SEISMIC VULNERABILITY ASSESSMENT OF ELECTRIC POWER DISTRIBUTION NETWORK IN IRAN

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ABSTRACT

In this paper, the most important activities for increase the seismic reliability and safety level of Electric Power Distribution Network (EPDN) in IRAN are presented. TAVANIR Co. as the manager of production, transmission and distribution of electricity in IRAN with the cooperation of NRI carried out a research project to develop seismic assessment and rehabilitation guideline of EPDN of IRAN and Crisis Management implementation. As the consequences, two guidelines have been developed and Great Tehran Electrical Distribution Co. collaborated in the mission and the SADATABAD Region as the first pilot to execute implementation of guidelines has been assessed and results of this assessment are briefly presented here.

INTRODUCTION

Most of the IRAN arena is high risk seismically and due to last seismic loss experiences, Electric Power Distribution Network (EPDN) has suffered high losses, which leads to search for a reliable network with less loss which it would be economically acceptable and reasonable. Meanwhile failure in power network services after strike tends to lake of services in other life lines such as water, sewage, gas lines, communication, civil, hygienic and treatment services, and leads to additional losses after strike. Thus the seismic assessment of power distribution network and rehabilitation of vulnerable network by the object of more reliable power network is highly desirable. There are some research activity has been reported about seismic behaviour of EPDN components. [1], [2], [3].
Toward such objective, TAVANIR Co. as the manager of production, transmission and distribution of electricity in IRAN with the cooperation of NRI proceeded to develop seismic assessment and rehabilitation guideline of power distribution network of IRAN and Crisis Management implementation. As the consequences, two guidelines have been developed and Great Tehran Electrical Distribution Co. collaborated in the mission and the EPDN of SADATABAD Region in TEHRAN, as the first pilot to execute implementation of guidelines has been selected.
The most important results of seismic assessment and retrofit methods of selected pilot as a case study have been presented in this paper.

SEISMIC DAMAGES OF EPDN IN PAST EARTHQUAKES

Failure studies of power distribution networks in the past earthquakes have indicated the potential of structural damage in the most components of network. Failure of some components of EPDN in past earthquakes has been shown in the Figures 1 to 3.

Figure.1: Shear failure in distribution pole (Bam, 2003)

Figure.2: Collapse of substation building (Manjil, 1990)

Figure.3: Rotation of overhead transformer (Bam, 2003)

Generally, seismic damages in the most components of EPDN is due to adjacent building's collapse or geotechnical ground failure and in some cases, direct failure of unanchored equipments or components due to ground shaking. The most common observed failure modes in the components of power distribution network due to past earthquakes have been introduced in table 1.

Table.1: observed seismic failure modes in the most important components of EPDN

Component or Equipment	Failure Modes
Transformer of Substations	Displacement or overturning due to connection failure
Overhead distribution lines	Overall failure due to building's collapse or Geotechnical ground failure (liquefaction, landslide etc.)
Overhead distribution poles	Overturning or flexural failure
Building of Substations	Overall collapse

BASIC METHODOLOGIES FOR SEISMIC VULNARABILITY ASSESSMENT OF EPDN

Depend on accuracy, simplicity and quickness, there are two seismic assessment methodologies including primary (qualitative) and comprehensive (quantitative) methods. Based on past observed failure mode investigation, a qualitative seismic assessment methodology for EPDN has been developed and assessment worksheets have been designed and provided. The qualitative assessment is simple, quick and economical method. If seismic vulnerability of some components couldn't have assessed by qualitative method, the comprehensive quantitative method by structural analysis has been used for seismic assessment. The methodology, requirements and provisions for these two assessment methods have been developed in this research work and assessment guideline has been provided.

CASE STUDY OF SEISMIC VULNARABILITY ASSESSMENT OF EPDN IN TEHRAN

Using developed seismic assessment guideline, seismic vulnerability of distribution network of two feeders in SADATABAD Region in TEHRAN has been assessed using qualitative and quantitative methods as a case study. [4] Power distribution network of these two feeders has consisted on about 29 distribution substation, 11.5 Km overhead distribution line and 33 Km underground distribution line. The seismicity of considered region is very high according to seismic zonation map of Iran (design based ground acceleration=0.35g). As shown in figure 4, minimum distance of studied area to mail faults is less than 5 Km.

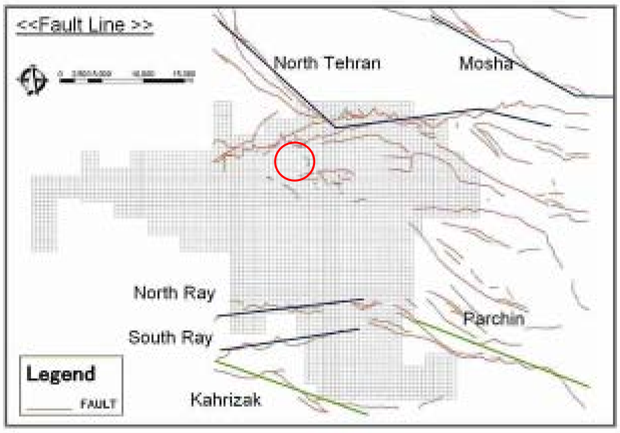

Figure.4: Main fault map of Tehran city

Based on existing documents, potential of seismic geotechnical ground failure (liquefaction, landslide and so on) is very low in the region because of flat topography and low level of underground water. Finally, the results of seismic assessment show that the most components of considered power distribution network are seismically vulnerable due to lack of anchor, insufficient connections, and damages in the component and so on.

