FERC TECHNICAL CONFERENCE: INCREASING REAL-TIME AND DAY-AHEAD MARKET EFFICIENCY AND ENHANCING RESILIENCE THROUGH IMPROVED SOFTWARE (6/23 – 6/25, 2020)

PROBABILISTIC ZONAL RESERVE REQUIREMENTS FOR IMPROVED DELIVERABILITY WITH WIND POWER UNCERTAINTY

PRESENTER: ZHI ZHOU[1]

CO-AUTHORS: BYUNGKWON PARK[2], AUDUN BOTTERUD[1], PRAKASH THIMMAPURAM[1]

[1]ARGONNE NATIONAL LABORATORY

[2]OAK RIDGE NATIONAL LABORATORY

zzhou@anl.gov

OUTLINE

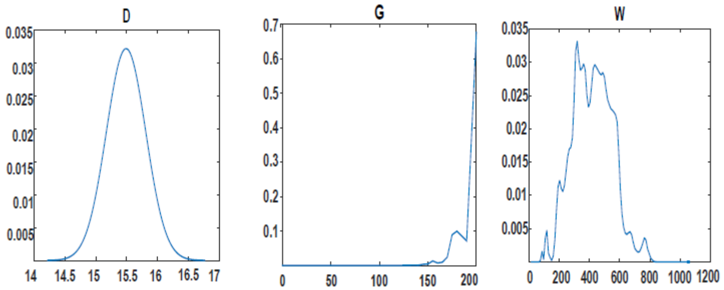
- Introduction
- Probabilistic Zonal Reserve Requirement
- Enhanced Unit Commitment Formulation with Zonal Reserve
- Simulation and Results
- Discussion and Future Work

INTRODUCTION

1. System uncertainty due to renewable energy integration
2. Current reserve requirement settings are mostly deterministic, and can’t adaptive with system reliability condition
3. Stochastic dispatch models are still computationally difficult for large-scale systems.
4. Existing dispatch models usually ignore or simplify reserve deliverability issues caused potentially by network congestion.
5. Improve system flexibility and deliverability by zonal reserve requirement setting and deliverability assurance.

PROBABILISTIC ZONAL RESERVE REQUIREMENT

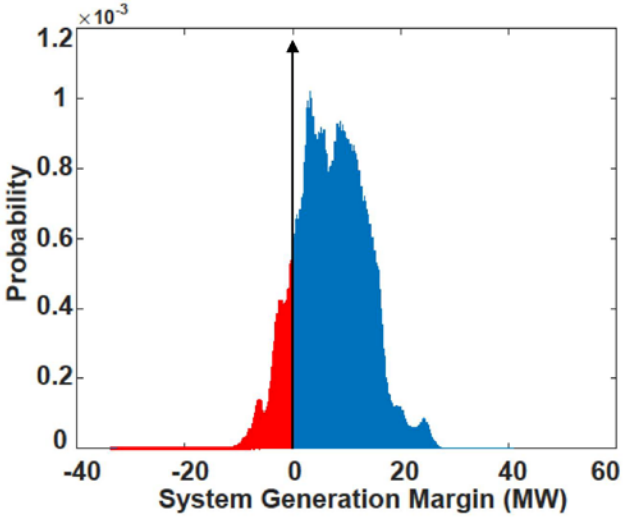
- Uncertainty sources



(a) Load (b) Conventional Unit (c) Wind

- Injection margin

$$
\begin{aligned}
P_M^i(M_i) &= P_M^i(W_i + G_i + (-D_i)) \\
&= \sum_{d=-\infty}^{\infty} \sum_{g=-\infty}^{\infty} P_W^i(W_i = M_i + D_i - G_i) \\
&\cdot P_G^i(G_i) \cdot P_D^i(D_i)
\end{aligned}
$$

