ATTACHMENT 3

Inter-Zonal Congestion Payments

- Using Constraint Shadow Costs:

$$R = \sum_j \mu_j P_{j\max}$$

j : zonal interface index

μ_j : constraint shadow cost $\quad$ $P_{j\max}$: zonal interface rating

Inter-Zonal Congestion Charges

- Using Zonal Prices:

$$R_l = \sum_k \lambda_{l,k} \sum_{i \in Z_k} (D_{l,i} - G_{l,i})$$

$$\lambda_{l,k} = \frac{\sum_{i \in Z_k} \lambda_{l,i} \sum_l (D_{l,i} - G_{l,i})}{\sum_{i \in Z_k} \sum_l (D_{l,i} - G_{l,i})}$$

$$R = \sum_l \mathrm{R}_l = \sum_k \sum_{i \in Z_k} \lambda_i (D_i - G_i) = \sum_i \lambda_i (D_i - G_i)$$

l : SC index $\quad$ Z_k : set of nodes in zone k

k : zone index $\quad$ $\lambda_{l,i}$: nodal price

i : node index $\quad$ $\lambda_{l,k}$: zonal price

D : demand $\quad$ G : generation

Revenue Adequacy

$$R = \sum_{l} R_l = \sum_{j} \mu_j P_{j\max} = \sum_{i} \lambda_i (D_i - G_i)$$

l: SC index

i: node index

j: zonal interface index

Congestion Management and Pricing

Congestion Pricing

- Fundamental Assumptions:
  - Inter-zonal congestion:
    - relatively frequent; global effect; high cost
    - marginal pricing
    - congestion revenue allocated to TCCs
  - Intra-zonal congestion:
    - infrequent; local effect; low cost
    - cost-based (pay as bid) pricing
    - congestion cost rolled in as a zonal uplift

Inter-Zonal CM

- Fundamental Assumptions:
  - It is performed over the whole network.
  - It has a minimum cost objective.
  - SC portfolios are kept in balance.
  - SC portfolios are not optimized within zones.
  - Only inter-zonal constraints are monitored.
  - Lossless linear network models are used.

Inter-Zonal CM Algorithm

$$\min \sum_{l=1}^{L} \sum_{i=1}^{N} C_{l,i} \Delta P_{l,i}$$

$$s.t. \quad \mathbf{B}'\Delta\delta = \Delta\mathbf{P}$$

$$\mathbf{F}\delta \leq \mathbf{P}_{F\max}$$

$$P_{l,i\min} \leq P_{l,i} \leq P_{l,i\max} \qquad \therefore l = 1,2,\dots,L; i = 1,2,\dots,N$$

$$\sum_{i=1}^{N} \Delta P_{l,i} = 0 \qquad \therefore l = 1,2,\dots,L-1$$

P: power injection

$\mathbf{P}$: nodal power injection vector

$\mathbf{B}'$: linearized Jacobian

$\mathbf{F}$: branch power flow coefficient matrix

δ : voltage phase vector

l: SC index

i: node index

c: inc.bid

$\mathbf{P}_{F\max}$: branch power flow limit vector

Intra-Zonal CM

- Fundamental Assumptions:
  - In is performed for each zone separately.
  - It has an “economic” minimum shift objective.
  - Only zonal resources are used and pooled.
  - Only zonal constraints are monitored, including zonal ties and interfaces.
  - Lossless linear network models are used.

Intra-Zonal CM Algorithm

$$\min \sum_{i=1}^{N} (c_i^+ \Delta P_i^+ + c_i^- \Delta P_i^-)$$

$$s.t.\ \mathbf{B}'\Delta\delta = \Delta\mathbf{P}$$

$$\mathbf{F}\delta \le \mathbf{P}_{F\max}$$

$$P_{i\min} \le P_i = P_i^+ - P_i^- \le P_{i\max} \qquad \therefore i = 1, 2, \ldots, N$$

$$\Delta P_i^+ \ge 0, \Delta P_i^- \ge 0 \qquad \therefore i = 1, 2, \ldots, N$$

$$c_i^+ \ge 0, c_i^- \ge 0 \qquad \therefore i = 1, 2, \ldots, N$$

P: power injection

$\mathbf{P}$: nodal power injection vector

$\mathbf{B}'$: linearized Jacobian

$\mathbf{F}$: branch power flow coefficient matrix

i: node index

c: cost coefficients

$\mathbf{P}_{F\max}$: branch power flow limit vector

δ : voltage phase vector