



Incorporating Reserve Deployment Impact on Transmission Constraints into Co-optimization of Energy and Ancillary Service Procurement

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ASM Design on Reserve Deliverability

- **Overview of current method of treating transmission constraints in AS procurement**
 - **Enforce reserve zone requirement constraints inside SCUC and SCED**
 - Minimum zonal regulating reserve constraints
 - Minimum zonal regulating plus spinning reserve constraints
 - Minimum zonal operating reserve constraints
 - **Count on offline study to provide**
 - Reserve zone definition (quarterly update)
 - Minimum zonal reserve requirements (three-day ahead study)

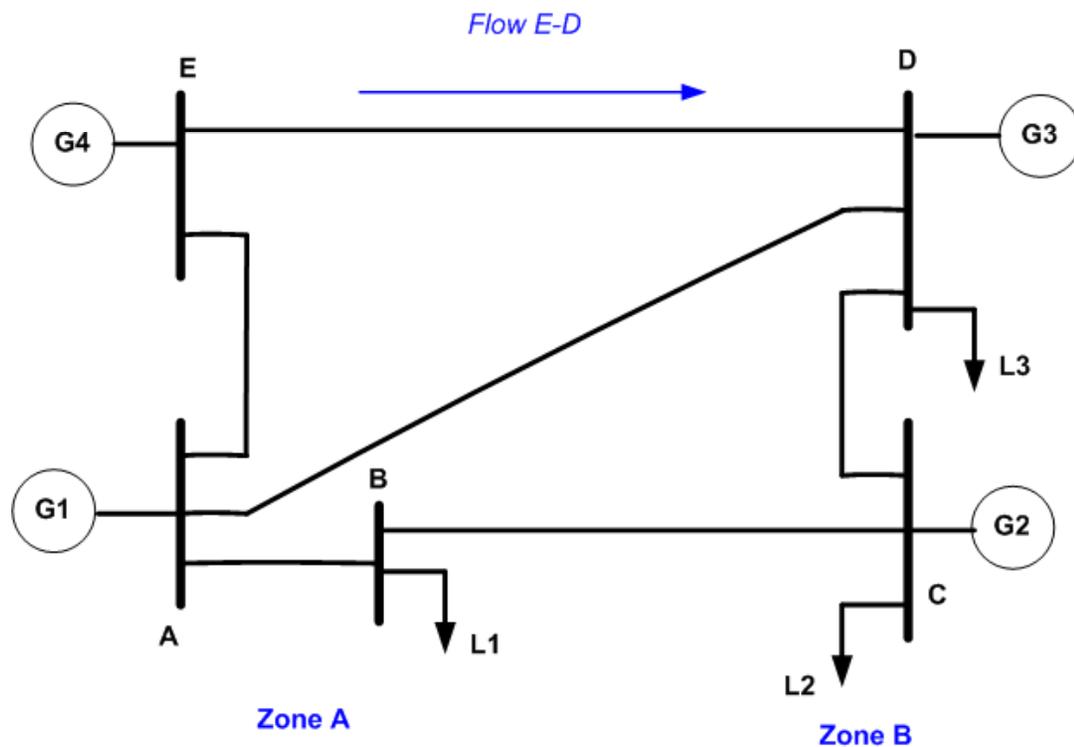
Issue with the Approach

- **Scenario differences between offline studies and actual system conditions**
 - When offline line studies understate transmission limitation on AS deliverability
 - Zonal reserve requirements may not be sufficient to ensure reserve deliverability
 - MISO real time operators have to disqualify resources from clearing AS products when deployment of the AS products will cause violation of transmission limits
 - When offline line studies overstate transmission limitation on AS deliverability
 - Zonal reserve requirements may be enforced unnecessarily

5-bus Example

	RegQualified	RegMin	RegMax	Previous Target	Ramp (MW/Min)	Energy Offer	Reg Offer	Spin Offer	Gen_Sens (to line E-D)	Zone	Zsens (to line E-D)
G1	Y	0	200	110	10	20	7.7	4.62	0.1	a	0.205
G4	Y	0	600	450	30	10	5.5	2.3	0.24	a	0.205
G2	Y	0	500	67	20	30	6.5	4.5	-0.04	b	-0.0533
G3	Y	0	220	70	10	8	17.05	10.23	-0.08	b	-0.0533

Zsens: zonal aggregated generation sensitivities to line E-D flow



- **Market wide requirements:**

- Regulating reserve: 40MW
- Spinning reserve: 60MW
- Supplemental reserve: 21MW



- Regulating plus spinning reserve: 100MW
- Operating reserve: 121MW
- Contingency reserve: 81MW

