A Multi-Objective Distribution System Expansion Planning Incorporating Customer Choices on Reliability

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***Abstract*—This paper proposes a new multi-objective framework for primary distribution system planning (DSP). Further consideration is devoted to early DSP formulations in order to assess the risk imposed by probabilistic customer choices on reliability (CCOR). The CCOR is a buy/sell strategy that permits customers to pay the electricity price equiponderant to the reliability level provided by the distribution utility over the contract period. A Monte Carlo-based simulation is carried out to examine the effects of the probability of a customer's interest in adopting the CCOR on profit-at-risk. Furthermore, the DSP was conducted to simultaneously minimize both total planning cost and profit-at-risk. The resultant optimization problem is solved through the non-dominated sorting genetic algorithm (NSGA-II) accompanied by a fuzzy decision making method to select the best result among the obtained Pareto optimal set of solutions. The developed method is applied to an actual large-scale distribution system with about 140 000 customers, followed by a discussion on results.**

***Index Terms*—Customer choices on reliability (CCOR), distribution system planning (DSP), Monte Carlo simulation, non-dominated sorting genetic algorithm (NSGA-II), power system reliability, profit-at-risk.**

NOTATION

The notation used throughout this paper is reproduced below for quick reference.

Sets:

Ω^l	Set of load points (electrical domains).
Ω^n	Set of network nodes.
Ω^s	Set of existing and candidate substations.
Ω^b	Set of existing and candidate branches.
Ω^c	Set of conductor types.
Ω_{ss}	Set of selected substations (existing and proposed).
Ω_{sb}	Set of selected branches (existing and proposed).
Ω_{sc}	Set of selected cross-connections.
Ω_i^n	Set of nodes that can connect directly to node i.
$\Omega_{s,i}^{tr}$	Set of allowed standard-size transformers in substation i.
$\Omega_{l,i}^b$	Set of branches in which the fault leads to supply interruption at load point i.
$\Omega_{l,i}^s$	Set of substations in which the fault leads to supply interruption at load point i.

Constants:

C_h^l	Per unit cost of energy loss at year h ($/kWh).
C^{sw}	Total cost of installing a switch ($).
C_h^{se}, C_h^{SI}	Electricity selling price/cost of supply interruption at year h at a load point uninterested in CCOR.
n_y	Number of years in planning period (year).
PW	Present worth factor.
Ifr, Itr	Inflation/interest rate.
$\underline{\psi}, \overline{\psi}$	Minimum/maximum permissible loading percentage of substations.
α	Number of hours in a year (8760).
γ	Loss factor.
κ	Load factor.
d_{ij}	Distance between nodes i and j (km).
λ_{ij}	Failure rate in branch $i-j$ (fail/km/year).
τ_{ij}	Average repair time in branch $i-j$ (h).
$P_{ih}^D, Q_{ih}^D, S_{ih}^D$	Expected active/reactive/total load demand at node i at year h (MW/MVAr/MVA).
$\Delta V_{\max}$	Maximum allowed voltage drop.
V_0	Nominal voltage magnitude (V).

Functions:

Γ_{DSP}	Profit of the DSP within the planning horizon ($).
P_{ijh}^{loss}	Copper losses of feeder located between nodes i and j at year h (kW).
C_{DSP}^{inv}	Total DSP cost ($).
C_{DEP}	Total DSP cost while $\xi_i = 0$ for all customers ($).
C_{ih}^{sell}	Electricity selling price at load point i at year h.

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