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Optimal Operation of Combined Wind Power Generation and Pumped-Storage Units in the Electricity Markets

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Abstract – *At present, wind power is the fastest growing kind of renewable energy in the world. Since wind has no production costs, all the productions are taken through the system. However, one of the major features of wind power is that the capacity of wind power changes according to the wind speed and consequently, wind forecasting is accompanied with uncertainty even in the short-term. In order to eliminate this shortcoming, in this paper the combination of pumped-storage units and wind farm are suggested. By this combination, pumped-storage unit can rectify uncertainty in wind power forecasting. In the present study, optimized operation of system power, along with the combination of pumped-storage and wind units are considered with the aim of minimizing the expected social cost in a short-term. Also, the uncertainty of the demand forecasting is discussed, too. The present model in this paper is scheduled on a three-bus system. Moreover, numerical results obtained from the operation of three cases (i.e., Base case and Base case with wind power unit and Base case with pump-wind coordination) have been demonstrated.*
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Keywords: *Electricity Markets, Energy Storage, Stochastic Security, Uncertainty, Wind Power*

Nomenclature

Indices

i	Index of thermal units running from 1 to I
m	Index of buses running from 1 to M
t	Index of scheduling periods running from 1 to T
s	Index of scenarios running from 1 to S

Variables

r_{it}^{up}	Spinning reserve up of unit i in period t [MW]
r_{it}^{dn}	Spinning reserve down of unit i in period t [MW]
r_{mt}^{up}	Spinning reserve up of load at bus m in period t [MW]
r_{mt}^{dn}	Spinning reserve down of load at bus m in period t [MW]
P_{sit}	Power generation of unit i in period t and scenario s [MW]
P_{it}	Power generation of unit i in period t and error-free scenario [MW]
P_{wst}	Power output of the wind farm in period t and scenario s [MW]
P_{pPst}	Power generation of the pumped-storage plant in the pumping mode in period t and scenario s [MW]
P_{gPst}	Power generation of the pumped-storage plant in the generation mode in period t and scenario s [MW]
PC_{st}	Power generation of wind-storage coordination in period t and scenario s [MW]
L_{smt}^{shed}	Involuntarily shed load at bus m in period t and scenario s [MW]
SP_{st}	Wind power generation spillage in period t and scenario s [MW]
L_{smt}	Power consumed by load at bus m in period t and scenario s [MW]
V_{st}^{up}	Energy stored in the upper reservoir in period t and scenario s [MWh]
V_{st}^{dn}	Energy stored in the lower reservoir in period t and scenario s [MWh]
n_{st}	The number of units that are running in the pumping mode in period t and scenario s $\{0, 1, \dots, N\}$
y_{st}	The number of units that are start-up in the pumping mode in period t and scenario s $\{0, 1, \dots, N\}$
z_{st}	The number of units that are shut-down in the pumping mode in period t and scenario s $\{0, 1, \dots, N\}$
u_{it}	Binary variable is equal to 1 if generator i is online in period t
K_{it}	Binary variable is equal to 1 if generator i is start-up in period t
m_{st}	Binary variable is equal to 1 if pumped-storage plant is in the generating mode in period t and scenario s

Parameters and constants

P_{wt}	Hourly wind generation forecast in period t [MW]

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