AIN SHAMS UNIVERSITY
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Optimal Planning for Distributed Generation In Distribution Networks

Thesis

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STATEMENT

This dissertation is submitted to Ain Shams University in partial fulfillment of the degree of Master of Science in Electrical Engineering (Electrical Power and Machines).

The included work in this thesis has been carried out by the author at the Electrical Power and Machines Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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Optimal Planning for Distributed Generation
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Abstract

As a result of the restructuring of electricity markets, increasing amounts of distributed generation (DG) are connected to distribution networks to face load growth and distribution capacity bottlenecks. DG is expected to play an important role in the electric power system infrastructure and market.

The typical way to meet the demand is to build additional central power generation where the transmission and distribution (T&D) infrastructure, in such a case, represents significant cost in both fixed and running domains. A DG unit does not have T&D burden because it is already at the site of electrical use. DG can provide better service at lower cost in many applications by avoiding the extra cost and lower reliability imposed by transmission and distribution. The problem however, with DG is to reach the optimal sizing and siting of the units.

In this thesis an optimization model has been used to obtain the optimal sizing and siting of DG units. The model has been used to estimate the optimum penetration of the distributed generation in distribution networks. Environmental impact, CO_2 emission, has been considered as a constraint in the optimization problem.

Two realistic case studies have been analyzed to verify the validity of the adopted approach.

Key words: Distributed generation DG, optimal placement, benefits of distributed generation, cost analysis, Losses reduction based optimization and sizing & siting of DG units.

Table of Contents

List of Figures

List of Tables

List of Symbols & Abbreviations

DG	Distributed Generation
CHP	Combined heat and power systems
PV	Photo voltaic
T&D	Transmission and distribution
$f(x)$	Objective function
$g(x)$	Equality constraints
$h(x)$	Inequality constraints
x	Vector of control and state variables
n	Total number of system buses
c_{gca}	Active power component of distributed generation investments costs
c_{gcr}	Reactive power component of DG investments costs
P_g^{max}	Maximum distributed generation active power
Q_g^{max}	Maximum distributed generation reactive power
a_i	Generator constant LE/hr
b_i	Generator constant LE/MW/hr
c_i	Generator constant LE/MW^2/hr
c_{gr}	Running cost of DG output reactive power (LE/Mvar/hr)
P_g	Active DG generated power in (MW)
Q_g	Reactive DG generated power in (Mvar)
c_{sa}	Market price for active power (LE/MWh/hr)

c_{sr}	Market price for reactive power (LE/Mvar/hr)
P_s	System active power in (MW)
Q_s	System reactive power in (Mvar)
P_{loss}	active and reactive power losses in (MW)
Q_{loss}	reactive power losses in (Mvar)
P_D	Active power demand
Q_D	Reactive power demand
P_s^{max}	Max distribution substation capacity
P_{ij}	Power flow from bus i to bus j in (MW)
P_{ij}^{max}	Thermal capacity of distribution lines and cables (MW)
ΔV	Voltage drop
pf	Power factor
BCR	Benefit-cost-Ratio
GHG	Green House Gases
CO_2	Carbon Dioxide
CH_4	Methane
N_2O	Nitrous Oxide
SF_6	Sulfur hexafluoride
K_1	CO_2 emission factor for the central stations
K_2	Gas turbine CO_2 emission rate
P_{sb}	System power for base case

Chapter 1

Introduction

1.1. General

Normally, electrical power systems are designed following a typical arrangement that adopts the concept of a large central power generation plants. The central power plants produce all the power which is needed to feed the connected loads through a transmission network. Transmission network is used to transport the generated power from the generation point to the delivery points of the customers, sometimes over considerable distance, which leads to high technical system losses. In some cases, it will be difficult to supply customers within the required voltage levels.

Recently, a new concept has considered an alternative solution for electric power generation. Small generating units are connected directly to serve a part of the connected loads. This concept is known as distributed generation DG.

DG is expected to play an important role in the electric power system infrastructure. DG reduces (i) capital investments, by reducing the need