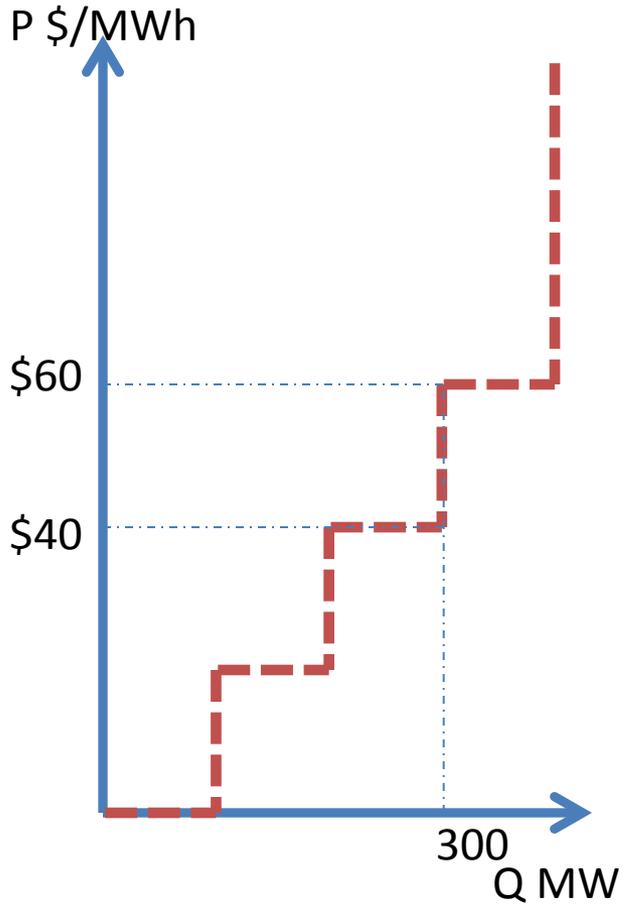# Finding Unique Prices Under Degeneracy

B.F. Hobbs
Chair, CAISO MSC
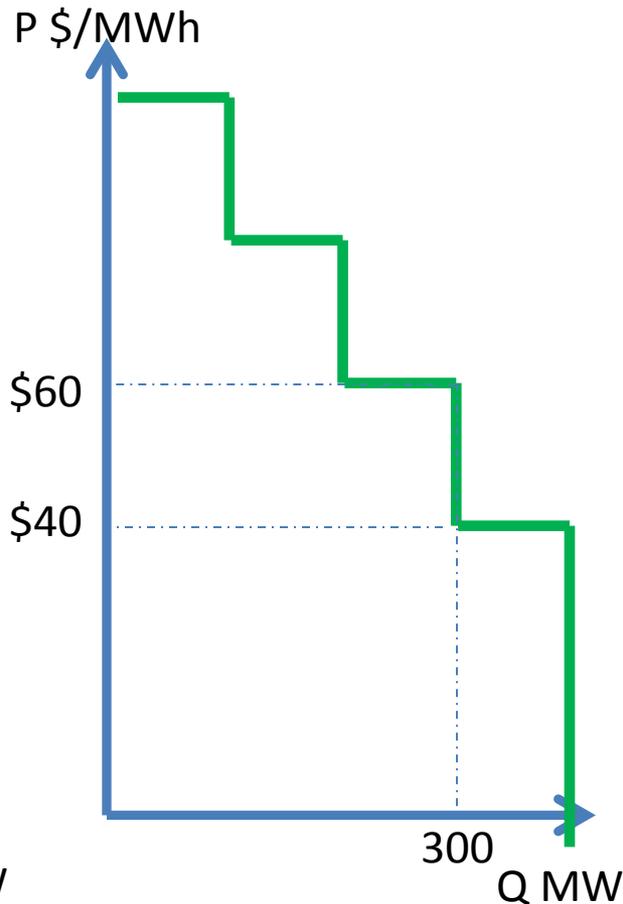
Market Surveillance Committee Meeting
General Session
October 15, 2014

