Flexible ramping product refinements discussion

Kun Zhao, Ph.D.
Market Analysis and Forecasting

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General Session
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FRP Enhancements

- Previous CAISO analysis showed deliverability to be one of the main issues impacting FRP efficacy

- FRP enhancements will rely on new formulation to consider nodal procurement to tackle FRP deliverability

FRP Enhancements – Overview

- Enhanced methodology to calculate FRP requirement as a function of demand, solar, and wind forecast
- Remove NIC/NEC, FRU/FRD credit from uncertainty requirement in market optimization
- Enforce transmission constraints and EIM transfer constraints in FRP deployment scenarios
- FRP nodal pricing

FRU requirement constraint – Existing

- BAA level requirement constraints
  - Lower bound

$$\sum_{i \in BAA_j} FRU_i + \gamma_j \cdot (FRUS_j) \geq FRUReq_j - \begin{cases} NIC_j, & if\ BAA\ j\ pass\ FRU\ sufficiency\ test, \\ FRUCredit_j, & if\ BAA\ j\ fail\ FRU\ sufficiency\ test \end{cases}$$

  - Upper bound

$$\sum_{i \in BAA_j} FRU_i + \gamma_j \cdot FRUS_j \leq FRUReq_j + NEC_j$$

  - Minimum requirement under conditions

$$\sum_{i \in BAA_j} FRU_i + \gamma_j \cdot FRUS_j \geq Factor \cdot FRUReq_j$$

- EIM system level requirement constraints

$$\sum_{j \in EIM} \sum_{i \in BAA_j} FRU_i + \sum_{j \in EIM} FRUS_j + FRUS^{sys} \geq FRUReq^{sys}$$

FRU requirement constraint – Enhancements

- BAA level requirement constraints for each BAA that has failed FRU sufficiency test

$$\sum_{i \in BAA_j} FRU_i + FRUS_j = FRUReq_j$$

- Group level requirement constraints for BAAs that have passed FRU sufficiency test

$$\sum_{j} \sum_{i \in BAA_j} FRU_i + \sum_{j} FRUS_j = FRUReq^{Group}$$

- Requirements are not adjusted by NIC or credit

Slack(surplus) variable – Existing

BAA j slack variable $FRUS_j$

- Inactive when the BAA is able to meet its requirement with its local capacity

- Active when the BAA is not able to meet is requirement with its local capacity

$$FRUS_j \leq FRUReq_j - NIC_j - \sum_{i \in BAA_j} FRU_i$$

Slack(surplus) variable – Enhancements

BAA j slack variable $FRUS_j$

- Non-negative
- Demand elasticity by BAA level demand curve
- For passing group, the slack variable for a BAA is limited by the distributed requirement of that BAA

$$FRUS_j \leq F\widehat{RUR}eq_j$$

California ISO

FRU deployment scenario

Assumption:

- FRU awards are fully deployed
- Net demand forecast is increased by the FRU requirements
  - The FRU requirement is divided among load, solar, and wind resources
  - Load, solar, wind components are distributed as positive demand changes

Transmission constraint in deployment scenario

- Base case

$$\underline{FL}_m \le \tilde{F}_m + \sum SF_{i,m} \cdot \Delta En_i \le \overline{FL}_m$$

- FRU deployment scenario

$$\underline{FL}_m \le \tilde{F}_m + \sum_i SF_{i,m} \cdot (\Delta En_i + FRU_i) + \sum_j \sum_i SF_{i,j,m} \cdot FRUS_j$$

$$- \sum_j SF_{j,m} \cdot Factor_i^{Load} \cdot FRUReq_j$$ Load component

$$- \sum_i SF_{i,m} \cdot Factor_i^{Solar} \cdot FRUReq$$ Solar component

$$- \sum_i SF_{i,m} \cdot Factor_i^{Wind} \cdot FRUReq$$ Wind component

$$\le \overline{FL}_m$$

Net EIM transfer in deployment scenario

- For a BAA that fails the sufficiency test

$$T_j^{FRU} = T_j$$

- For a BAA that passes the sufficiency test

$$T_j^{FRU} = T_j + \left(\sum_{i \in BAA_j} FRU_i + FRUS_j - \widehat{FRURe}q_j \right)$$

- T_j is the sum of inter-BAA ETSRs

FRP enhancements – pricing

Locational FRU marginal price:

Pricing location in a BAA that fails the sufficiency test

- Shadow price of the FRU requirement constraint (BAA)
- Congestion contributions from all binding transmission constraints in the FRU deployment scenarios

Pricing location in a BAA that passes the sufficiency test

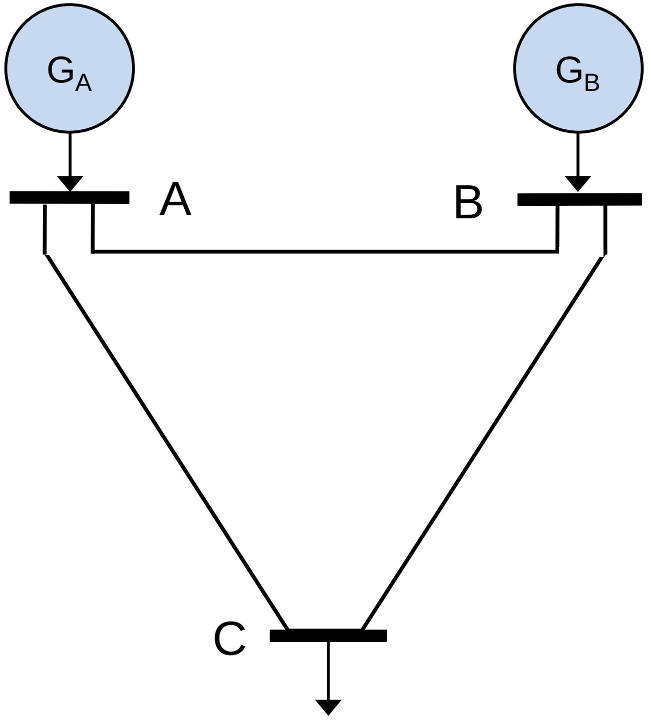
- Shadow price of the FRU requirement constraint (passing group)
- Congestion contributions:
  - Binding transmission constraints in FRU deployment scenario
  - Net EIM transfer constraint in FRU deployment scenario

Formulation summary and implication

- Requirement constraint:
  - BAA level constraint for BAA failing
  - Group level constraint for all BAAs passing
  - No two level nested requirement
  - No NIC/NEC, credit

