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Transmission-expansion planning based on a non-linear programming algorithm

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Abstract

In this formulation, the objective function and operating constraints include the corona power-loss term. The objective function consists of three terms: cost of investment of new transmission lines, ohmic power loss of new and existing lines, and corona-power loss of new lines. This combination of terms results in a non-linear objective function. The non-linear programming or the non-convex optimization technique is used to solve such large-scale practical problem. The new formulation has been applied to the 28-bus Jordanian high-voltage transmission network in order to test and justify its applicability.

Keywords: Corona power loss; Expansion; Non-linear programming; Planning; Transmission lines

1. Introduction

Transmission-expansion planning (TEP) is a mathematical optimization challenge. The complication arises from the large number of variables involved in the expansion process.

To the authors' knowledge, all TEP approaches reported in the literature formulated their objective functions and the corresponding constraints to account for the cost of investment and/or the cost of ohmic-power loss. The linear programming (LP) technique has been adopted by many investigators [1–3]. In this case, the objective function is linear, i.e., the ohmic-power loss is neglected and the constraints are also linear. Other investigators adopted the integer (IP) or mixed integer

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Nomenclature

AD	total number of lines added to the expanded network
b	barometric pressure (76 cm Hg)
bs	kW base
C_i	path use cost of the ith overloaded route
C_{kwh}	cost of one kWh (Dollar / kWh)
E_{d}	effective value of disruptive field in air, 21.1 kV/cm (rms)
f	frequency of the applied voltage (Hz)
k	loss coefficient, $k = 8760 \times \text{NYE} \times C_{\text{kwh}}$
l_i	length of the ith added line in km
NB	number of existing and new isolated buses
NC	number of connected buses
NL	number of the existing lines
NYE	estimated life-time of the expansion network (years)
OL	number of the overloaded lines
P_i	net real power injection at the ith bus
r_i	conductor radius of the ith added line (cm)
R_i	resistance of the ith line
S_i	phase spacing of the ith added-line (cm)
T	temperature in degrees Centigrade (35 °C)
V	applied voltage to neutral (kV, rms)
V_{di}	critical disruptive voltage to neutral (kV, rms)
x_i	primitive reactance of the ith line
X_i	flow on the ith line (KW)
Greeks	
$\alpha 1$, $\alpha 2$	lower and upper bounds on conductor radius (r) of each added line, respectively
β_i	upper thermal limit of the flow on the ith existing line
δ	relative air-density factor
$\rho 1$, $\rho 2$	lower and upper bounds on phase spacing (S) of each added line, respectively

programming technique [4,5]. Their work neglected the ohmic-power loss. In both cases, the objective function is linear, while some or all of the decision values are given integer numbers. The quadratic programming (QP) technique has been utilized in Refs. [6–8], where the exact ohmic-power loss is considered in the expansion process. Zero-one implicit enumeration programming is another mathematical programming approach that has received the attention of investigators [9]. The objective function is linear and the constraint of adding an integer number of lines is converted zeros and ones. Non-linear programming (NLP) is one of the old mathematical programming tools used for solving the TEP problem. An approach for