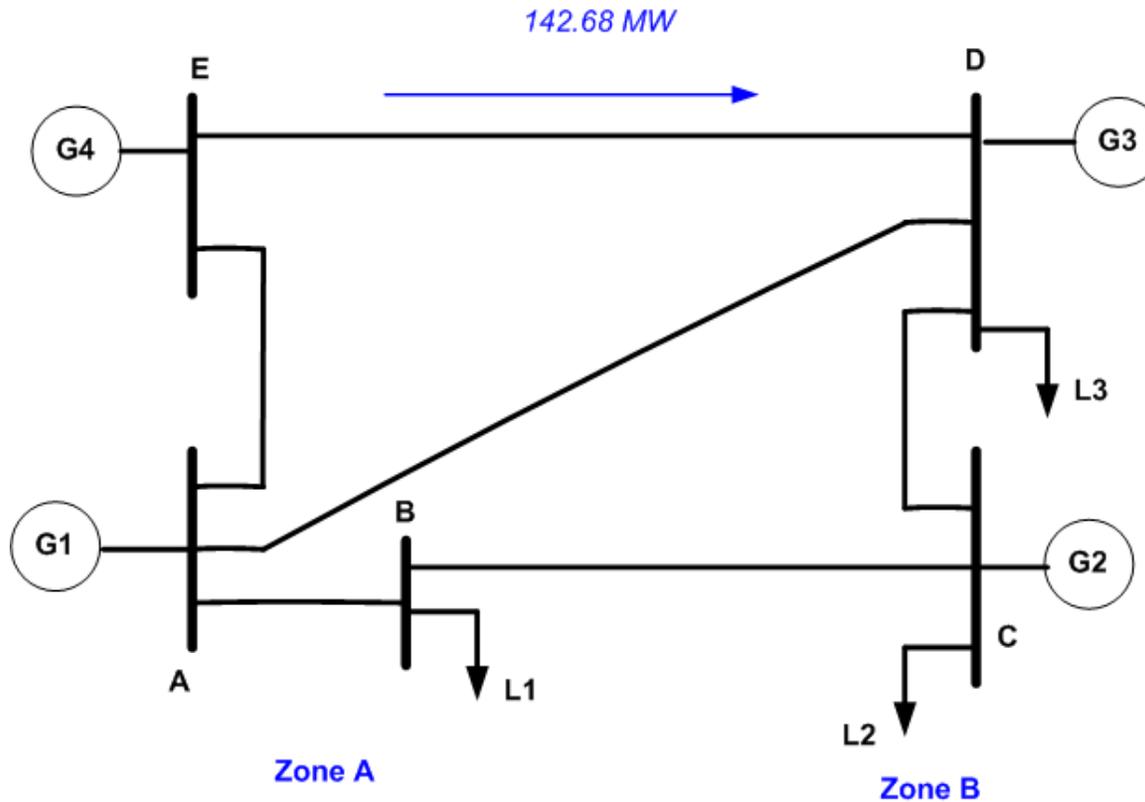
- **No zonal requirements from offline study**

- **Scenario 1: no transmission constraint**

- Solution

Line E-D flow: 142.68MW

G4: energy dispatch at 600MW with no reserve cleared



Scenario 1 – no transmission constraint

	CONTROLSTATUS	ENERGYMW	REGMW	SPINMW	SUPPMW	LMP	REGMCP	SPINMCP	SUPPMCP
G1	2	82.81	40	0	0	20	7.7	4.5	0
G4	2	600	0	0	0	20.06	7.7	4.5	0
G2	2	0	0	81	0	20.32	7.7	4.5	0
G3	2	120	0	0	0	19.08	7.7	4.5	0

