2. Reasons and Characteristics of Transmission Line

The transmission line includes iron tower and electric line, which tower is made of hot rolling same angel steel and electric line use copper wire. Because tower is very high and its seismic ability is low, the destroy traits usually are breaking off in one third or middle of tower and then abruption by line. The destruct reason is excessive tall-thin ratio of tower and exceeding admit bending strength which makes tower break off and line rupture when earthquake happens.

2.3. Reasons and Characteristics of generatrix

There are two types of generatrix in substation, hard generatrix and soft generatrix. The former is made of aluminum pipe and aluminum line, while the latter is made of aluminum line. The destroy cause of hard generatrix is breaking of post insulators, while the cause of soft generatrix is insulators snapped by high strength itself.

2.4. Reasons and Characteristics of buildings in electric power system

The shapes of buildings in electric power system are usually high, massive and wide which can meet the special need of electric equipments. The load of electric equipments is very high which leads to insufficient strength and stiffness and easier to be destroyed in earthquakes. For instance, the plant is composite of steamer structure and intergovernmental framework, as the stiffness of two parts is so larger that the connections prone to fracture. The boiler framework can not afford the swing caused by earthquake resulting to fracture. The control building in Substation showed relatively weak seismic reliability because heavy reinforced concrete slabs and thin abdominal beams are often used in roof and frame.

3. MEATURES OF IMPROVING ELECTRIC POWER SYSTEM SEISMIC RELIABILITY

Based on the analysis of the characteristics of the damage of the electric power system, we can see that the electric power system must be adopted some measures from the three main levels to improve the earthquake reliability, that is, from electrical equipment level, class and power substation level to take corresponding measures to increase its seismic performance.

3.1. Measures of improving electric equipment seismic reliability

For the characteristics of various kinds of electrical equipment, it can be separately assessing seismic reliability. The strength of ceramic casing used in electrical equipments with ceramic casing such as circuit breakers, current transformers and voltage transformer should be increased as far as possible, using high-intensity porcelain and other high-silicon material is a good way to strength it.

The high-voltage electrical equipments with slender support, such as high-pressure isolation switch and insulator, are close to resonance with ground motion because of its relatively small damping, great power amplification factor and similar natural frequency with ground frequency. For this type of electrical equipment, it may be used shock absorber damping to change the frequency of system equipment and damping ratio, thereby reducing the equipment earthquake response.

For the unfixed equipment such as transformers, switchgear and accumulators, it should be enhanced connection between base and body, or set up the necessary rope to prevent slipping, dumping and other damages when earthquake happened.

In addition, the electrical equipment should be strengthened and supported in the connection. At present, the majority connection style of electrical equipments is flange bolt connection. Improving the reliability of these connections is very important to ensure the reliability of the overall electrical equipment

3.2. Measures of improving electric generatrix

There are 4 types of main electrical connection such as single generatrix, double generatrix, double with adjacent generatrix and one half circuit breakers. The style of equipments in these 4 types is same basically, while the seismic ability is different because of the different connection form. The seismic ability of one half circuit breakers is better than that of double with adjacent generatrix, the double with adjacent generatrix better than double generatrix, while the seismic ability of single generatrix is the poorest. Therefore, if the electrical equipment and site conditions permit, it should be chosen double with adjacent generatrix style at first.

3.3. Measures of improving electric net work

Power System network is usually composite by power points (nodes), transmission lines, substations (meeting points). In these components, the nodes and the meeting points have strong earthquake sensitivity and transmission lines have small seismic vulnerability. Therefore, it should be analyzed all aspects of the power system, especially the major part of it, to study seismic vulnerability and identify key factors of reliability to optimize the seismic design.

4. SEISMIC RELIABILITY RESEARCH STATUS OF ELECTRIC POWER SYSTEM

In recent years, the Earthquake Prevention and Disaster Reduction Engineering of the lifeline System is the most popular domestic and international earthquake engineering research topic. With the research of lifeline system continued to deeper scope, as an important part of lifeline system, the electric power system's seismic reliability problems is getting increasing attention by earthquake engineering at home and abroad. It is introduced from three levels as following.

4.1. research status of electric net work

So many scholars have attached great importance to seismic research for a long time.

R.V.Whitman proposed lifeline design standards, which regulated power failure area was not more than 20 percent and within one month back to normal power supply when large earthquake happened. Power outage in the earthquake area not more than one percent, within a few hours return to normal power supply when medium earthquake happened.

AH-S.Ang (1992) studied seismic performance of the power supply system and designed the power supply system reliability model. He believed that the failure of the power supply system in two ways: (1) due to structural damage, loss of power supply network functions, (2) current problems arising from the power supply network nodes or a clear line overload.

Italian scholars Vanzi (1996) advanced the power system analysis model. He regarded high-voltage electrical equipment (high-voltage electrical equipment vulnerability using test data) as one component. According to the analysis of each component, the structure of state power supply system can be determined.