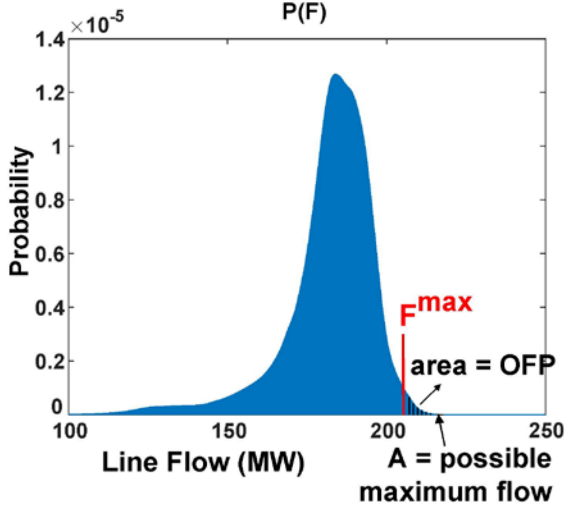


PROBABILISTIC ZONAL RESERVE REQUIREMENT

- Probability distribution of line flow

$$F_l = \sum_i ISF(l,i) \cdot (W_i + G_i - D_i)$$

$$P(F_l) = P(\sum_i ISF(l,i) \cdot M_i)$$



- Zonal generation margin

$$P(ZM_z) = P(\sum_{i \in N_z} M_i + \sum_{l \in L_z} F_l),\ z \in Z$$

$$\approx P(\sum_{i \in N_z} M_i) + \sum_{l \in L_z} mean(P(F_l)),\ z \in Z$$

$$Prob\big(ZM_z + ZN_z^{\text{up}} < 0\big) \le \alpha,\ z \in Z$$

- Energy Deliverability Improvement – critical line between zones

$$\sum_{i \in FZ_l} (ISF(l,i) \cdot Reserve_i) \le F_l^{\max} - A_l,\ l \in L_c$$

$$\sum_{i \in FZ_l} (ISF(l,i) \cdot Reserve_i) \ge -F_l^{\max} - A_l,\ l \in L_c$$

ENHANCED UNIT COMMITMENT FORMULATION WITH ZONAL RESERVE SETTINGS

- Objective

$$\min \sum_{g,t} \tilde{c}_g\{p_{g,t}\} + SU_g z_{g,t} + SD_g y_{g,t} + RP_g^{\text{up}}(r_{g,t}^{\text{up}})$$
$$+ RP_g^{\text{dw}}(r_{g,t}^{\text{dw}}) + CR(rns_{g,t}^{\text{up}}) + CR(rns_{g,t}^{\text{dw}}) + \sum_{i,t} CE(e_{i,t})$$

- Reserve requirement constraints:
  - System level:

$$\sum_g r_{g,t}^{\text{up}} + rns_{g,t}^{\text{up}} \geq SYS_t^{\text{up}}, \forall t$$

$$\sum_g r_{g,t}^{\text{dw}} + rns_{g,t}^{\text{dw}} \geq SYS_t^{\text{dw}}, \forall t$$

  - Zonal level:

$$\sum_{g \in G_z} r_{g,t}^{\text{dw}} \geq ZN_{z,t}^{\text{dw}},\ z \in FZ_l, l \in L_c, \forall t$$

$$\sum_{g \in G_z} r_{g,t}^{\text{up}} \geq ZN_{z,t}^{\text{up}},\ z \in FZ_l, l \in L_c, \forall t$$

