Electrical Power and Energy Systems 62 (2014) 103–109

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Numerical electromagnetic analysis of a junction tower with cable arrangements

Yi-Hsuan Jiang [a,b], Wu-Chung Su [c], Ming-Yen Wey [a,*,1]

[a] Dept. of Environmental Engineering, National Chung Hsing University, Taiwan, ROC
[b] Dept. of Electrical Engineering, Hsiuping University of Science and Technology, Taiwan, ROC
[c] Dept. of Electrical Engineering, National Chung Hsing University, Taiwan, ROC

ARTICLE INFO

Article history:
Received 1 July 2013
Received in revised form 7 April 2014
Accepted 9 April 2014
Available online 13 May 2014

Keywords:
Junction tower
Cable
Electromagnetic field
Eddy current loss
Finite element method

ABSTRACT

Electric energy is an indispensable resource in daily life, but the safety-related problems associated with it remain a general concern, such as unhealthful electric shocks and magnetic fields. Therefore, many scholars are dedicated to research on electric energy, particularly on overhead lines and underground cables. This paper analyzes a junction tower, the interface between overhead lines and underground cables. The analysis reveals that the optimal arrangement of cables noticeably reduces losses in tower steels and the magnetic field around a junction tower without any new facilities. The results are useful for designing power transmission systems.

Introduction

Underground cables are often used in their power transmission systems of cities. In addition to their excellent electrical properties, underground cables can beautify the landscape of urban areas because they replace the unsightly overhead lines.

Electric power transmitting facilities can install underground cables practically anywhere in cities. Thus, many scholars are attracted to conducting research on this subject. Neher conducted a thermal analysis of direct buried cable systems and conduit cable systems [1]. Hanna et al. investigated the effect of the materials and geometric components of direct underground cable systems [2–4]. Hwang examined the increase in the temperature of underground cables in addition to eddy current losses in steels [5]. Hwang et al. performed a thermal analysis of cables in duct banks [6,7]. Rachek et al. extended the model of Hwang and analyzed multi-circuit three-phase cable systems [8].

Electromagnetic fields have become a subject of public concern [9–12]. Farag et al. created a series of magnetic fields for power cables and suggested several management methods for reducing the field levels [13–16]. The World Health Organization suggested that engineers should explore low-cost ways of reducing exposure to magnetic fields [17], encouraging more scholars to devote research on this topic [18–21].

Given that underground cables must cross rivers, power engineers apply special techniques to deliver power. Conduits for power lines are commonly constructed below bridges. However, this method is obviously inapplicable to places without a bridge. In these situations, engineers usually convert underground cables to overhead lines to cross rivers by junction towers. On the other side of the river, either overhead lines are used or underground cables are connected again. Fig. 1 shows a sketch of a junction tower structure, which includes a set of three-phase overhead lines connected to three-phase underground cables.

In a power transmission system, junction towers are the interface between overhead lines and underground cables. Therefore, junction towers significantly affect a power transmission system. Although junction towers are popular in cities, the magnetic field of junction towers has not been investigated. Thus, in this paper, the magnetic field around a junction tower and the eddy current losses generated in the steels of a junction tower are evaluated by the finite element method [22,23]. The eddy current losses are calculated, and a technique for reducing magnetic fields is discussed. The results are useful for designing cable arrangements in power junction towers.

---

* Corresponding author. Tel.: +886 4 22840441x533; fax: +886 4 22862587.
E-mail address: mywey@dragon.nchu.edu.tw (M.-Y. Wey).

[1] Postal address: Dept. of Environmental Engineering, National Chung Hsing University, Taichung 402, Taiwan, ROC.

http://dx.doi.org/10.1016/j.ijepes.2014.04.029

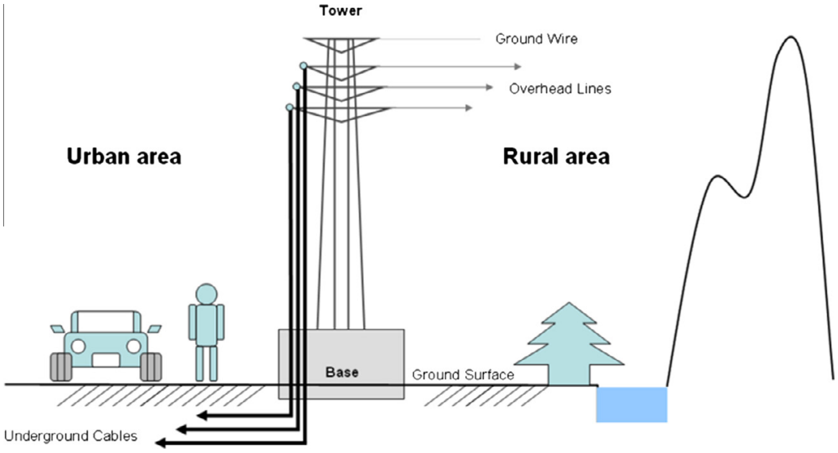

Fig. 1. Sketch of a junction tower structure.

Simulation of junction tower configurations

Model of junction tower configurations

As shown in Fig. 2, L-type structural steels are used in junction towers to provide a high degree of mechanical construction for the cable route. These steels are magnetic and are excellent conductors. Therefore, three-phase cables that run parallel to the steels produce a transverse magnetic field that induces eddy currents and losses inside the steels [5,6,8,24,25]. The junction tower in this study consists of a flat arrangement of six cables [5,6,26] (Table 1) with eight L-type steels (Fig. 3). These cables and steels are arranged almost parallel to each other. Thus, this study resolves the electromagnetic field problem with a two-dimensional model, which can promote computation speed and lower hardware costs. The finite element method is performed with Magsoft Flux 3D.

Cross-linked polyethylene (XLPE) cables are one of the most popular cables in underground power systems. Fig. 4 shows an overhead view of the junction tower, which has six XLPE cables, four large L-type steels, and four small L-type steels on the tower base. The steel resistivity is $9.71 \times 10^{-6}\,\Omega$ m. Furthermore, as shown in Fig. 5, the height of the tower is about 20 m as well as the tower base is 2 m tall with a platform, 3 m × 3 m, on it.

Fig. 2. Junction tower with structural steels.

Table 1
Cable ratings [5,6,26].

Cable size (m^2)	0.001
Insulation	XLPE
Rated voltage (kV)	161
Operating current (A)	650

Fig. 3. Lateral view of a junction tower.

Electromagnetic field equations

This study examines a steel tower with cables and steels in nearly parallel arrangement, which makes the problem to a two-dimensional one. Therefore, the analyses in this paper are based on the following assumptions:

- The load currents are sinusoidal and balanced.
- Only the *z*-directional component of the magnetic vector potential can be observed; this component is sinusoidal.