- **Scenario 2: Line E-D limit 100MW**

- Solution under existing tariff

- Line E-D flow: 100 MW

- G4: energy dispatch at 458.66MW

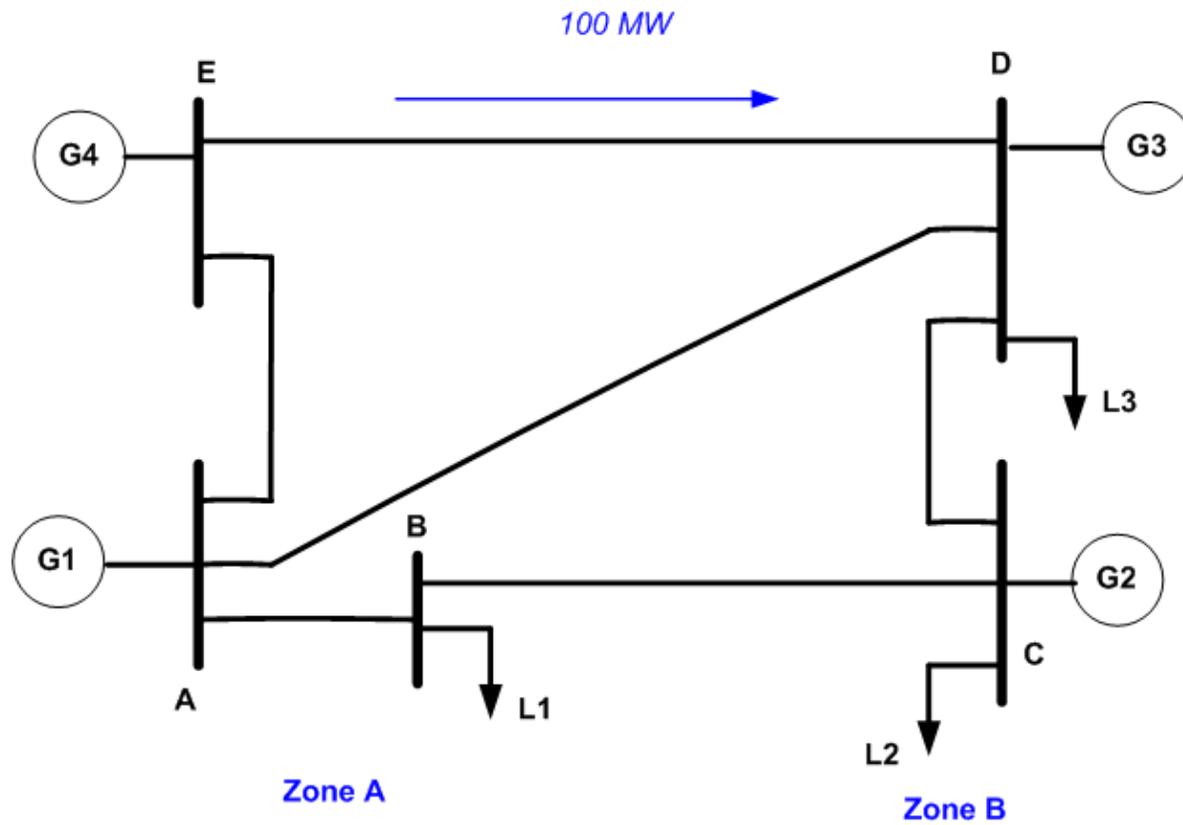
- regulating reserve 40MW and spinning reserve 81MW

- G4 energy dispatch is moved down to relief congestion

- With no minimum zonal reserve requirements for zone B, more regulating and contingency reserves are cleared on G4
 - Reserve deployment will cause violation of transmission flow limit on E-D

- Similar scenario happened in actual system

- Energy were dispatched down in a zone to relief congestion
 - No zonal reserve requirements from offline study
 - 600MW (~75%) of spinning reserve was cleared in that zone
 - Most of the spinning reserve would not be deliverable if deployed



Scenario 2: Line E-D limit 100MW

	CONTROL	STATE	ENERGY	MW	REG	MW	SPIN	MW	SUPP	MW	LMP	REG	MCP	SPIN	MCP	SUPP	MCP
G1	2		60		0		0		0		19.74	5.5		2.3		0	
G4	2		458.66		40		81		0		10	5.5		2.3		0	
G2	2		161.97		0		0		0		30	5.5		2.3		0	
G3	2		120		0		0		0		31.14	5.5		2.3		0	

Statistics of Disqualifying Reserves for Transmission Constraints

MISO real time operators have to disqualify resource from clearing AS products when deployment of the AS products will cause violation of transmission limits

Year 2009	
Number of Events	202
Number of disqualified units	572

Proposed New Approach

- **Solve co-optimized reserve zone requirements**
 - to meet market wide reserve requirements
 - to meet deliverability on a zonal basis
- **Constraints for solving co-optimized reserve zone requirements**
 - Co-optimized reserve zone requirements constraints (A)
 - Market-wide reserve requirements constraints (B)
 - Post-deployment transmission constraints (C)

Proposed New Approach (Cont)

- **Ancillary Service Market Clearing Prices (MCPs) will include signals on congestion**
 - MCPs will incorporate shadow prices of constraints (A)
 - Shadow prices of constraints (A) reflect:
 - Marginal cost to meet market-wide reserve requirements (From (B))
 - Marginal cost to relieve congestions on new post-deployment transmission constraints (From (C))

Proposed New Approach (Cont.)