- FRP deployment scenario:
  - Transmission feasible
  - EIM transfer feasible

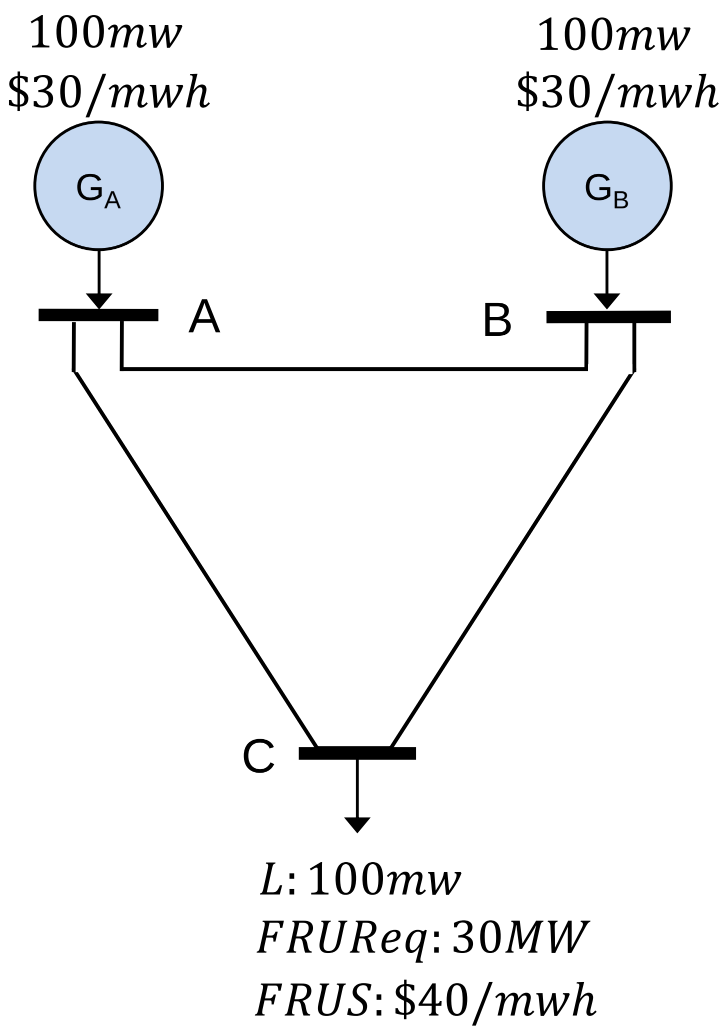
Scenario: One BAA



Single BAA

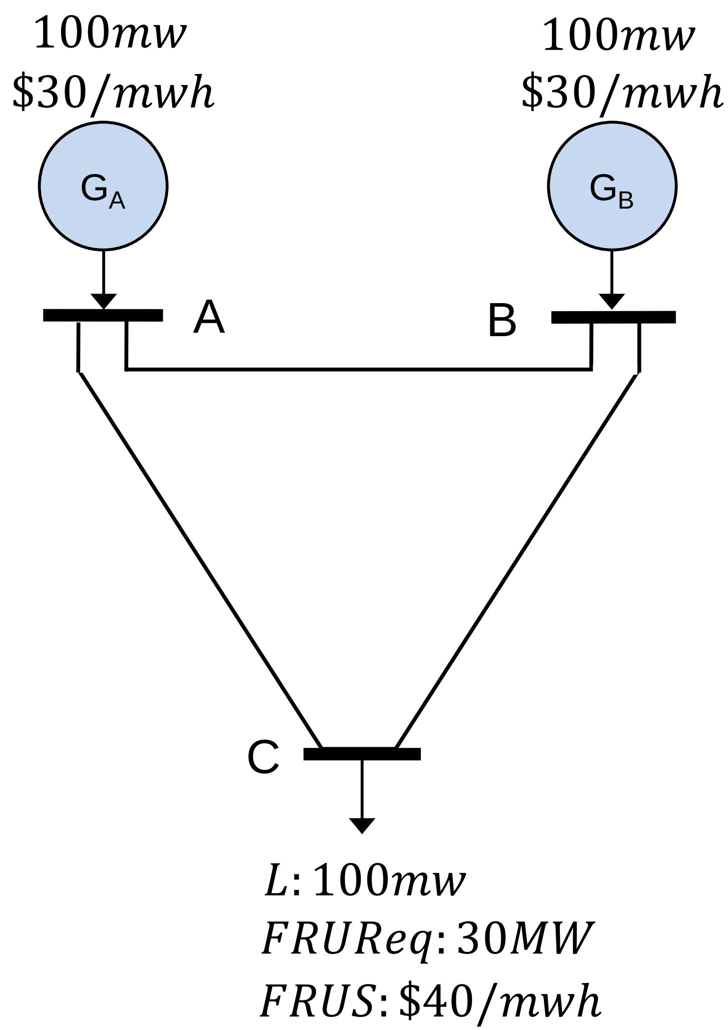
- Load 100mw
- FRU requirement 30mw
- G_A: $\$30/mwh, 100mw$
- G_B: $\$30/mwh, 100mw$
- FRU demand elasticity $\$40/mwh$

Scenario: One BAA



From	To	On	Shift factor
A	C	L_{AB}	1/3
A	C	L_{BC}	1/3
A	C	L_{AC}	2/3
B	C	L_{AB}	-1/3
B	C	L_{BC}	2/3
B	C	L_{AC}	1/3

