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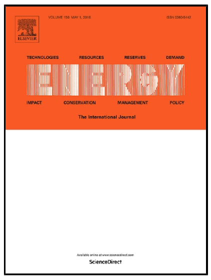

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Stochastic Day-ahead Scheduling of Multiple Energy Carrier Microgrids with Demand Response

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Abstract: Microgrids are indispensable components of active energy systems that supply diverse electrical and thermal demands. A microgrid is composed of distributed energy resources (DER) including renewable resources, combined heat and power generation (CHP) and conventional generation resources that rely on fossil fuels. Energy hubs in microgrids facilitate the conversion of different types of energy resources. The coupling among natural gas and electricity distribution networks introduces new challenges to the short-term operation planning of microgrids. In this paper, a two-stage stochastic optimization problem is formulated for the short-term operation planning of microgrids with multiple-energy carrier networks to determine the scheduled energy and reserve capacity. The problem is formulated as a mixed integer linear programming problem in which the objective function is to minimize the expected operation cost in the short-term operation horizon. The uncertainties in the renewable generation including the wind and solar photovoltaic generation, and electrical and thermal demands are captured by introducing scenarios with respective probabilities. The proposed solution framework ensures the reliability and security of energy supply in multiple scenarios. The advantage of capturing the interdependence among the electricity and natural gas systems to promote energy efficiency is presented. Furthermore, the effectiveness of demand response programs to reduce the operation costs and improve the security measures is investigated. The sensitivity of the operation costs to the variation of natural gas flow and congestion in pipelines and energy prices is addressed to highlight the interdependence among natural gas and electricity infrastructure systems.

Keywords: Energy Hub, Microgrid, Multiple-Energy Carrier, Stochastic Programming.

Nomenclature

	Subscripts and Superscripts
t	Time periods, t= 1, 2, …, T
i,j	Energy carriers nodes, i= 1, 2, …, I
n	CHPs, n= 1, 2, …, N
bo	Boilers, bo= 1, 2, …, BO
m	Diesel generators, m= 1, 2, …, M
hs	Heat storages, hs= 1, 2, …, HS
b	Batteries, b= 1, 2, …, B
d	Responsive loads, d= 1, 2, …, D
s	Scenarios, s= 1, 2, …, NS
wt	Wind turbines wt=1, 2, …, WT
pv	Photovoltaic systems pv=1, 2, …, PV
g	Natural Gas
e	Electricity
h	Heat
st	Steps of offered capacity by responsive loads
ch	Charge/Store energy
dis	Discharge/Withdraw energy
U	Up-spinning reserve
D	Down-spinning reserve
max/min	Upper/lower limits
	Variables and parameters
S	Apparent power [kVA]
P	Power of energy carriers [kW]
Q	Reactive Power [kVar]
ES	Stored energy in heat storages [kWh]
SOC	State of charge in batteries [kWh]
V	Magnitude of voltage [p.u.]
δ	Voltage angel [rad]
Pr	The pressure of natural gas in pipelines [$Psig$]
q	Offered capacity by responsive load [kW]
SUC	Start-up cost [$]
R	Scheduled reserve [kW]
EDR	Scheduled electrical demand response reserve [kWh]
TDR	Scheduled thermal demand response reserve [kWh]
r	Deployed reserve [kW]
edr	Deployed electrical demand response reserve [kW]
tdr	Deployed thermal demand response reserve [kW]
$EENS$	Electrical energy not supplied [kW]
$TENS$	Thermal energy not supplied [kW]
u	Indicates on/off (charge/discharge) status (1/0)
EL	Electric load [kW]
TL	Thermal load [kW]
η	Efficiency of components
K	Start-up cost constant [$]
G_{ij}	The real part of Y_{ij}, element in microgrid admittance matrix [p.u.]
B_{ij}	The imaginary part of Y_{ij}, element in microgrid admittance matrix [p.u.]
π	Prices [$]
$VoLL_e$	Value of loss of electrical load [$/kWh]
$VoLL_h$	Value of loss of thermal load [$/kWh]
ρ_s	The probability of scenario s