- **Model post-deployment transmission constraints**
 - Reflect AGC reserve deployment logics
 - Contingency reserves include spinning reserve and supplemental reserve.
 - Supplemental reserve can be met by on-line supplemental qualified resources and quick start offline resources
 - Spinning reserves and on-line supplemental reserves are deployed proportionally by AGC following a contingency reserve deployment event
 - Offline supplemental reserves are called on if deployment of on-line contingency reserve is not enough
 - After disturbance recovery period (~15-min), contingency reserves are un-deployed

5-bus Example Under New Approach

- **Nomenclature**

- *“Flow from energy dispatch”*: Transmission constraint flow (based on cleared energy dispatch)
- *ClearedReg(r)*: Cleared regulating reserve on resource r (to be solved)
- *ClearedSpin(r)*: Cleared spinning reserve on resource r (to be solved)
- *ClearedSupp(r)*: Cleared supplemental reserve on resource r (to be solved)

- *ZMinRegReq(z)*: minimum zonal regulating reserve requirement in zone z (to be solved)
- *ZMinSpinReq(z)*: minimum zonal spinning reserve requirement in zone z (to be solved)
- *ZMinSuppReq(z)*: minimum zonal supplemental reserve requirement in zone z (to be solved)

5-bus Example (cont.)

- **New Constraints – (C)**

- Post-Regulating Reserve Deployment Transmission Const.

- Post Regulating Reserve Deployment Up (1)

- Post Regulating Reserve Deployment Down (2)

$$\text{“Flow from energy dispatch”} + 0.205 * ZMinRegReq(A) - 0.0533 * ZMinRegReq(B) \leq 100 \quad (1)$$

$$\text{“Flow from energy dispatch”} - 0.205 * ZMinRegReq(A) + 0.0533 * ZMinRegReq(B) \leq 100 \quad (2)$$

- Post-Contingency Deployment Transmission Constraints

- One aggregated outage per zone

- Largest event in zone A (assume 81MW for the 5-bus system) (3)

- Largest event in zone B (assume 81MW for the 5-bus system) (4)

– Zonal aggregation based calculation

- Impact from the outage is calculated as negative of the size of the outage multiplying zonal aggregated sensitivities
- Impacts of reserve deployments are calculated as total zonal allocated reserve deployments multiplying corresponding zonal aggregated sensitivities

$$\begin{aligned}
 & \text{“Flow from energy dispatch”} - 81 * 0.205 + \{0.205 * ZMinRegReq(A) - 0.0533 * ZMinRegReq(B)\} \\
 & + 60/60 * \{0.205 * ZMinSpinReq(A) - 0.0533 * ZMinSpinReq(B)\} \\
 & + 21/21 * \{0.205 * ZMinSuppReq(A) - 0.0533 * ZMinSpinReq(B)\} \\
 & \leq 110 \text{ (higher emergency limit)} \qquad (3)
 \end{aligned}$$

$$\begin{aligned}
 & \text{“Flow from energy dispatch”} - 81 * (-0.0533) + \{0.205 * ZMinRegReq(A) - \\
 & 0.0533 * ZMinRegReq(B)\} + 60/60 * \{0.205 * ZMinSpinReq(A) - 0.0533 * ZMinSpinReq(B)\} \\
 & + 21/21 * \{0.205 * ZMinSuppReq(A) - 0.0533 * ZMinSpinReq(B)\} \\
 & \leq 110 \text{ (higher emergency limit)} \qquad (4)
 \end{aligned}$$

5-bus Example (cont.)

- **Modified Constraints – (B)**

- Market-wide regulating reserve constraint (5)
- Market-wide regulating plus spinning reserve constraint (6)
- Market-wide operating reserve constraint (7)

$$ZMinRegReq(A) + ZMinRegReq(B) \geq 40 \quad (5)$$

$$ZMinRegReq(A) + ZMinRegReq(B) + ZMinSpinReq(A) + ZMinSpinReq(B) \geq 40+60 \quad (6)$$

$$ZMinRegReq(A) + ZMinRegReq(B) + ZMinSpinReq(A) + ZMinSpinReq(B) + ZMinSuppReq(A) + ZMinSuppReq(B) \geq 40+81 \quad (7)$$

5-bus Example (cont.)