Scenario: One BAA



- Power balance
- Resource capacity G_A, G_B
- FRU requirement constraint

$$FRU_A + FRU_B + FRUS = 30$$
$$FRUS \leq 30$$

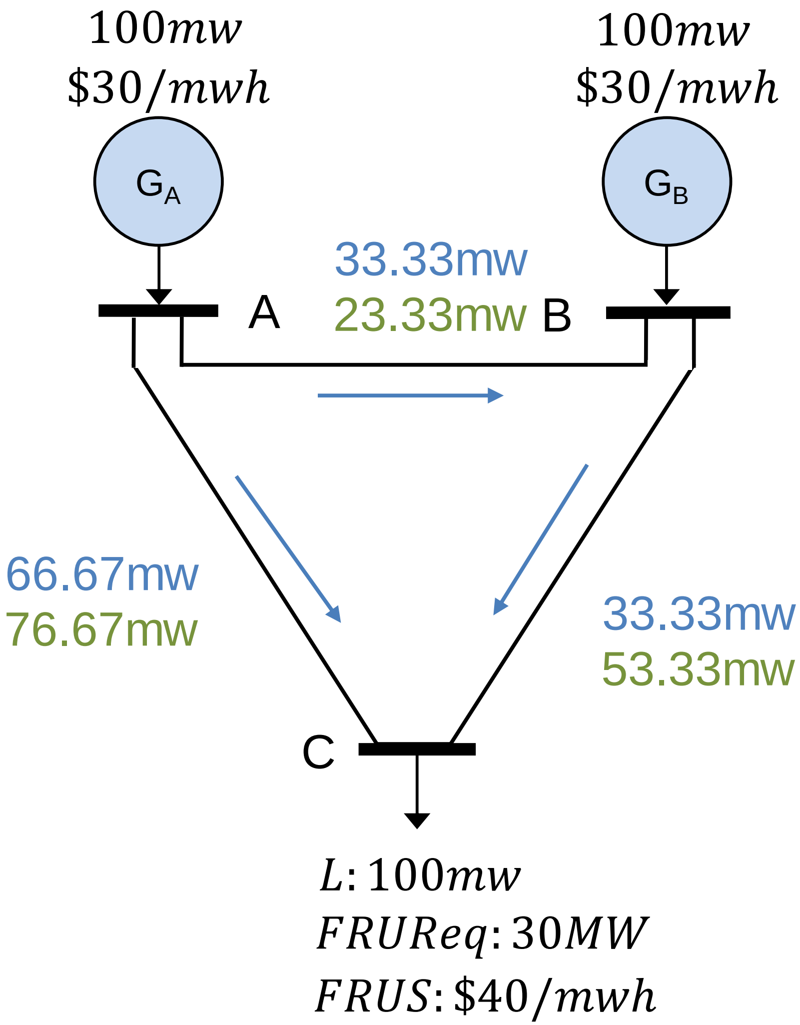
- Transmission constraints
  - Base case

$$\underline{Fl}_m \leq \sum_{i \in \{A,B\}} SF_{i,m} \cdot En_i \leq \overline{Fl}_m$$

  - FRU deployment scenario

$$\underline{Fl}_m \leq \sum_{i \in \{A,B\}} SF_{i,m} \cdot (En_i + FRU_i) \leq \overline{Fl}_m$$
$$\forall m \in \{L_{AB}, L_{BC}, L_{AC}\}$$

Case 1: transmission not binding



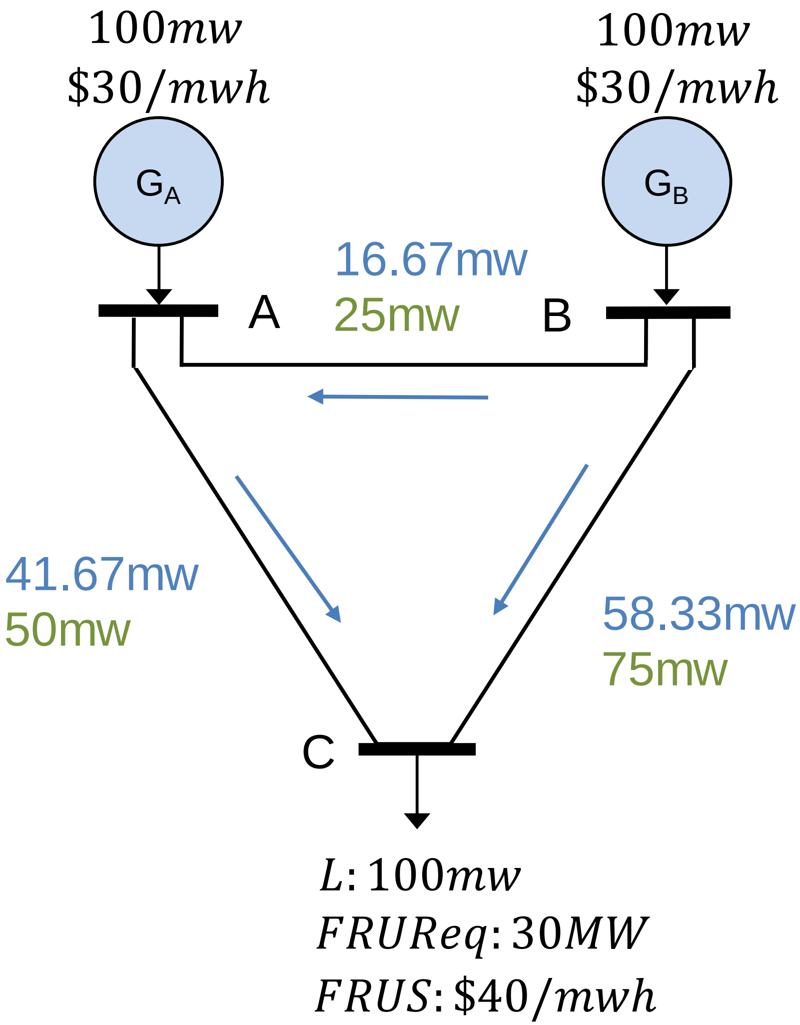
Assumption:

- L_{AB} flow limit = 100
- L_{BC} flow limit = 100
- L_{AC} flow limit = 100

Solution:

- $En_A = 100mw, FRU_A = 0mw$
- $En_B = 0mw, FRU_B = 30mw$
- FRU requirement shadow price $0
- No binding transmission constraint
- FRU nodal price $0 at A, B, C

Case 2: transmission binding



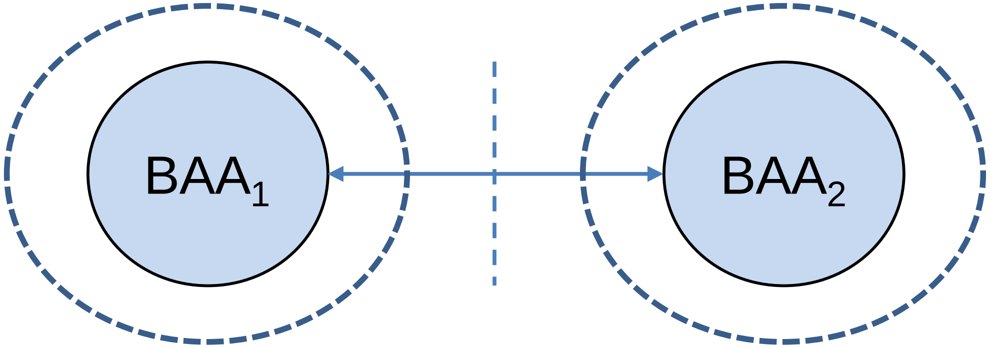
Assumption:

- L_{AB} flow limit = 100
- L_{BC} flow limit = 100
- L_{AC} flow limit = 50

Solution:

- $En_A = 0mw, FRU_A = 25mw$
- $En_B = 100mw, FRU_B = 0mw$
- $FRUS = 5mw$
- FRU requirement shadow price $40
- L_{AC} flow A to C binding at $60
- FRU nodal prices:
  - Node A: $40 - \frac{2}{3} \cdot 60 = \$0$
  - Node B: $40 - \frac{1}{3} \cdot 60 = \$20$
  - Node C: $\$40$

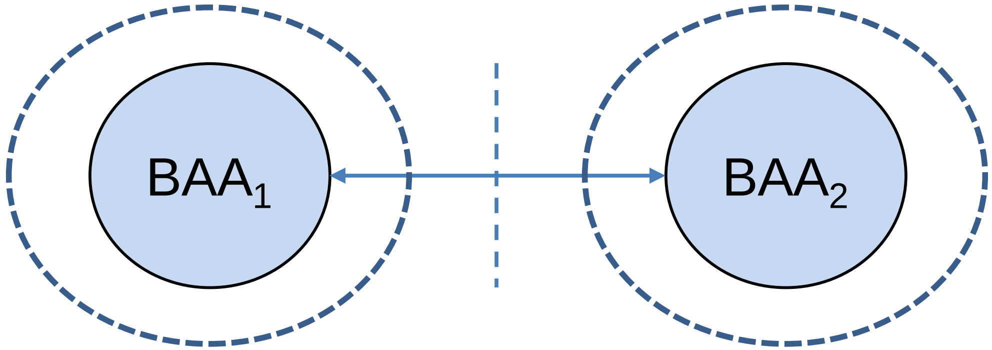
Scenario: Two BAA, fail sufficiency test



- BAA 1
  - Load 100mw
  - $G_1: 200\text{mw}, \$20/\text{mwh}$
  - FRU demand elasticity: $\$40/mwh$
- BAA 2
  - Load 100mw
  - $G_2: 110\text{mw}, \$30/\text{mwh}$
  - FRU demand elasticity: $\$50/mwh$
- Net base transfer 0

Case 3: fail sufficiency test

G_1: $200mw$, $\$20/mwh$
L_1: $100mw$
$FRUReq_1$: $30mw$
$FRUS_1$: $\$40/mwh$



G_2: $110mw$, $\$30/mwh$
L_2: $100mw$
$FRUReq_2$: $30mw$
$FRUS_2$: $\$50/mwh$

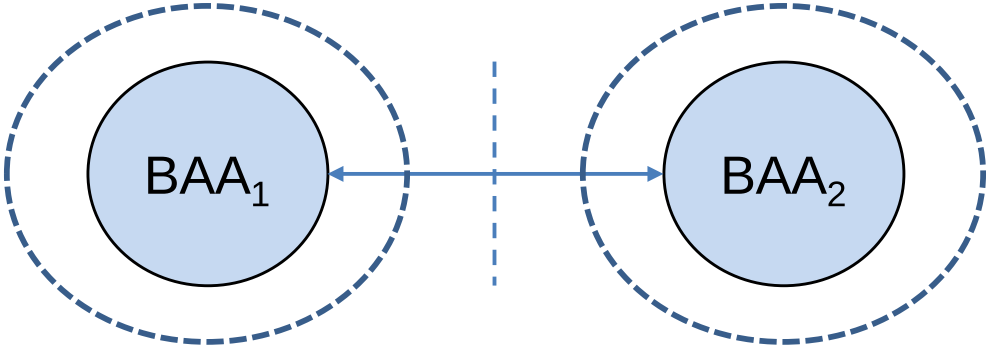
Assumption: fail sufficiency test, $FRUReq = 30mw$ for each BAA

- Power balance BAA 1, BAA 2
- Resource capacity G_1, G_2
- FRU requirement BAA 1: $FRU_1 + FRUS_1 = 30$
- FRU requirement BAA 2: $FRU_2 + FRUS_2 = 30$
- Transfer deployment scenario:

$$T_1^{FRU} = T_1, \qquad T_2^{FRU} = T_2$$

Case 3: fail sufficiency test

$G_1: 200mw,$
$\$20/mwh$
$L_1:\ 100mw$
$FRUReq_1: 30mw$
$FRUS_1: \$40/mwh$

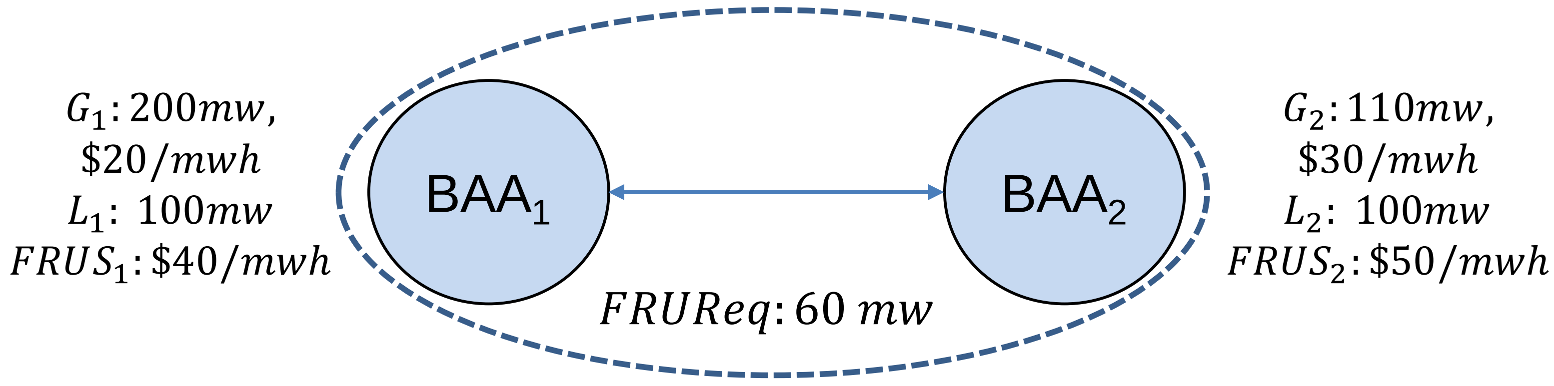


$G_2: 110mw,$
$\$30/mwh$
$L_2:\ 100mw$
$FRUReq_2: 30mw$
$FRUS_2: \$50/mwh$

Solution:

- $En_1 = 100mw, FRU_1 = 30mw, FRUS_1 = 0mw$
- $En_2 = 100mw, FRU_2 = 10mw, FRUS_2 = 20mw$
- FRU requirement BAA 1 shadow price $0
- FRU requirement BAA 2 shadow price $50
- FRU nodal prices
  - Node 1: $0
  - Node 2: $50

