Power Substation and Earthquake: A Survey

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Abstract

The earthquake disaster was a vast risk for a sustainable and harmonious societal and economic development. The performance of substation equipment during an earthquake depends on their configuration, dynamic properties, ductility, and strength of construction. Substation equipment’s are lightly damped structures having natural modes within the frequency band of ground excitation. The satisfactory operation of substation during and after an earthquake depends on the survival, without malfunction, of many diverse type of equipment. Porcelain components are identified as most vulnerable parts against earthquake vibrations than any other components. This paper presents a field survey and some reviews that are useful to sustain seismic vibration by power substation during earthquake.

Keywords: Circuit Breaker, Earthquake, Porcelain Components, Power Substation, Seismic vibration

I. INTRODUCTION

The electric power industry cascades at three levels, in the chain between power supply and power generation. Considerable damage to the power systems is occurred due to occurrence of even an elementary fault in substation equipment may disrupt power supply. Besides collateral losses, direct losses could be humongous besides loss of precious human life. The experience of past earthquakes shows that damages of the Electrical network installation are very extensive in length and area but they are infrequent. The significance of these installations makes their protection and stability more important. Moreover, an unacceptable gaps is developed in economic interrelated issues because of failure in electrical power system develops.

The most important lifeline which feeds all other lifelines is power network and its lack of operation will cause severe consequences during and aftermath of severe earthquakes. Power transmission and sub transmission substations must considered as the most vulnerable and also the most risky nodes of power network experienced at the time of earthquakes. The higher number of consumers of substation, higher the voltage of substation, then the higher the consequents and risk of malfunction of substation. Seismic vulnerability of equipment increases with substations voltage due to the fact that higher voltage in substation leads to higher isolation distances and then higher height of substations equipment. Higher performances must be expected from higher voltage substation structures. Unlike to performance objectives of general structures that are concentrated essentially on the structures and nonstructural performance features, performance objectives of substations structures are oriented toward protection of equipment rather than protection of structures. According to these objectives, the structures supporting equipment may be scarified to prevent the equipment to be damaged, under seismic effects.

About the assessment of equipment seismic vulnerability, the injury studies and similar structures during past earthquakes will always be checked, as a starting point perfectly reasonable and logical is desired. Equipment such as current transformer, power transformer, and the circuit breaker, is fixed components and critical component of every single process. The failure rate of theses equipment have a direct connection with operating voltage, and Failure patterns each of them is nearly equal. The effect of the earthquake occurred because of high vulnerability of substation equipment such as use of brittle materials in the core and critical part of equipment (including ceramic materials) inadequate lateral strength and stiffness. Low levels of equipment damping, interactions between adjacent equipment, interactions with the internal components of equipment, excessive equipment load, Inadequate and irregular distribution of load on height, inappropriate installation and maintenance [2].
II. BACKGROUND

A. Substations and Earthquakes:
Sudden rupture of a geologic fault causes earthquakes. Shock waves radiate from the fault fracture zone and arrive at the earth’s surface as a complex multi frequency vibratory ground motion, having both vertical and horizontal components. Response of building and structures to earthquake ground motion depends on factors, including their configuration, ductility, strength of construction, and their dynamic properties. Lightly damped structures having one or more natural modes of oscillation within the frequency band of ground excitation can experience considerable amplification of the component stresses, forces, and deflections. Mechanisms that absorb energy in a structure, in response to its deformation, provide damping. If two or more equipment or structures are linked together, such as through a conductor, they may interact with one another producing a modified response and interaction loads. Even when the link is sufficiently flexible to accommodate the relative displacement, forces may be transferred between the equipment and structures including dynamic effects. Therefore, particular care should be given to that design to take such forces into accounts. In particular, many items of substation equipment, for electrical reasons, are highly interconnected and often contain brittle, relatively low damping materials (e.g., porcelain) and/or low strength. The conductors are often installed with very small slack. In these cases damping nonlinear interaction, including impacting between connected equipment will begin after only a little relative motion occurs. Thus, items of substation equipment whose natural frequencies lie in the normal frequency range of earthquake ground motion are particularly vulnerable to damage by seismic events [1].

B. Power Substation:
In order to reduce the electricity energy losses of the power transmission lines, voltage must be increased and amperage must be decreased consumption and distribution of electrical power should reduce the voltage to make it possible for consumers to use electricity. Substation is named on collection equipment, electrical or electromechanical that connects the multi-input electrically to the multi-output electrically and operations such as maintain, conversions, care, monitor and control the switching will be done as shown in figure.

Switching voltage is the main task of post, in many substations are seen with the combination of two modes. The task of distribution post is delivers it to the distribution system by taking over the power from transmission system. Safety and economic aspects of consumers connected directly to the transmission network is not cost efficient. So the task of substation is isolating each of the distribution networks or transmission that happens by errors occurring in the other. Electric substation is an important part of electric power systems. The electric power industry cascades at three levels, in the chain between power supply and power generation. Power supply may disperse because of occurrence of even an elementary fault in substation equipment, cause considerable damage to the power systems. Besides direct losses, collateral losses could be humongous besides loss of precious human life.