- **New Constraints – (A)**

- Co-optimized reserve zone regulating reserve const. (8,9)
- Co-optimized reserve zone reg. and spin. reserve const. (10,11)
- Co-optimized reserve zone operating reserve const. (12, 13)

$$\text{ClearedReg}(G1) + \text{ClearedReg}(G4) \geq Z\text{MinRegReq}(A) \quad (8)$$

$$\text{ClearedReg}(G2) + \text{ClearedReg}(G3) \geq Z\text{MinRegReq}(B) \quad (9)$$

$$\begin{aligned} \text{ClearedReg}(G1) + \text{ClearedReg}(G4) + \text{ClearedSpin}(G1) + \text{ClearedSpin}(G4) \\ \geq Z\text{MinRegReq}(A) + Z\text{MinSpinReq}(A) \end{aligned} \quad (10)$$

$$\begin{aligned} \text{ClearedReg}(G2) + \text{ClearedReg}(G3) + \text{ClearedSpin}(G2) + \text{ClearedSpin}(G3) \\ \geq Z\text{MinRegReq}(B) + Z\text{MinSpinReq}(B) \end{aligned} \quad (11)$$

$$\begin{aligned} \text{ClearedReg}(G1) + \text{ClearedReg}(G4) + \text{ClearedSpin}(G1) + \text{ClearedSpin}(G4) \\ \geq Z\text{MinRegReq}(A) + Z\text{MinSpinReq}(A) + Z\text{MinSuppReq}(A) \end{aligned} \quad (12)$$

$$\begin{aligned} \text{ClearedReg}(G2) + \text{ClearedReg}(G3) + \text{ClearedSpin}(G2) + \text{ClearedSpin}(G3) \\ \geq Z\text{MinRegReq}(B) + Z\text{MinSpinReq}(B) + Z\text{MinSuppReq}(B) \end{aligned} \quad (13)$$

Results under New Approach

- Proposed approach solution for scenario 2

	CONTROLSTATUS	ENERGYMW	REGMW	SPINMW	SUPPMW	LMP	REGMCP	SPINMCP	SUPPMCP	ZMinRegReq	ZMinSpinReq	ZMinSuppReq
G1	2	60	0	0	0	19.74	5.5	2.3	0	8.26	38.71	0.00
G4	2	458.66	8.26	38.71	0	10	5.5	2.3	0			
G2	2	161.97	31.74	42.29	0	30	6.5	4.5	0	31.74	21.29	21.00
G3	2	120	0	0	0	31.14	6.5	4.5	0			

- Post-deployment transmission constraints are satisfied
 - On a zonal basis, ensure reserve deployment will not cause flow E-D limits to be violated
- Market-wide reserve requirements are distributed to reserve zones economically and reliably

Business Process

- **Keep existing offline studies**
 - Quarterly reserve zone configuration study
 - Based on IROs and some significant SOL constraints
 - Daily minimum zonal reserve requirement study
 - Three days prior to the operating day
- **One step forward**
 - Evaluate reserve deployment impact **on a zonal basis** inside all DA and RT market clearing engines
 - Same set of IROs and some significant SOL constraints are incorporated into the co-optimization
 - Use aggregated zonal sensitivities
 - Solve zonal reserve requirements to
 - Meet market wide reserve requirement
 - Meet deliverability requirement

Reserve Zone Under New Approach

- **Reasons to keep reserve zone**
 - Maintain zonal reserve MCP
 - Locational MCP (nodal) would require significant change to the settlement system
 - SCUC and SCED solution performance
 - Focus on limited number of important transmission constraints
 - MISO operational goal
 - No violation of IROLs and significant SOLs
 - » reporting requirement for any IROL violations even down to 1 minute
 - Local and less significant SOL violation should not exceed 20 minutes
 - » SOL usually can be relieved within 20 minutes by RT-SCED
 - » Not necessary to increase reserve procurement cost by considering all SOL constraints

Optimization Size

- **Number of post-deployment constraints can increase significantly**
 - Assume evaluating post-deployment impact on “n” transmission constraints
 - Number of zones is “z”
 - Number of new post-deployment constraints will be $n * (z + 2)$
- **New primal variables and co-optimized reserve zone requirements constraints**
 - Proportional to number of zones

Performance Results

- **RT-SCED stand alone testing**
 - Production case with 29 transmission constraints
 - 6 reserve zones
 - Including post-deployment constraints for all:
 - Total number of post-deployment constraints:
 $(6+2)*29=232$
 - LP solution time:
 - Production software: 8.99 sec.
 - **Software with the new approach: 9.33 sec. (+0.34 sec.)**

Performance Results (Cont.)

- **DA-SCUC**

- Production case with 6 reserve zones
- 36-hour commitment
- Including post-deployment constraints for 11 transmission constraints (both “<=” and “>=”):
 - Total number of post-deployment constraints:
 $(6+2)*11*2*36=6336$
- MIP solution time:
 - Production software:
1286 seconds (MIP gap 0.069%), 1880 seconds (MIP gap 0.061%)
 - **Software with the new approach:**
934 seconds (MIP gap 0.095%), 1562 seconds (MIP gap 0.052%)