Scenario: two BAA, passing group



Assumption: both pass sufficiency test, $FRUReq = 60mw$ for the group

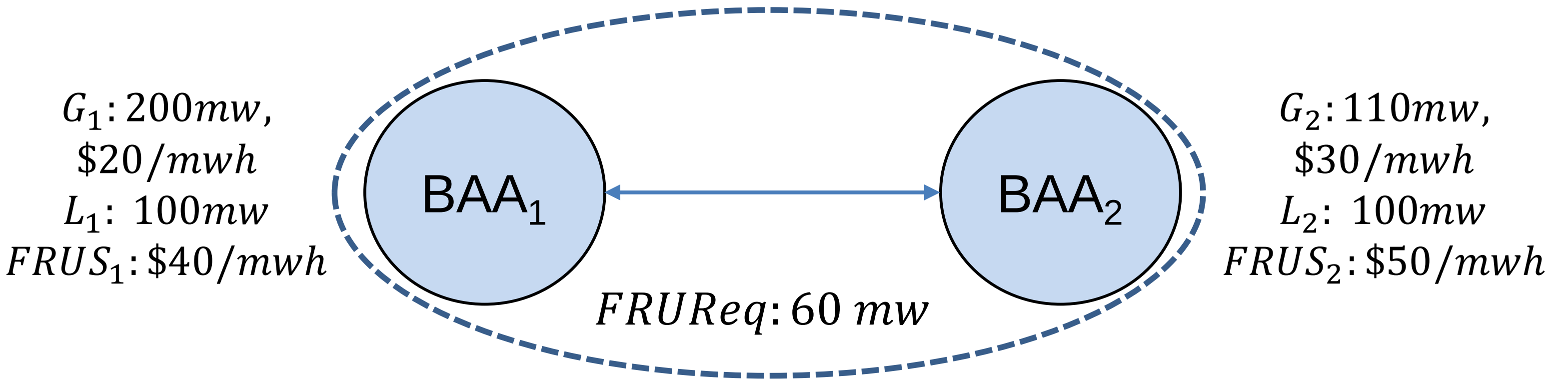
- Power balance BAA 1, BAA 2
- Resource capacity G_1, G_2
- FRU group requirement: $\sum_{i\in\{1,2\}} FRU_i + \sum_{j\in\{1,2\}} FRUS_j = 60$
- Transfer deployment scenario:

$$T_1^{FRU} = T_1 + (FRU_1 + FRUS_1 - 30)$$
$$T_2^{FRU} = T_2 + (FRU_2 + FRUS_2 - 30)$$

- FRU slack variable upper bound: $FRUS_j \leq 30, \forall j = 1,2$

California ISO

Case 4: pass sufficiency test, transfer not binding

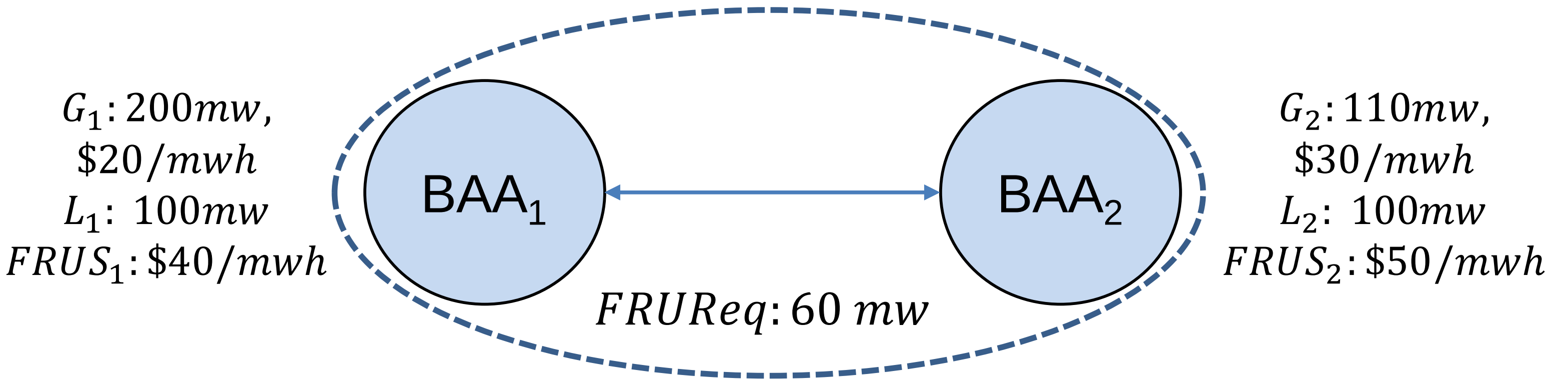


Assumption: Transfer limit 999mw

Solution:

- $En_1 = 200mw, FRU_1 = 0mw, FRUS_1 = 0mw$
- $En_2 = 0mw, FRU_2 = 60mw, FRUS_2 = 0mw$
- Net transfer, base scenario: $T_1 = 100mw, T_2 = -100mw$
- Net transfer, FRU deployment: $T_1^{FRU} = 70mw,\ T_2^{FRU} = -70mw$
- FRU group requirement, shadow price: \$0
- Transfer deployment scenarios, shadow prices: BAA1 \$0, BAA2 \$0
- FRU nodal prices: \$0 at node 1, 2

Case 5: pass sufficiency test, transfer binding

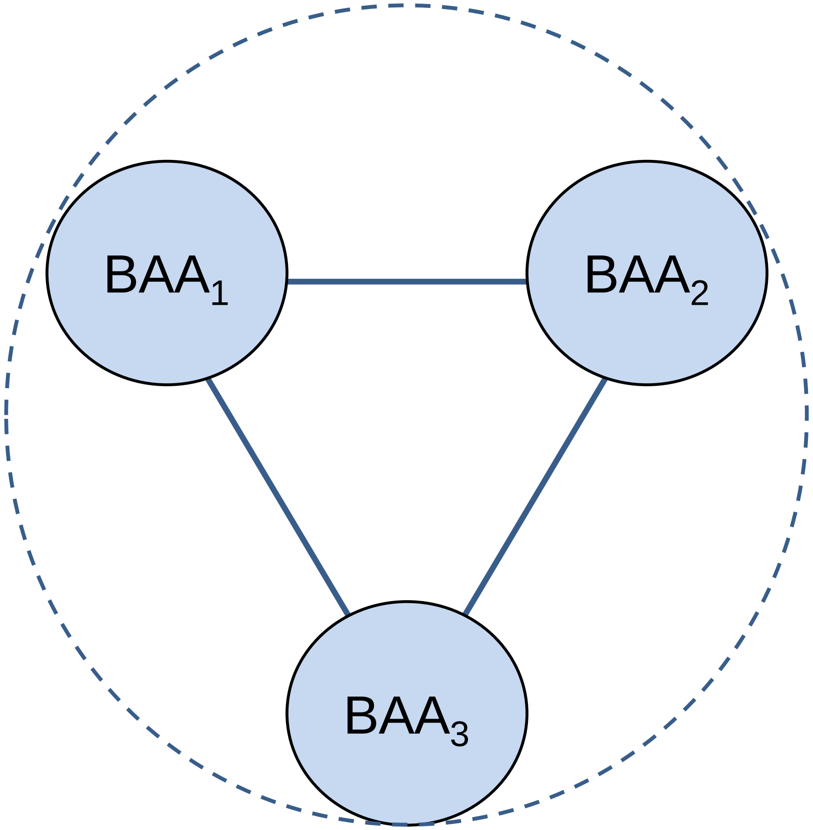


Assumption: Transfer limit 15mw

Solution:

- $En_1 = 115mw, FRU_1 = 30mw, FRUS_1 = 0mw$
- $En_2 = 85mw, FRU_2 = 25mw, FRUS_2 = 5mw$
- Net transfer, base scenario: $T_1 = 15mw,\ \ T_2 = -15mw$
- Net transfer, FRU deployment: $T_1^{FRU} = 15mw,\ T_2^{FRU} = -15mw$
- FRU group requirement, shadow price: $50
- Transfer deployment scenarios, shadow prices: BAA1 -$50, BAA2 $0
- FRU nodal prices:
  - Node 1: $50 - 50 = \$0$, Node 2: $50

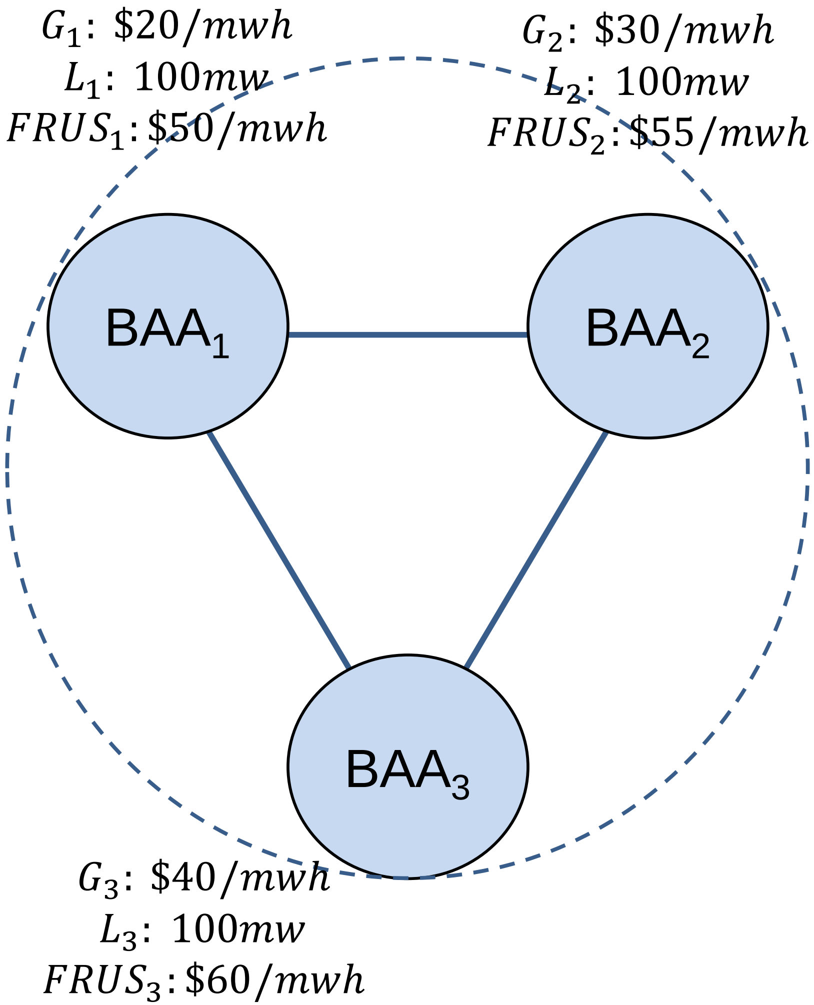
Scenario: three BAA, passing group



- BAA 1
  - Load 100mw
  - $G_1: \$20/mwh$
  - FRU demand elasticity: $\$50/mwh$
- BAA 2
  - Load 100mw
  - $G_2: \$30/mwh$
  - FRU demand elasticity: $\$55/mwh$
- BAA 3
  - Load 100mw
  - $G_3: \$40/mwh$
  - FRU demand elasticity: $\$60/mwh$

- FRU group requirement: 90mw

Scenario: three BAA, passing group



Assumption:

Pass sufficiency test,

FRU group req = 90mw

- Power balance BAA 1, 2, 3
- Resource capacity G_1, G_2, G_3
- FRU requirement group:

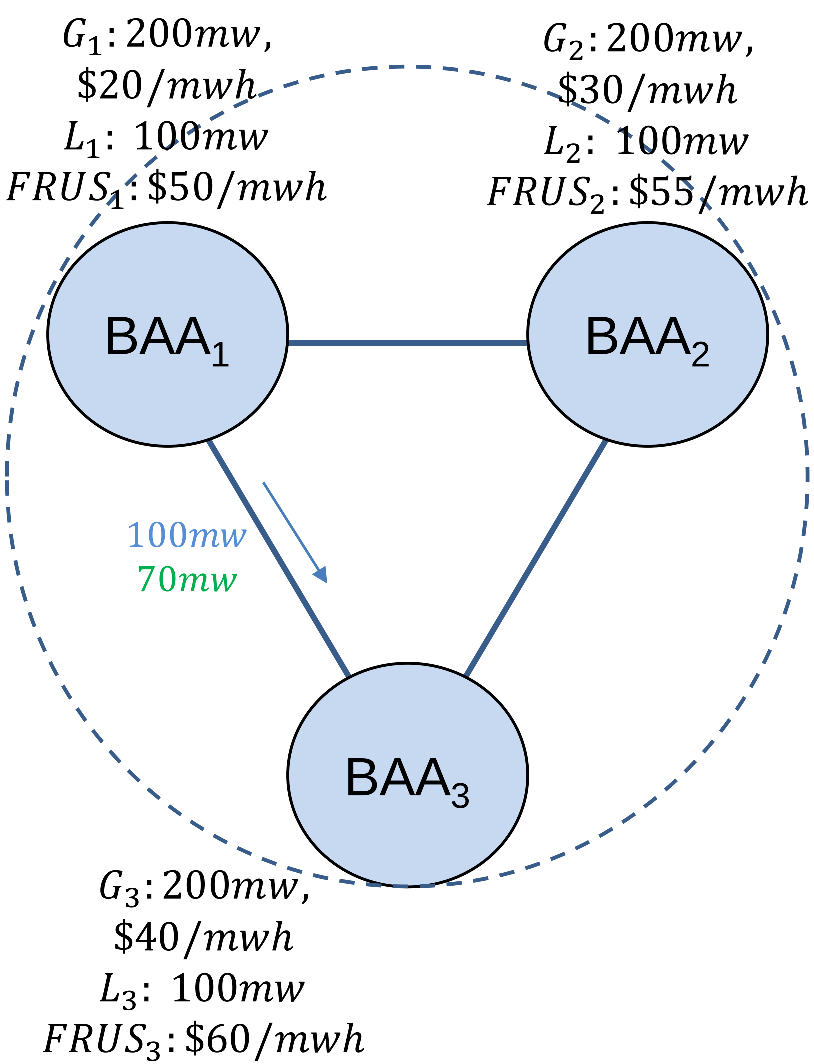
$$\sum_{i\in\{1,2,3\}} FRU_i + \sum_{j\in\{1,2,3\}} FRUS_j = 90$$

