Microgrid Planning Under Uncertainty

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Abstract—This paper presents a model for the microgrid planning problem with uncertain physical and financial information. The microgrid planning problem investigates the economic viability of microgrid deployment and determines the optimal generation mix of distributed energy resources (DERs) for installation. Net metering is considered for exchanging power with the main grid and lowering the cost of unserved energy and DER investments. A robust optimization approach is adopted for considering forecast errors in load, variable renewable generation, and market prices. The microgrid islanding is further treated as a source of uncertainty. The microgrid planning problem is decomposed into an investment master problem and an operation subproblem. The optimal planning decisions determined in the master problem are employed in the subproblem to examine the optimality of the master solution by calculating the worst-case optimal operation under uncertain conditions. Optimality cuts sent to the master problem will govern subsequent iterations. Numerical simulations exhibit the effectiveness of the proposed model and further analyze the sensitivity of microgrid planning results on variety levels of uncertainty.

Index Terms—Distributed energy resource, microgrid planning, real-time market price, robust optimization, uncertainty.

NOMENCLATURE

Indices

b	Index for hour.
ch	Superscript for energy storage charging mode.
dch	Superscript for energy storage discharging mode.
g	Superscript for uncertain renewable generation.
h	Index for day.
i	Index for DERs.
l	Superscript for uncertain load.
p	Superscript for uncertain market price.
t	Index for year.

$\wedge$	Index for calculated/given variables.
$\sim$	Index for forecasted parameters.

Sets

D	Set of dual variables.
G	Set of dispatchable units.
P	Set of primal variables.
S	Set of energy storage systems.
U	Set of uncertain parameters.
W	Set of nondispatchable units.

Parameters

c	Generation price for dispatchable units.
CC	Annualized investment cost of generating units.
CE	Annualized investment cost of storage—energy.
CP	Annualized investment cost of storage—power.
$C^{\max}$	Rated capacity of energy storage systems.
d	Discount rate.
D	Load demand.
K	Large positive constant.
$P^{\max}$	Rated power of DERs.
$P_M^{\max}$	Flow limit between microgrid and the main grid.
κ	Coefficient of present-worth value.
ρ	Market price
υ	Value of lost load (VOLL).
η	Energy storage efficiency.
Γ	Limit on uncertainty option.

Variables

LS	Load curtailment.
P	DER output power.
P_M	Main grid power.
Q	Total operation cost.
u	Auxiliary binary variables for uncertain parameters.