Circuit Breaker is the most important units in the electrical power system. The protection, stability and continuity of the system depend on the circuit breaker’s ability to switch line, existing currents and load and to interrupt fault currents. The high level of performance required for the reliable operation of the electrical system is assured by the SF6 gas circuit breaker by making full use of the exceptionally good electrical insulating characteristics and excellent arc quenching properties of sulphur hexafluoride (SF6) gas. The reliability of the system is further increased by the use of a SF6 gas insulating system and a single pressure dual flow SF6 gas puffer interrupter which reduces the number of moving cylinder and auxiliary system in the circuit breaker. The pressure required to blast the SF6 gas against the arc and interrupt the current is generated by the compression of the gas between the moving cylinder and the stationary position of the interrupter during the opening operation.

III. PREVIOUS WORK IN THE FIELD OF POWER SUBSTATION DURING EARTHQUAKE

High-voltage equipment (e.g. transformers, porcelain members, bushing, porcelain members) are the most vulnerable parts of the substation during an earthquake. Performance evaluation of high-voltage substation equipment during a seismic event has become a crucial issue. For substations and its components, this reviews past earthquake induced damage and current state of practice on vulnerability assessment.

Sabelli et al. [3] worked on ground motion amplification and dynamic characteristics of concentrically braced steel frames as earthquake ground motion controls the performance of the structure. Based on the results he had improved design procedures and code provisions. Discussions were presented regarding the mechanical properties of buckling-restrained braced frames and special concentric braced frames. Buckling restrained frames became effective to overcome many potential problems associated with special concentric and ordinary moment resistant frames.

Mircea et al. [4] considered 220kV circuit breaker for combined analysis as a combination of EMA tests (Experimentally Modal Analysis using impact hammer tests) and direct vibratory tests (sine sweep tests) on the seismic platform in identifying seismic capability assessment. Theoretical analysis also can be made as an extension to EMA. Modal analysis parameters and frequency response functions are determined. Both the methods are comparable. The method combined analysis is proposed as strong method accepted by manufacturers and customers of high voltage equipment.

Stewart et al. [5] past earthquake performance of high-voltage substation components typically, voltage rating of components of a substation is one of the factors that are related to its seismic vulnerability. Equipment with 115kV or below showed satisfactory performance during past earthquakes, if seismic installation practices of anchorage and conductor interconnection flexibility were present. Different types of damages in substations observed from the past earthquake records are:

- Leaking or breaking of bushing,
- Falling of inadequately anchored rail-supported transformers from the elevated platforms,
- Damage of bushings and post insulators,
- Failure of cast-aluminum hardware,
- Failure of porcelain insulator,
- Tilting of lighting arresters, and
- Tilting of dead end transmission tower.

Past earthquake records showed that damage to substation components may lead to severe consequences. For example, the 1994 Northridge earthquake caused severe damage to the electric power facilities of Los Angeles. The damage to electric power could have far reaching consequences, as well. British Columbia, Montana, Wyoming, Idaho, Oregon and Washington experienced power outages due to the damage to substations in the Los Angeles area. The Los Angeles Department of Water and Power’s (LADWP) Sylmer Converter Station suffered severe damage that included transformer bushings, lightning arresters, disconnect switches, circuit breakers, bus supports, and potential measuring devices. Similar damages were found in the 1988 Saguenay earthquake, the 1989 Loma Prieta earthquake, the 1995 Kobe earthquake, the 2010 Christchurch earthquake, etc.

Matt and Filiatrault [6] researched the seismic response of five power transformers. Time history analyses were performed to determine the dynamic response and amplification at the base of the transformer bushing. The highest amplifications occurred
when the two natural frequencies were close. Su et al. developed a method to calculate accelerograms to match a design target spectrum for appropriate earthquake magnitude, distance, and site conditions. They found that the shape of the response spectra exhibited strong magnitude and site dependency and weak distance dependency. Thus, the normalized spectra from a large earthquake recorded on a soft soil site are likely to exceed IEEE 693-1997 over long periods.

Takhirov et al. [7] developed a set of earthquake ground strong motion time histories suitable for seismic qualification testing of electrical substation equipment in accordance with IEEE 693-1997. Some 35 three component historic records from 18 earthquakes were analyzed and cross-compared based on several parameters, and the best candidate for input strong motion was selected and modified. The resulting strong motion time history preserved the non-stationary behavior of the real earthquake record while its response spectra enveloped the IEEE target response spectra in a broad range of natural. Reiter, Leon (1990). Earthquake Hazard Analysis. Reiter provides an introduction to the subject of identification of earthquake sources and modelling of the occurrence of earthquakes on these sources. Models for the occurrence of future earthquakes are based on historical seismicity, crustal geology and tectonic processes. There are two sources of earthquake:
1) Area sources are geographical areas within which an earthquake of a given magnitude is equally likely to occur at any time or location, where the local geological features that cause the earthquakes have not been identified.
2) Fault sources are usually individual faults where the tectonic and geological features causing earthquakes have been identified.

IV. CONCLUSIONS

Earthquakes are caused by sudden rupture of a geologic fault. Shock waves radiate from the fault fracture zone & arrive at the earth’s surface as a complex multifrequency vibratory ground motion having both horizontal & vibration components. Past earthquake records showed that large magnitude earthquakes could cause severe damage to substations and result in major service disruption of a power system. This paper presents field survey and some reviews that are useful to sustain seismic vibration by power substation during earthquake.

REFERENCES