$$FRUS_j \leq 30, \qquad \forall j = 1, 2, 3$$

- Transfer deployment scenario:

$$T_1^{FRU} = T_1 + (FRU_1 + FRUS_1 - 30)$$
$$T_2^{FRU} = T_2 + (FRU_2 + FRUS_2 - 30)$$
$$T_3^{FRU} = T_3 + (FRU_3 + FRUS_3 - 30)$$

Case 6: three BAA, passing group



Assumption:

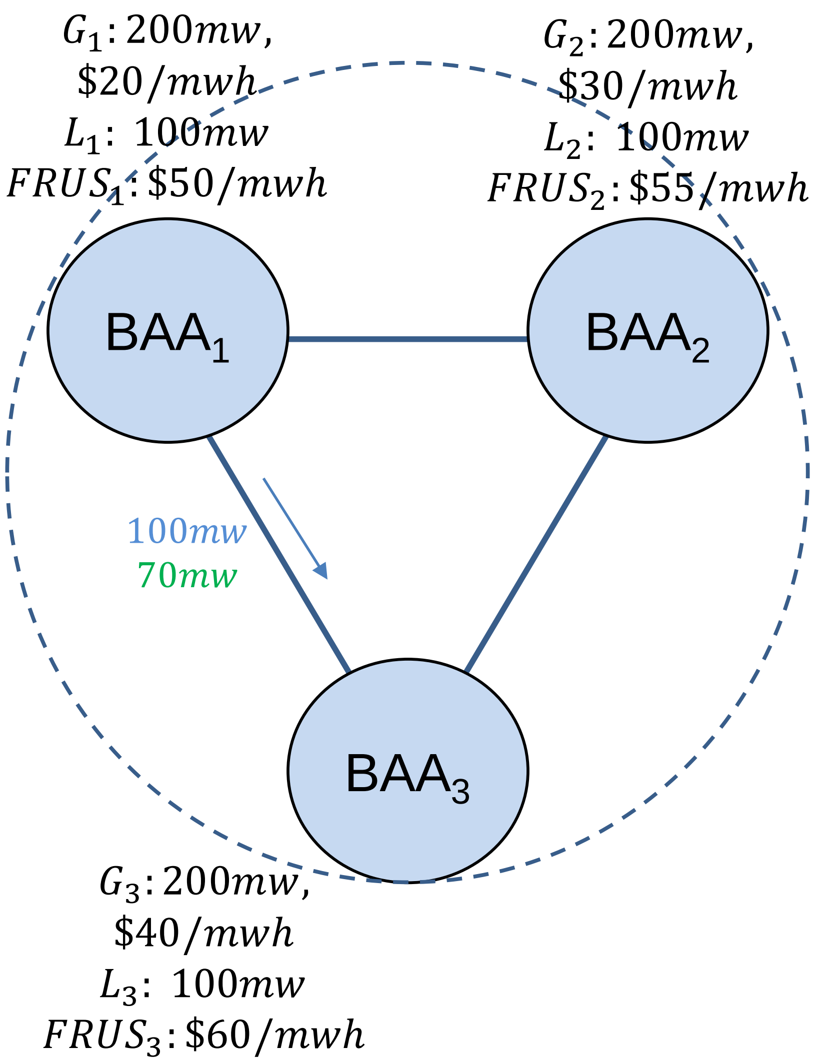
Resource capacity 200mw for G_1, G_2, G_3

Transfer limit 999mw, for each BAA_j to $BAA_k, \forall j, k = 1,2,3$

Solution:

- $En_1 = 200mw$, $FRU_1 = 0mw, FRUS_1 = 0$
- $En_2 = 100mw$, $FRU_2 = 30mw, FRUS_2 = 0$
- $En_3 = 0mw$, $FRU_3 = 60mw, FRUS_3 = 0$
- $T_{12} = 0, T_{12}^{FRU} = 0$
- $T_{23} = 0, T_{23}^{FRU} = 0$
- $T_{13} = 100, T_{13}^{FRU} = 70$
- $T_1 = 100, T_1^{FRU} = 70$
- $T_2 = 0, T_2^{FRU} = 0$
- $T_3 = -100, T_3^{FRU} = -70$

Case 6: three BAA, passing group



Assumption:

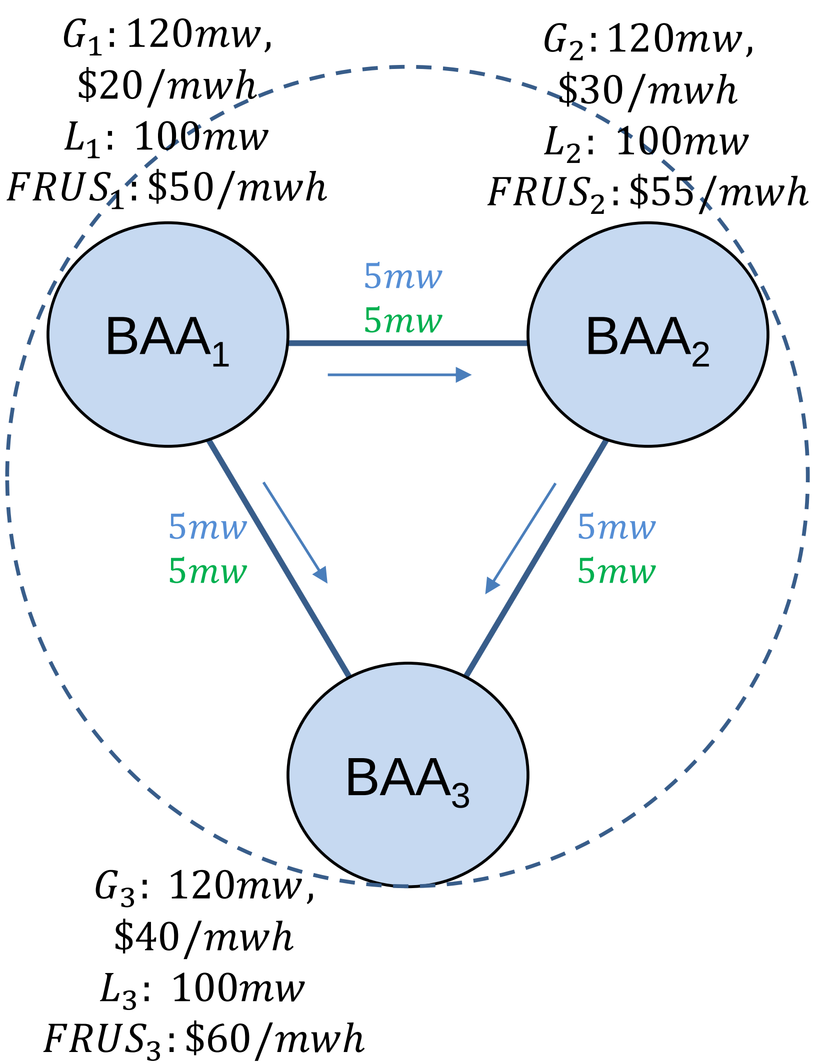
Resource capacity 200mw for G_1, G_2, G_3

Transfer limit 999mw, for each BAA_j to $BAA_k, \forall j, k = 1,2,3$

FRU prices:

- FRU Requirement group: shadow price $0
- Transfer deployment scenarios shadow prices $0
- FRU nodal prices: $0 at node 1, 2, 3

Case 7: three BAA, passing group



Assumption:

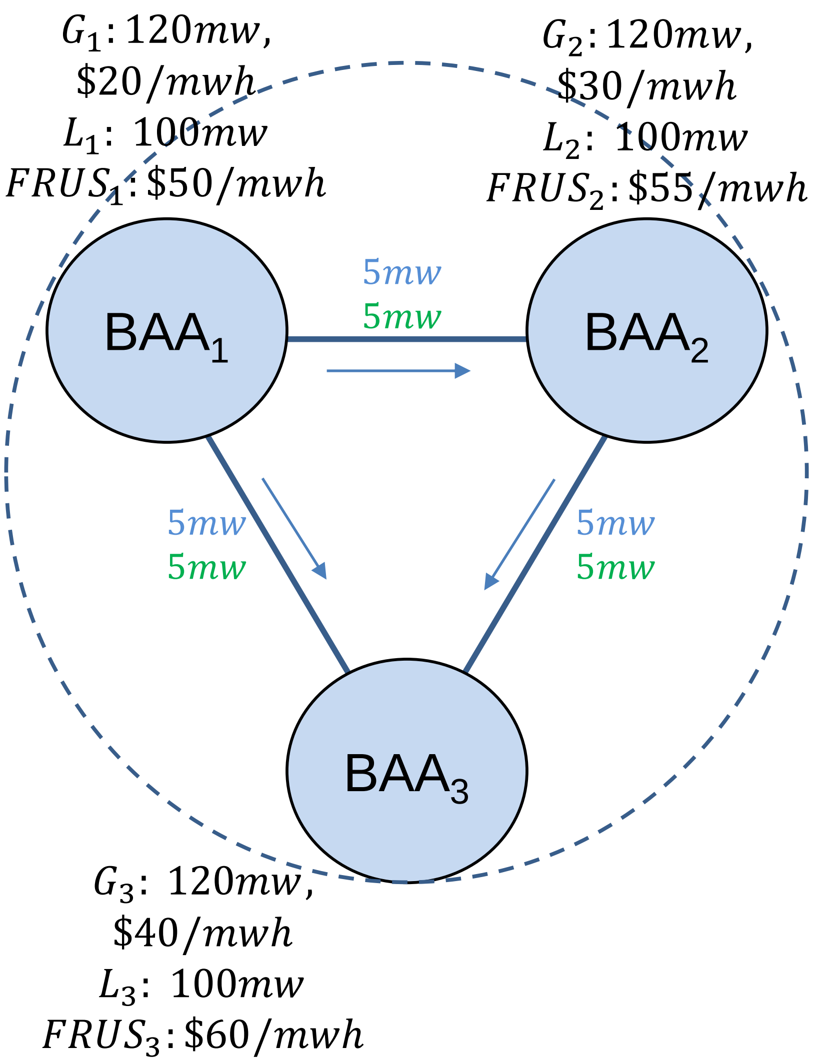
Resource capacity 120mw for G_1, G_2, G_3

Transfer limit 5mw, for each BAA_j to $BAA_k, \forall j, k = 1,2,3$

Solution:

- $En_1 = 110mw,$
  $FRU_1 = 10mw, FRUS_1 = 20mw$
- $En_2 = 100mw,$
  $FRU_2 = 20mw, FRUS_2 = 10mw$
- $En_3 = 90mw,$
  $FRU_3 = 30mw, FRUS_3 = 0mw$
- $T_{12} = 5mw, T_{12}^{FRU} = 5mw$
- $T_{23} = 5mw, T_{23}^{FRU} = 5mw$
- $T_{13} = 5mw, T_{13}^{FRU} = 5mw$
- $T_1 = 10mw, T_1^{FRU} = 10mw$
- $T_2 = 0mw, T_2^{FRU} = 0mw$
- $T_3 = -10mw, T_3^{FRU} = -10mw$

Case 7: three BAA, passing group



Assumption:

Resource capacity 120mw for G_1, G_2, G_3

Transfer limit 5mw, for each BAA_j to $BAA_k, \forall j, k = 1{,}2{,}3$

FRU prices:

- FRU group requirement: shadow price \$60
- Transfer deployment scenario shadow prices
  - BAA 1: - \$10
  - BAA 2: - \$5
  - BAA 3: \$0
- FRU nodal prices:
  - Node 1: $60 - 10 = \$50$,
  - Node 2: $60 - 5 = \$55$,
  - Node 3: $60 + 0 = \$60$

Thanks for your time!

Questions?