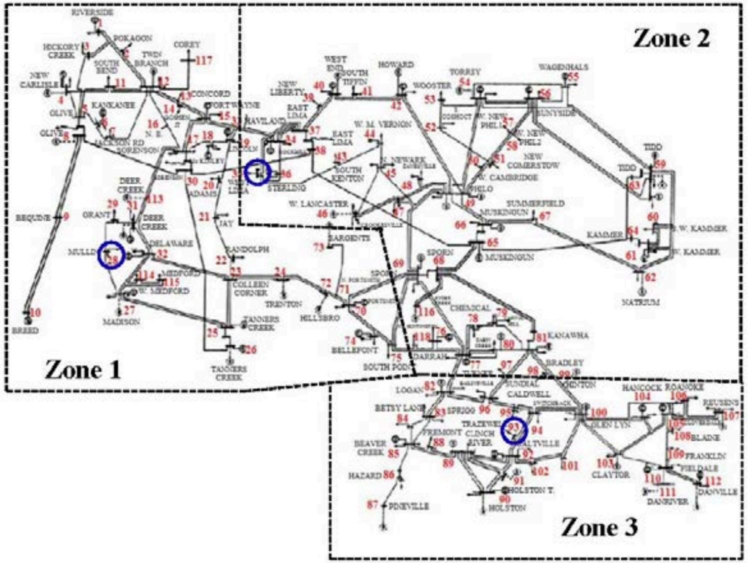
  - Deliverability constraints

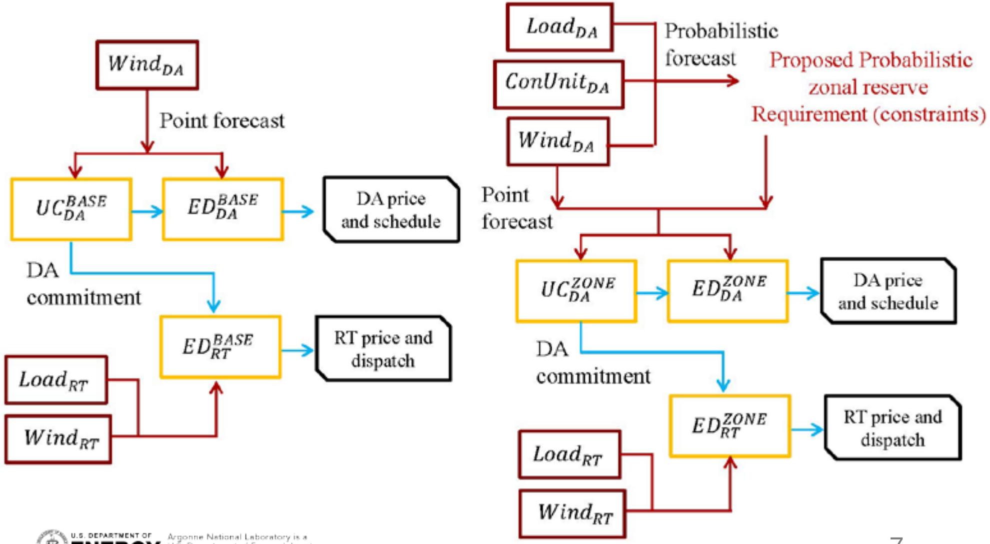
$$-\sum_{i \in FZ_l} (ISF(l,i) \sum_{g \in G_i} r_{g,t}^{\text{dw}}) \leq F_l^{\max} - A_{l,t}, l \in L_c, \forall t$$

$$\sum_{i \in FZ_l} (ISF(l,i) \sum_{g \in G_i} r_{g,t}^{\text{up}}) \geq -F_l^{\max} - A_{l,t}, l \in L_c, \forall t$$

