Effects of demand response program and energy storage system on optimal stochastic short-term generation scheduling of grid-connected microgrid

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Abstract—**In this paper, effects of demand response program (DRP) and energy storage system (ESS) on optimal stochastic short-term generation scheduling of grid-connected microgrid (MG) have been investigated considering uncertainties. The options of purchasing power include micro-turbines (MTs) as local dispatchable units, and renewable energy sources (RESs) (photovoltaic (PV) systems and wind-turbines (WT)) and charge/discharge of ESS as well as upstream grid (UG). In optimal operation of microgrid (MG), ESS and DRP have been used to reduce the expected operation cost. Meanwhile, the proposed stochastic model considers the uncertainty models of upstream grid price, load and RES output powers by allocating proper amount of spinning reserve and by using a scenario stochastic model instead of classical deterministic model. Finally, in optimal operation of MG, the effects of ESS and DRP have been investigated. To show the capability of presented stochastic framework, four case studies have been studied and the results are compared with each other.**

Keywords- Demand response program (DRP; energy and reserve markets; microgrid (MG); photovoltaic (PV); stochastic short-term generation scheduling; wind-turbine (WT).

Nomenclature:

Indices:

h	Index of blocks for piecewise linear modeling of cost function of micro-turbine
i	Minimum ON-time and OFF-time constraints modeling index running from 1 to max {MDT_j and MUT_j}.
j	Micro-turbine index
s	Scenario index
t	Time period index

Parameters:

DRmax	Maximum amount of load that can participate in DRP
$G^{a}_{t,s}$	Irradiation of sun at time *t* in scenario *s*
G_{a_0}	Standard condition irradiation (W/m^2)
Incmax	Maximum amount of load that can increase at each time
$load^{0}_{t,s}$	Based load without considering DRP at time *t* in scenario *s*
MUT_j, MDT_j	Minimum up/down time of micro-turbine *j* [h]
N_h	Total generation blocks of micro-turbines
N_{MT}	Total number of micro-turbines
N_s	Total number of scenarios
$NOCT$	Normal operating cell temperature of photovoltaic system
P_s	Probability of scenario *s*
$P^{MAX}_{j,h}$	Maximum amount of generation block h of j^{th} unit of micro-turbine [MWh]
p_r	Nominal power of wind-turbine [MW]
$P^{wind}_{t,s}$	Available power from wind-turbine at time *t* in scenario *s*
$P^{PV}_{t,s}$	Available power from photovoltaic system at time *t* in scenario *s*
$P^{\max}_{charge}$, $P^{\max}_{disc}$	Maximum charging/discharging power of battery storage at time *t* in scenario *s*
$P^{M}_{Max,0}$	Rated power at the standard condition in photovoltaic system
P^{max}_{grid}	Maximum power capacity of connected line between MG and upstream grid (MW)
R^{up}_j, R^{down}_j	Maximum ramp up/down rating power constraints of micro-turbine *j* [MW/h]
$S^{MT}_{j,h}$	Related operation cost of generation block h of j^{th} unit of micro-turbine [$/MWh]
T	Time periods [hour]
$T^{a}_{t,s}$	Environment temperature at time *t* in scenario *s* [^{0}C]
$T_{M,0}$	Module temperature in photovoltaic system at the standard condition [^{0}C]