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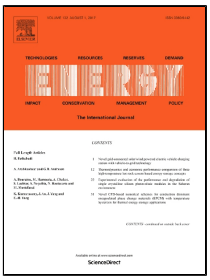

Co-optimized Trading of Wind-Thermal-Pumped Storage System in Energy and Regulation Markets

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Co-optimized Trading of Wind-Thermal-Pumped Storage System in Energy and Regulation Markets

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***Abstract*— Trading of wind energy in day-ahead electricity markets entails significant risks. Wind traders are, therefore, interested in mitigating their trading risks in a number of ways. This work suggests addressing this issue in a comprehensive manner by coordinating the trading of wind resources with thermal resources and a pumped-hydro storage system (PHS) and co-optimizing the trading in energy and regulation markets. The trading strategy is modeled as a mixed integer linear stochastic program that takes into account several uncertain parameters, including wind power outputs, prices for energy, balancing, and regulation, and regulation deployments. In this optimization, the trader's attitude toward risks is controlled by using the metric of conditional value at risk (CVaR). Simulation results show that coordinated and co-optimized trading of the generation resources and PHS significantly improve the total expected profits and mitigates trader's risks.**

***Index Terms*— Pumped-hydro storage system (PHS), wind-thermal generation, coordination, Risk, Regulation market, mixed integer linear program, stochastic programming.**

NOMENCLATURE

The notations used through the paper are stated below:

A. Indices:

t	Bidding period
s	Scenario
g	Thermal unit
n	PHS unit
d	Wind plant
e	Segment

B. Decision variables:

Pt, Pw, Ph	Optimal bid of thermal/wind/PHS unit
P^{ac}	Total actual thermal power output
P^{acm}	Actual thermal power output to the market
P^{acp}	Actual thermal power output to PHS
W^{acm}	Actual wind power output to the market
W^{acp}	Actual wind power output to PHS
H^{ac}	Actual power output from PHS unit
M	Optimal offer from PHS to purchase energy from the market

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