SIMULATION AND RESULTS

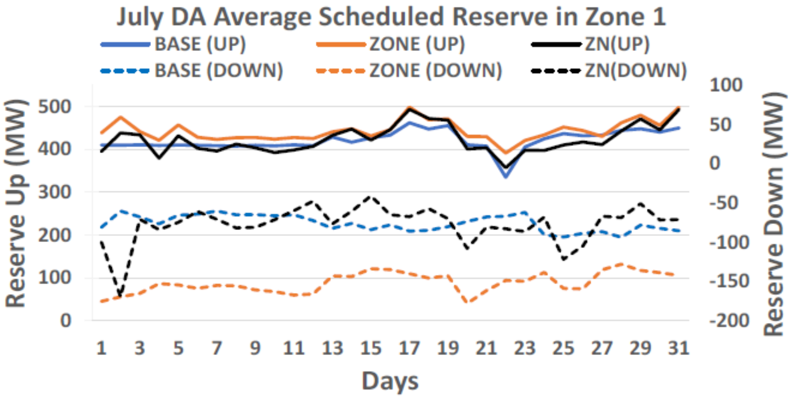
- Test System
- Simulation Overflow



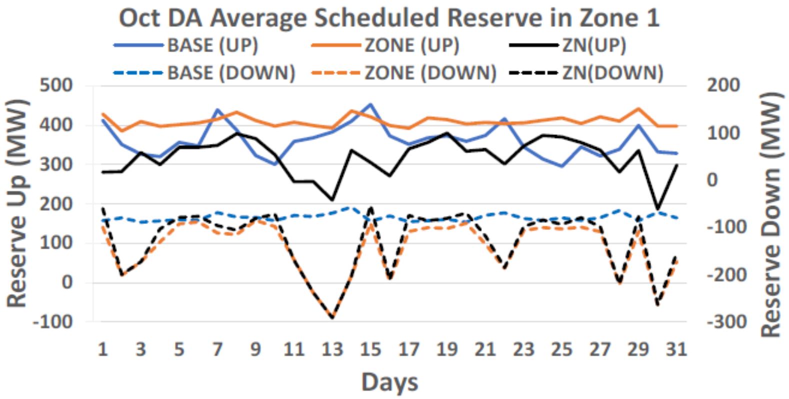


SIMULATION AND RESULTS

- Impacts on Operating Reserves



(a) July



(b) October

SIMULATION AND RESULTS

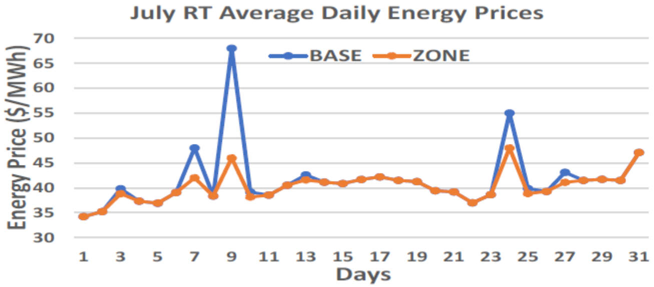
- Operational Cost

TABLE I
RT AVERAGE OPERATIONAL COST IN JULY AND OCTOBER.

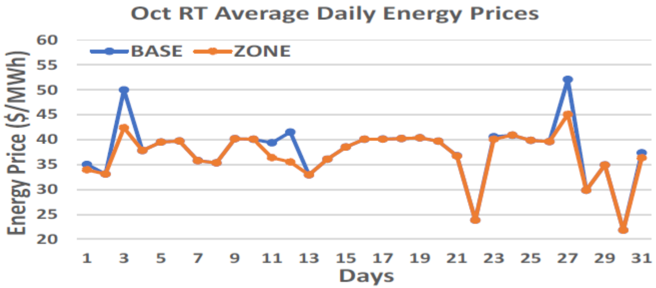
RT-Cost (K$)	July		October	
	BASE	ZONE	BASE	ZONE
Energy/Reserve	3896.17	3902.6	3230.25	3233.5
Unserved Energy	32.22	8.94	0	0
Unserved Reserves	79.51	58.22	16.32	8.38
Wind Curtailment	12.23	6.35	53.63	51.60
Total	**4020.13**	**3976.11**	**3300.2**	**3293.23**

