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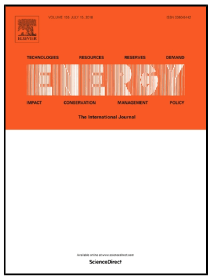

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Co-optimization Scheduling of Interdependent Power and Gas Systems with Electricity and Gas Uncertainties

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Abstract

The rapid growth of natural gas fuel consumption by gas-fired generators and the new emerging power-to-gas technology have intensified interdependency of electric power and natural gas systems. Consequently, such interdependency, together with heterogeneous uncertainties of the power system (e.g., power loads and renewable energy) and the gas system (e.g., gas loads), has brought new challenges to energy system operators for the secure and economic operation of interdependent power and gas systems. Specifically, uncertainties from one infrastructure could easily spread to the other, which consequently increase vulnerability and eventually lead to cascading outages of both systems. This paper proposes a two-stage adjustable robust model to study day-ahead coordinated optimal scheduling of the interdependent power and gas systems. Dual-fuel generating units are also considered for shaving gas fuel consumptions and ensuring the security of both systems during peak gas demand hours. Moreover, Weymouth gas flow constraints are linearized via Taylor series expansion, which facilitates the implementation of column-and-constraint generation algorithm to effectively solve the proposed two-stage adjustable robust model with nonlinear gas flow constraints in the second stage. Numerical case studies illustrate that dual-fuel units can enhance the secure and economical operation of interdependent power and gas systems, especially when natural gas demands present upward uncertainties. It is also demonstrated that power-to-gas facilities can facilitate a deeper penetration of volatile renewable energy by effectively converting excessive renewable generation into natural gas.

Keywords: Inderdependency; day-ahead scheduling; power-to-gas; dual-fuel; secure and economical operation; robust optimization

Nomenclature

A. Acronyms:

CCG	Column-and-constraint generation.
DC	Direct current.
HHV	Higher heating value.
IPGS	Interdependent power and gas systems.
LP	Linear programing.
MILP	Mixed-integer linear programing.
PtG	Power-to-gas.
UC	Unit commitment.

B. Indices:

a, j, g, s	Indices of PtG facilities, natural gas wells, gas loads, and gas storage facilities.
e, m	Indices of power buses and natural gas nodes.
l, p	Indices of transmission lines and gas pipelines.
t, i, h, d, w	Indices of hours, generating units, curve segments, power loads, and wind farms.

C. Sets and Functions:

$\boldsymbol{GU},\boldsymbol{DF},\boldsymbol{TU}$	Set of gas-fired/dual-fuel/traditional units.
$N(e)$, $G(m)$	Set of components connected to power bus e /gas node m.
$s(l)$, $r(l)$	Set of sending/receiving buses of line l.
Ω_P, Ω_C	Set of inactive pipelines/active pipelines with compressors.
$\Omega_D, \Omega_W, \Omega_G$	Uncertainty set of power loads/ wind generations/ gas loads.
$\boldsymbol{L}^{\text{pg}}(\cdot)$	Compact form of IPGS operation constraints.

D. Variables:

E_{pt}^b, E_{st}^b	Base-case storage volume of inactive pipeline p/ storage facility s at time t.
f_{pt}^+, f_{pt}^-	Binary variables indicating gas flow direction of inactive pipeline p at time t.
$F_{it}^{b,\text{gas}}, F_{it}^{b,\text{fuel}}$	Base-case gas/ traditional fuel consumption of unit i at time t.
G_{jt}^b	Base-case gas production of gas well j at time t.
$G_{pt}^{b,\text{in}}, G_{pt}^{b,\text{out}}$	Base-case inflow/outflow of pipeline p at time t.
G_{it}^b	Base-case gas consumption of unit i at time t.
G_{at}^b	Base-case gas production of PtG facility a at time t.
$G_{st}^{b,\text{in}}, G_{st}^{b,\text{out}}$	Base-case gas inflow/outflow of gas storage facility s at time t.
$\tilde{G}_{pt}^b, \tilde{\pi}_{pt}^b$	Base-case average gas flow/pressure of pipeline p at time t.
I_{it}, I_{at}	Commitment status of unit i /PtG facility a at time t.
I_{it}^{gas}	Binary indicator which is 1 if unit i burns gas at time t, and otherwise 0.