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Market based transmission expansion and reactive power planning with consideration of wind and load uncertainties

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ABSTRACT

In this paper, a new methodology for Transmission Expansion Planning (TEP) in deregulated electricity market is presented. The proposed TEP is associated with Reactive Power Planning (RPP), reliability assessment and also consideration of wind and load uncertainties. The proposed planning aims at investment cost minimization, social welfare maximization and satisfying reliability constraint at the same time with taking into account wind and load uncertainties. Expected Energy Not Supplied (EENS) is used as an index for reliability evaluation. At first, Monte-Carlo simulation is used to obtain the Probability Density Function (PDF) of Wind Turbine Generator (WTG) output. Then, the WTG and load uncertainties are considered in TEP formulation. Particle Swarm Optimization (PSO) method is considered to solve the proposed planning problem which is a constrained nonlinear mixed integer optimization programming. Simulation results on two standard test systems (Garver and RTS systems) verify the effectiveness of the proposed planning for consideration of wind and load uncertainties in TEP problem under electricity market environment. Also, the proposed method leads to reduction of the total investment cost, the reliability improvement and the social welfare maximization.

Contents

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Nomenclature

Symbols and Indexes

b_{ij}^{sh} shunt susceptance of line or transformer ij (if ij is a transformer $b_{ij}^{sh}=0$) (p.u.)
b_{i}^{sh} shunt susceptance at bus i (p.u.)
c_{0k} and c_{1k} installation costs and unit costs for a VAr-plant at bus k ($)
c_1 and c_2 learning factors
$f_1(q,u)$ cost function of locally reactive sources ($)
$f_2(P_S, P_L,\Pi_L,\Pi_S)$ cost function of social benefit ($/h)
$g_{best}(t)$ global best value
g_{ij} and b_{ij} conductance and susceptance of the transmission line or transformer ij (p.u.)
i, j bus indices
N_B set of all buses
n_j number of new added transmission lines to branch j
n^{max} maximum number of new added lines to each branch
N_s number of scenarios
n_t project life-time
$P_{best}(t)$ i^{th} particle best solution
$p_{id}(t)$ position of the d^{th} dimension of the ith particle in tth iteration
P_G^{max} and Q_G^{max} maximum limit of real and reactive power generation limits (p.u.)
P_G^{min} and Q_G^{max} minimum limit of real and reactive power generation limits (p.u.)
q total amount of locally reactive sources (MVAr)
q_k amount of locally reactive source in bus k (MVAr)
q^{max} and q^{min} maximum and minimum amounts of reactive sources (p.u.)
r_t discount rate
S^{from} and S^{to} apparent power flow through the branches in both terminals (p.u.)
S^{max} apparent power flow limits (MVA)
v_0 total investment due to the addition of new circuits ($)
v_1 total investment of locally reactive sources ($)
v_2 total cost of social welfare ($/h)
v_{annual} annual cost of the proposed planning problem ($/year)
$v_{id}(t)$ velocity of the dth dimension of the ith particle in tth iteration
V^{max} and V^{min} maximum and minimum voltage magnitudes (p.u.)
v_{total} total cost of the proposed planning problem ($)
w inertia factor
Ω_1 set of all load buses
$k\in\Omega_1$ kth load bus

Vectors and matrixes

c lines cost vector ($)
n added lines vector
N matrices containing the new lines
N_0 matrices containing the existing lines
P_D and Q_D real and reactive power demand vectors (MW and MVAr)
P_G and Q_G real and reactive power generation vectors (MW and MVAr)
P_{Si} and P_{Li} vectors of supply and demand powers in bus i (MWh)
u binary vector that indicates whether or not to install reactive power sources
u_k binary vector that indicates whether or not to install reactive power sources at bus k
V and Θ magnitude and angle of voltages vectors (p.u. and radian)
Π_{Si} and Π_{Li} vectors of supply and demand bids in bus i ($/MWh)

Abbreviations

DG distributed generation
EENS expected energy not supplied
EENS^{max} maximum amount of expected energy not supplied
FOR forced outage ratio
GA genetic algorithms
ISO independent system operator
LMP local marginal prices
LOLE loss of load expectation
LOLE^{max} maximum amount of loss of load expectation
MCS Monte-Carlo simulation
MTTR minimum time to repair
OPF optimal power flow
PDF probability distribution function
PSO particle swarm optimization
RPP reactive power planning
RTS reliability test system
TEP transmission expansion planning
WTG wind turbine generator

1. Introduction

TEP problem aims at expanding the power system transmission network to serve the growing demand in the future. The TEP problem denotes where and when, new lines should be installed in the network to support the customers demand. The TEP problem in regulated power systems intends to minimize the investment cost, but in the deregulated electricity markets, the TEP plans to provide a competitive environment for all participants.

TEP problem is a nonlinear mixed integer constrained programming. The commonly used models for TEP problem modeling are DC [1] and AC models [2,3]. Also, many different methods have been applied to solve the TEP problem. These approaches are divided into mathematical and Meta-heuristic approaches. The mathematical methods such as Linear programming [4], nonlinear programming [5], mixed integer programming [6] and Bender's decomposition [7] have been carried out for solving the TEP problem. Also, some heuristic optimization methods such as PSO [8], Tabu Search [9], Harmony Search [10], Genetic Algorithms [11], Decimal Coded Genetic Algorithms [12], Genetic Algorithms-based quadratic programming [13], Chaotic [14], Ant Colony [15] and Differential Evolution [16] have been successfully used for solving the TEP problem.

From another view, in TEP problem, many different parameters have been considered as objective function. The minimization of the investment cost is a conventional objective function for TEP problem [2]. Transmission surplus capacity as an objective function for TEP problem has been investigated in [14]. The maximization of the transmission reliability and the minimization of the investment cost are considered as objective functions for TEP problem in [15]. Combination of TEP problem with RPP is presented in [17]. This paper has shown the TEP problem associated with RPP results in fewer new transmission lines to be installed in comparison with the conventional TEP method.