SIMULATION AND RESULTS

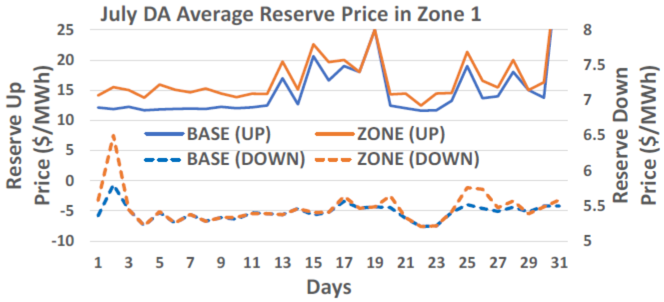
- Electricity and reserve prices



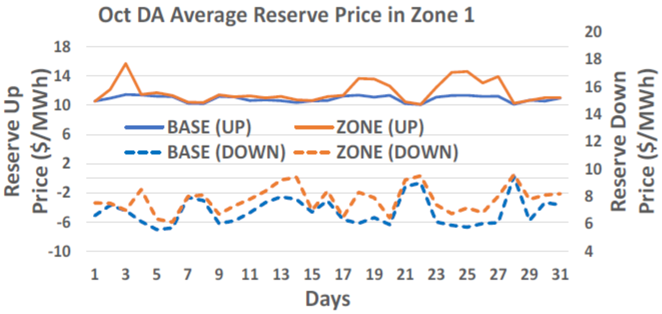
(a) July



(b) October



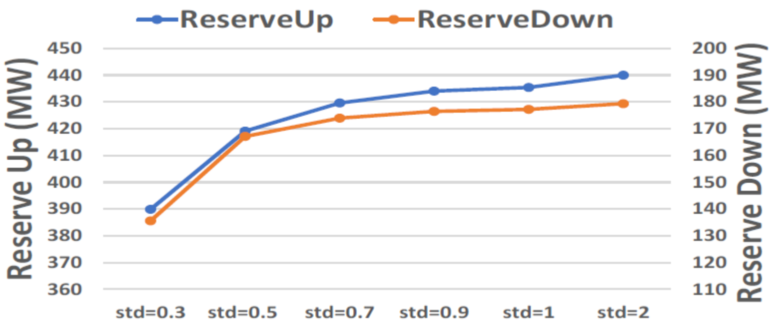
(a) July

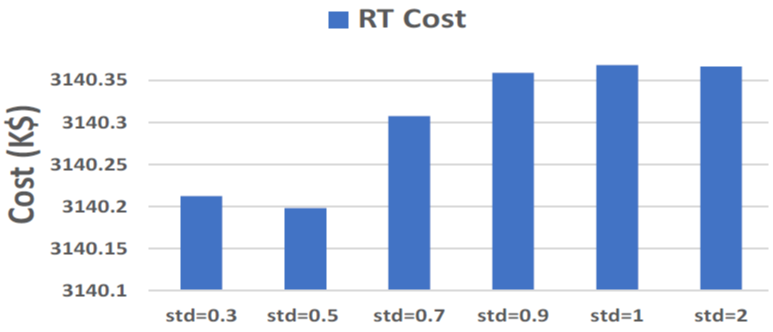


(b) October

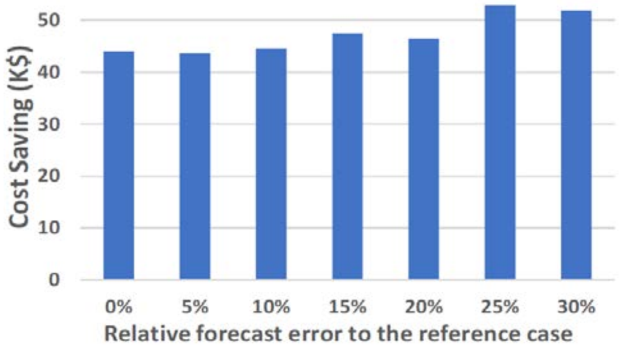
SIMULATION AND RESULTS

- Impacts of uncertainty on reserves and operational cost





- Impact of forecasting error on cost saving



DISCUSSION AND FUTURE WORK

- Discussion
  - More energy and reserve will be scheduled with more critical line identified, hence provide more flexibility
  - Performance better with
    - Higher uncertainties.
    - With systems that requires more flexibility
- Future work
  - Power flow probability distribution estimation
  - Zonal reserve requirement accounting for line outages

THANK YOU!

ZHI ZHOU

ARGONNE NATIONAL LABORATORY

ZZHOU@ANL.GOV