Taiwan scholars G.-Y.Liu (2002) also raised the possibility of power system probability of seismic methods, and this method is applied to the Taiwan Power System. The method adopted Monte Carlo simulation of undermining state of connectivity for analysis to determine the structure of power supply system damaged state and determined the functions of power supply systems and services capacity by several simulations.

China scholars Litian(2000) analyzed the reliability of high-voltage electrical equipments on based of the response spectrum theory and produced the model and calculation method, using maximum value distribution theory to reflect the distribution of the shock characteristics of random process.

Yang Yadi (2000) studied network analysis techniques and established functional coefficient calculation according to the network functional failure.

Su Youpo (2000) evaluated the city earthquake recovery timing through the lifeline influence analysis among the various systems.

Liu Chunguang(2000) considered changes between power and voltage on the basis of analysis power supply system connectivity, and studied the function of the power system failure in seismic intensity.

4.2. Research status of substation

Standard 693 prepared by American Institute of Electrical and Electronic Engineers (IEEE) described substation seismic design as a separate chapter, involving various types of electrical equipments, particularly providing clear seismic design requirements for high-voltage electrical equipments.

The U.S. Federal Emergency Management Agency (FEMA, 1997) improved substation seismic performance assessment methods, which divided substation-destroying type into five categories: intact, slightly damaged, middle-damaged, severely damaged and completely destroyed. It was believed that failure type of the damage substations was only related to transformers, isolation switches, circuit breakers and current transformers. Five categories of destroyed state were corresponded to these four categories of equipment damage.

Wen bo(2004) researched isolation building in substation and concluded that isolation technology in substation building can be used in high seismic fortification intensity areas.

4.3. Research status of electric equipment

After San Francisco earthquake, the United States research departments expanded the content of seismic code, including facilities such as power structures seismic design method. As early as 1978, they provided code of improving the seismic design (ATC306), which is the summary on the seismic design research in United States, using the equivalent side force method and vibration decomposition method to calculate earthquake Loading considering interaction of soil-structure, the lateral limits, gravity - displacement effect (P-Δ effect) and the two directions of the impact of the earthquake.

1999, Pacific Earthquake Engineering Research (PEER) firstly issued the theoretical analysis report of interaction between equipment and connection line in the system of seismic equipment. In the report, the hard generatrix and soft generatrix was used different models, the former was linear quality - spring - damper system, while the latter was catenary system without bending rigidity, connected devices using linear single degree of freedom model.

Song Junho (2004) studied the interaction of electrical equipments connected by cable, compared dynamic properties of electrical equipment with separate equipments. The results showed that the cables are connected to the electrical equipment connected with the dynamic response than the no connecting larger. So in actual design, it cannot be ignored the power wire connected to enlarge the role.

Gilani AS (1999) studied interaction of transformers and casing for a number of experiments and the results used in the formulation of the corresponding norms.

In 1982, the sixth Japanese earthquake engineering discussed the paper of seismic properties of electrical equipment laid in a building, and further explored the design guidelines resolved in electrical equipment reaction. In addition, the Japanese researchers paid great attention to electrical equipment vibration tests on the ground motion to verify the seismic design method reasonable and reliability.

Li yaqi (2002) studied seismic performance of high-voltage electric ceramic equipments outdoor. Through experiments and theoretical analysis, 3-D finite element model considering reversing effects was established.

Guo Zhenyan (2004) studied seismic performance of transformers, established calculation method in the earthquake, and gave the transformer anti-seismic design criteria and calculations.

Yin Ronghua (2005) analyzed the damage situation and seismic research status of high-voltage power transmission tower and pointed out future research trends.

5. DEVELOPING TREND OF ELECTRIC POWER SYSTEM SEISMIC RELIABILITY RESEARCH

Although the earthquake workers have received tremendous achievements after decades of efforts in researching earthquake reliability of electric power system on the theory and practice, there are still some issues needing further scientific study in the field of seismic engineering because of undeveloped earthquake information system and largely uncertain of earthquake factors. Such issues are showed as following. (1) Paying attention to the study of electric power project site seismic risk. As one of the lifeline system of country's economic and social life, electric power system once suffered earthquake damage the consequences are disastrous. Therefore, seismic risk analysis of large-scale power project (including thermal power plants, nuclear power plants, hydropower stations, 330 kV substations above) is the essential research topic before construction. (2)There is further improving on the research methods. It should be combined single power

engineering seismic research with large-scale power project seismic research. (3)Paying more attention to the application of new technologies and new materials. It should be taken great attention to multidisciplinary complex network of electrical work.

6. CONCLUTION

Electric power system is one of very important lifeline engineering system, which is directly related to the safety operation of the national economy. The research of it has value of important theoretical and practical application. Scholars at home and abroad are paying more concern to this direction. According to analyzing different levels of earthquake damage characteristics, this paper brings forward the seismic measures to improve the reliability of electric power system, giving research directions in the future. China is a serious earthquake country, with the rapid development of the national economy, which has the growing demand on the power system stability. Therefore, the power system reliability of seismic research for China's modernization drives more urgency and reality.

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