Substation Transformers and Switchgears

As shown in figures 5 and 6, the most important reason for seismic vulnerability of overhead and ground transformers is inappropriate anchorage to support structure or foundation. The lack of anchor in transformers leads to overturning, considerable displacement or rotation of them due to seismic ground shaking.
Because of proper anchorage to support and low weight of substation switchgears, they are not seismically vulnerable. (Figures 7 and 8)

Figure.5: lack of anchor in overhead transformer

Figure.6: lack of anchor in ground transformer's wheel

Figure.7: Proper anchor of switchgear to foundation in overhead substation

Figure.8: Proper anchor of switchgear in Ground substation

Substation Buildings

The structural system of the most substation buildings is unreinforced masonry walls. Because of inappropriate details and insufficient connections between bearing walls and roof, these buildings are seismically vulnerable. Typical substation masonry buildings have been shown in Figures 9 and 10.

Figure.9: Typical substation Building

Figure.10: Cracks in substation Building Walls

Overhead Distribution Poles

The most overhead distribution poles in studied area are H shaped reinforced concrete poles. The developed SCC method for Rapid Assessment of concrete poles has been used. Generally, the assessed overhead poles are not seismically vulnerable because of low building accumulation, stiff soil and low potential of ground failure in the studied area. Various existing damages in concrete or reinforcements are the only reason for vulnerability of overhead concrete poles. (Figure 11)

Figure.11: Concrete crush in overhead distribution pole

Finally, quantity of vulnerable components of considered power distribution network (in percent) has been presented in table 2.

Table.2: Quantity of vulnerable components in pilot EPDN

Type of Component or Equipment	% of vulnerable components
Transformer of Substations	100
Overhead distribution transformers	100
Distribution Switchgears	0
Overhead distribution poles	13
Building of Substations	92

METHODS FOR SEISMIC RETROFIT OF EPDN

Based on seismic weakness of vulnerable components, some methodologies for rehabilitation and retrofit of them are proposed and some of them have been shown in Figures 12 to 14. The main idea for retrofit details is addition of effective and appropriate anchors between components and their supporting structure or foundations.

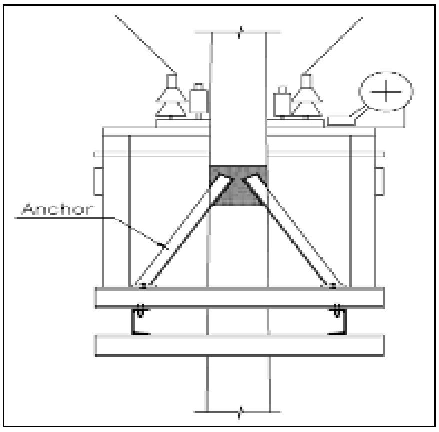

Figure.12: Anchor detail of overhead transformer

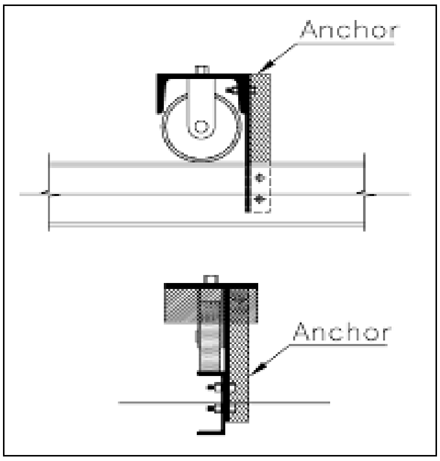

Figure.13: Anchor detail of transformer’s wheel

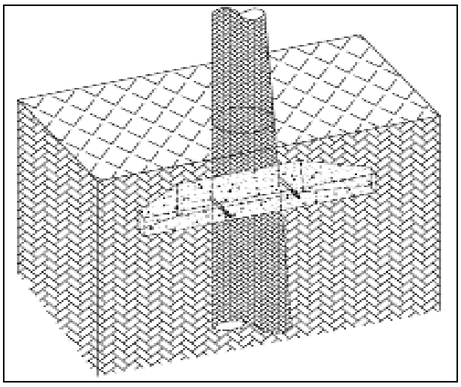

Figure.14: Retrofit of distribution pole embedment

CONCLUSIONS

In this paper, the main activities to reduce seismic risk and increase safety level in Electric Power Distribution Network (EPDN) in IRAN has have been briefly presented. Two guidelines about seismic assessment and retrofit and emergency management of EPDN were developed by collaboration of TAVANIR and NRI. The seismic assessment and retrofit guideline was implemented in a pilot region as a case study and their results have been presented here. It has been concluded that the most components of considered EPDN are seismically vulnerable and methods for rehabilitation and retrofit them, have been proposed. By rehabilitation and abandon vulnerable equipments, methods of fabrication or installation, it leads to fewer loss and more reliable networks during next seismic strikes.

Acknowledgments

The authors would like to thank the TAVANIR co. of the Islamic Republic of Iran for financing this research project.

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