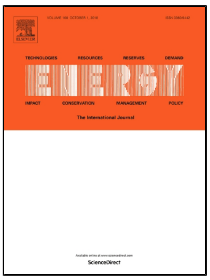
Accepted Manuscript



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PII:	S0360-5442(18)31736-5
DOI:	10.1016/j.energy.2018.08.200
Reference:	EGY 13676
To appear in:	*Energy*
Received Date:	17 March 2018
Accepted Date:	27 August 2018

Please cite this article as: Yan Zhang, Lijun Fu, Wanlu Zhu, Xianqiang Bao, Cang Liu, Robust Model Predictive Control for Optimal Energy Management of Island Microgrids with Uncertainties, *Energy* (2018), doi: 10.1016/j.energy.2018.08.200

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Abstract: As the increasing penetration of wind and PV generations in island microgrids, the intermittent nature of renewable energy resources and randomness of load demands are inevitable, therefore, maintaining system stability and reliability has become a challenging issue for microgrid operators. In addition, energy storage unit and demand side management technology are widely utilized in the island microgrids to alleviate the passive impacts introduced by renewable energy resources. Nevertheless, they produce uncertainties as well. To accommodate the combined uncertainties, a two-stage robust model predictive control based optimization approach is proposed in this paper. The mixed integer quadratic programming model is established in the first operation stage to minimize the operation cost under the joint worst case of uncertainty, then an economic dispatch model is used to minimize the adjustment cost after obtaining actual data in the second operation stage. Robust linearization methods with the consideration of three types of uncertainty scenarios and uncertainty budgets are utilized in the first operation stage. Finally, the case study indicates that the proposed approach is more robust and economical than the conventional two-stage robust optimization approach, then the sensitivity of typical parameters and important units are analyzed and discussed.

Key words: robust model predictive control (RMPC), robust linear optimization, island microgrid, uncertainty, mixed integer programming

Nomenclature

Indices and sets	
$\mathcal{H}$	Set of time slots, $\{1,\cdots t,\cdots,T\}$
Δt	Duration of a single time slot
$\mathcal{A},\mathcal{B}$	Set of CDGs ($a \in \mathcal{A}$), SWDGs ($b \in \mathcal{B}$)
Ω	Set of uncertain parameters, $\{PV,wind,load,water\}$
Parameters	
$c_a^{st},c_a^{sd},c_a^{o\&m}$	Start-up, shut-down, O&M cost coefficients of CDG a
T_a^{on},T_a^{off}	Minimum up and down time of CDG a
$\gamma_{a1},\gamma_{a2},\gamma_{a3}$	Cost coefficients of CDG a
P_a^{min},P_a^{max}	Minimum, maximum stable power output levels of CDG a
R_a^{max}	Ramp up limit of CDG a
$E_{ESS}^{max},E_{ESS}^{min}$	Maximum, minimum energy levels of BESS
$P_{ESSc}^{max},P_{ESSd}^{max}$	Charging, discharging power limits of BESS
η_c,η_d	Charging, discharging efficiencies of BESS
$c_{ESS}^{o\&m}$	Sunk cost of maintaining BESS
ε_{ESS}	'physiological' energy loss of BESS
$\overline{\boldsymbol{P}}_\varphi,\underline{\boldsymbol{P}}_\varphi$	Upper, lower bounds of φ, $\varphi \in \Omega$
$\hat{\boldsymbol{P}}_\varphi,\boldsymbol{P}_\varphi$	Forecast, actual values of φ, $\varphi \in \Omega$
$\beta_{PV}^{max},\beta_{wind}^{max}$	Maximum curtailment of PV, wind power output
$\lambda_{wind},\lambda_{PV}$	Penalty coefficients of wind, PV
Γ_{RES}	Budget of RESs power outputs uncertainty
Γ_{load}	Budget of electricity loads uncertainty
Γ_{water}	Budget of water demand uncertainty
T_b^{on},T_b^{off}	Minimum up and down time of SWDG b
$c_b^{o\&m}$	Sunk cost of maintaining SWDG b
p_b,w_b	Power demand, water production of SWDG b
$W_{water}^{max},W_{water}^{min}$	Maximum, minimum water levels of the tank
Auxiliary variables used for robust linear presentation	
$\boldsymbol{z}_{RES},\boldsymbol{z}_{cost}$	Auxiliary decision variables for power balance and objective
$\boldsymbol{q}_\varphi$	Auxiliary decision variables of φ ($\varphi \in \Omega$) for power balance constraint
$\boldsymbol{q}_{cost}^{PV},\boldsymbol{q}_{cost}^{wind}$	Auxiliary decision variables for RES penalty cost
$\boldsymbol{y}_{wind},\boldsymbol{y}_{PV}$	Auxiliary decision variables in the first stage
$\boldsymbol{y}_{cost}^{PV},\boldsymbol{y}_{cost}^{wind}$	Auxiliary decision variables for RES penalty cost
$\boldsymbol{z}_{load}$	Auxiliary decision variables for power balance constraint
$\boldsymbol{z}_{water}$	Auxiliary decision variables for water balance constraint
Decision variables for the first stage operation	
$\boldsymbol{P}_a^*$	Energy generation schedule of CDG a in the first stage
$\boldsymbol{\delta}_a^{onoff}$	Operation state of CDG a (binary)
$\boldsymbol{\delta}_a^{std},\boldsymbol{\delta}_a^{shd}$	Start-up, shut-down action of CDG a (binary)
$\boldsymbol{E}_{ESS}^*$	Energy level of BESS in the first stage
$\boldsymbol{P}_{ESSc}^*,\boldsymbol{P}_{ESSd}^*$	Charging, discharge power of BESS in the first stage
$\boldsymbol{\delta}_{ESSc}^*$	Charging state of BESS in the first stage
$\boldsymbol{\beta}_{wind}^*,\boldsymbol{\beta}_{PV}^*$	Curtailment of wind, PV power output in the first stage
$\boldsymbol{\delta}_b^{onoff}$	Operation state of SWDG b in the first stage (binary)
W_{water}^*	Water level of the tank in the first stage
Decision variables for the second stage operation	
$P_a^\star$	Energy generation schedule of CDG a in the second stage
$E_{ESS}^\star$	Energy level of BESS in the second stage
$P_{ESSc}^\star,P_{ESSd}^\star$	Charging/Discharging power of BESS in the second stage
$\delta_{ESSc}^\star$	Charging state of BESS in the second stage
$\beta_{wind}^\star$	Curtailment of wind in the second stage