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Original Research Article

Structural performance of concrete poles used in electric power distribution network

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ABSTRACT

This paper presents an experimental study on structural performance of concrete poles used in electric power distribution network (EPDN). Three full scale 12-m concrete poles were tested; and a numerical study on a 7-span distribution line was also carried out in order to investigate lateral behavior of the network under severe weather conditions, as it is believed EPDN has a vital role on sustainability of power transmission from the power planet to the consumers which might be hundreds kilometers far away. One of the main issues in EPDN is concrete poles' collapse under simultaneous wind and ice loads in some unreachable snow covered areas. However, the results show that the prescribed loading regimes by standards do not induce any damage into the distribution network nevertheless some unforeseen loads like gust wind load in heavy weather conditions cause the poles' failure. Therefore, a non-linear pushover analysis was carried out to find out the weakest part of the distribution network; and finally some suggestions for increasing the EPDN's sustainability are made.

1. Introduction

The electric power distribution networks are like man's circulatory system. The transmission networks may be compared with arteries in the human body and distribution network with capillaries. They play the same role of supplying the consumer in the cities with the life giving blood of civilization electricity. A power distribution line consists of poles, cross arms, and insulators (Fig. 1). One of the fundamental issues in electric power distribution network which usually happens in severe weather condition areas is concrete poles' collapse under simultaneous wind and ice loads (Fig. 2). This leads to power outage which may cause catastrophic human and financial losses. Therefore the purpose of this study is to study the structural behavior of the concrete poles under the standards' prescribed loadings over their whole life cycle time.

Yang et al. [1] carried out a dynamic analysis on a distribution network under different load cases. They established a finite element model of three span conductors employing software ANSYS [2]. They reported that increase of ice thickness will decrease the dynamic impact factors; also, the impact factors of conductors with accreted ice are less than those of conductors without accreted ice, considerably. Khanverdi et al. [3] investigated the structural performance of high voltage distribution network's concrete poles under wind, snow and earthquake loads. They concluded that earthquake loads have crucial impacts on the network; and the poles should be redesigned and strengthened in order to come up with the applied loads.

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Although reinforced concrete poles are widely being used in power distribution networks, there are very few studies on the structural performance of this system. Thus, the aim of the current research is to evaluate the structural performance of the currently in-use H section reinforced concrete poles; and providing some suggestions in order to enhance their performance in order to prevent undesirable collapse in heavy weather conditions.

It is necessary to mention that the EPDN is designed mainly based on both electrical and mechanical criteria including ground characteristics, and loading parameters. Hence, in this study, a distribution network located in Semirom (a heavy weather region in Iran) is considered. The loading in heavy weather conditions is shown in Table 1. Based on some available technical reports, 12-m concrete poles–type 400 kgf, are assumed to be used in EPDN. It should be mentioned that the nominal resistance of the pole is 400 kgf which means the pole is able to carry 400 kgf force which is applied at 60 cm from the top of the pole without any crack. In this case, the ultimate strength of the pole is 1200 kgf. The detailed information of the pole is illustrated in Table 2 and Fig. 3.

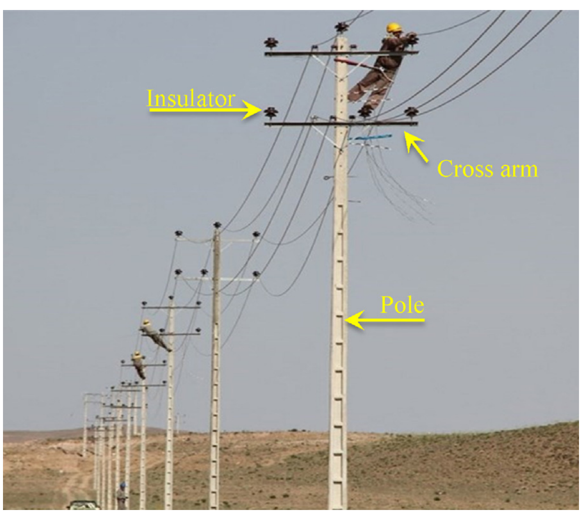


Fig. 1 – Electric power distribution network.

It is worth mentioning the mid span poles are placed on the distribution line in which their strong axes are same as the line longitudinal direction as shown in Fig. 4. In contrast,

Table 1 – Loading in heavy weather conditions [4].

Loading type	Temperatures (°C)	Radial ice thickness (mm)	Wind load (kgf/m^2)
Balanced loading			
Standard			
Moderate wind and ice	20	20	25
Limit state			
Heavy winds	15	–	100
Heavy ice	−5	40	–
Unbalanced loading			
Unbalanced longitudinal Load	−5	40	–
Ice and wind on one side of the span-wind without ice on the other side	−20	0–20	25
Minimum temperature	−30	–	–
Maximum temperature	35	–	–

Table 2 – Specifications of 12-m pole type 400.

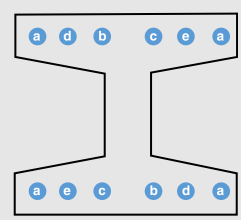
No.	Type	12 m–400 kgf
1	Dimensions of top section (mm)	220 × 190
2	Dimensions of bottom section (mm)	460 × 310
3	F_y (MPa) transverse rebars	300
4	F_y (MPa) longitudinal rebars	400
5	Reinforcement pattern	
6	a	Φ 16 L = 12 m
7	b	Φ 14 L = 9.5 m
8	c	Φ 14 L = 7.5 m
9	d	Φ 14 L = 5.5 m
10	e	Φ 14 L = 4.5 m

Fig. 2 – Collapse of concrete poles under simultaneous sever wind and snow loads.