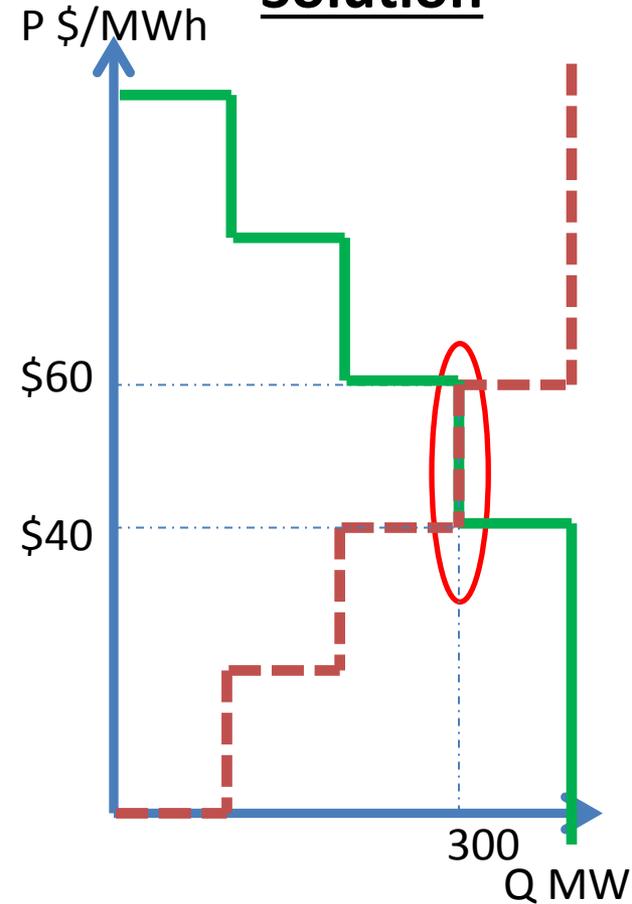# Example 1

Supply
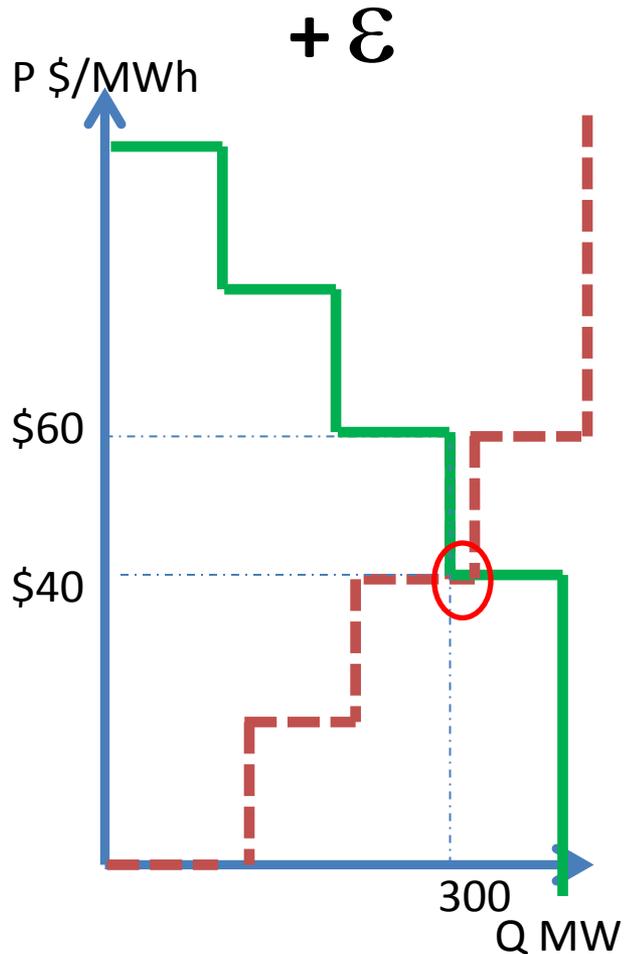
P $/MWh

Q MW

300

Demand

P $/MWh

$60

$40

300

Q MW

Market Clearing Solution

P $/MWh

$60

$40

300

Q MW

- *Unique schedule*
- *Multiple prices*

Solution 1: Permute Constraint by +/- ε: Load – Gen = +/- ε

+ ε

P $/MWh
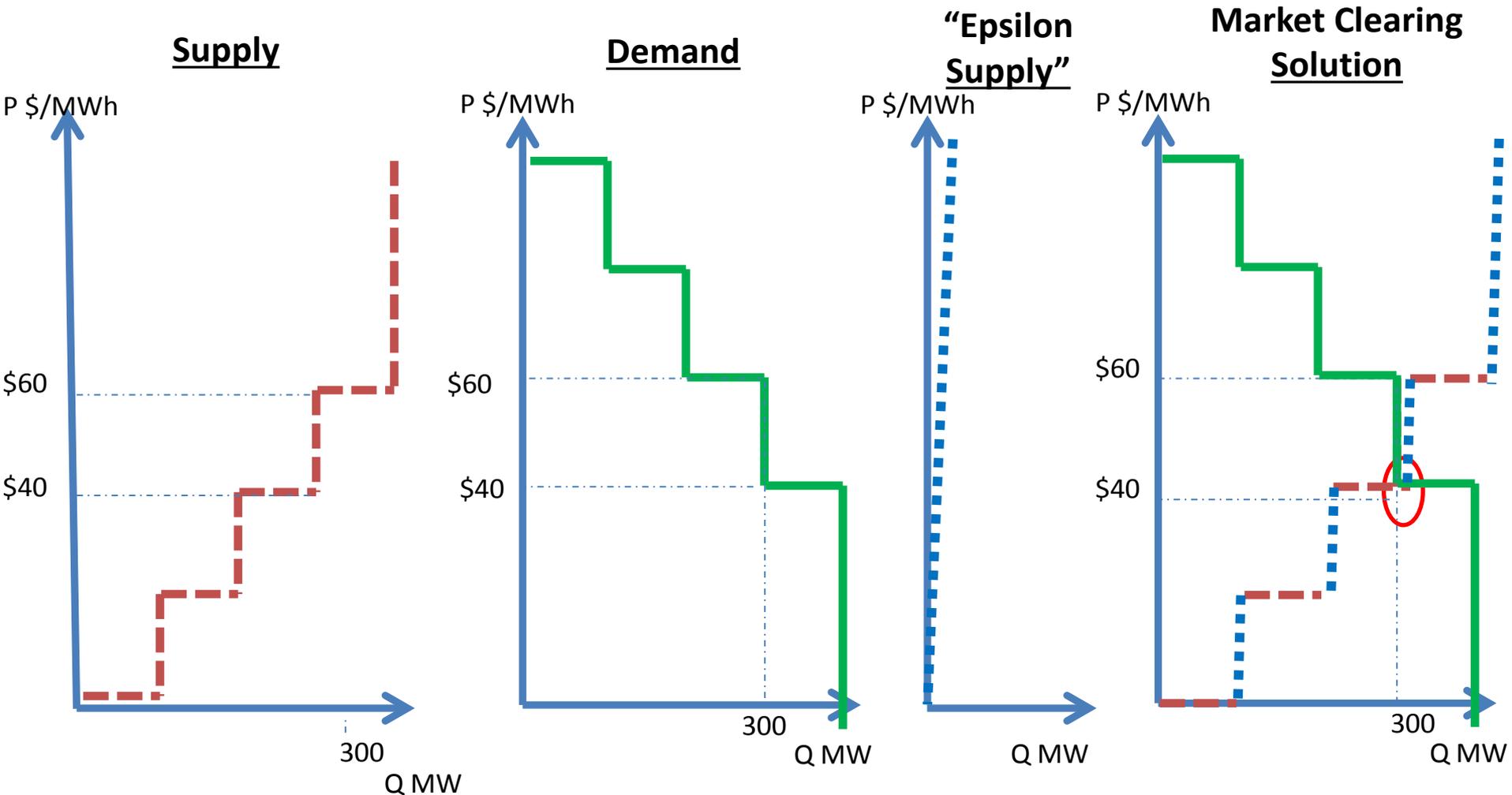
$60

$40

300

Q MW

- ε

P $/MWh

$60

$40

300

Q MW

- *Unique price favors load*
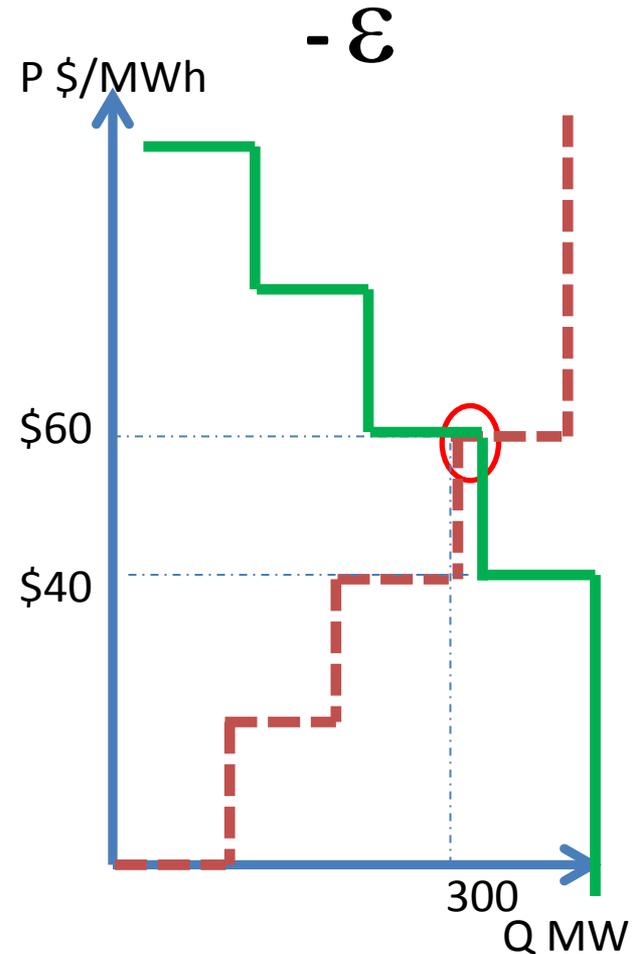
- *Unique price favors gen*

Solution 2: Add "Slope" By Creating Slack (Artificial Supply) with Quadratic Penalty

Supply — P $/MWh, Q MW, $60, $40, 300

Demand — P $/MWh, Q MW, $60, $40, 300

"Epsilon Supply" — P $/MWh, Q MW

Market Clearing Solution — P $/MWh, Q MW, $60, $40, 300

- *Changes linear program → nonlinear program*
- *Unique price favors load*
- *Larger "epsilon" makes it more likely that sloped part sets price*
- *If instead use "artificial load", this would favor gen (reverse effect)*

Example 2

300 MW Flow Limit

A — B

P $/MWh

$40

300
Q MW

P $/MWh

$60

200

400 MW
Load
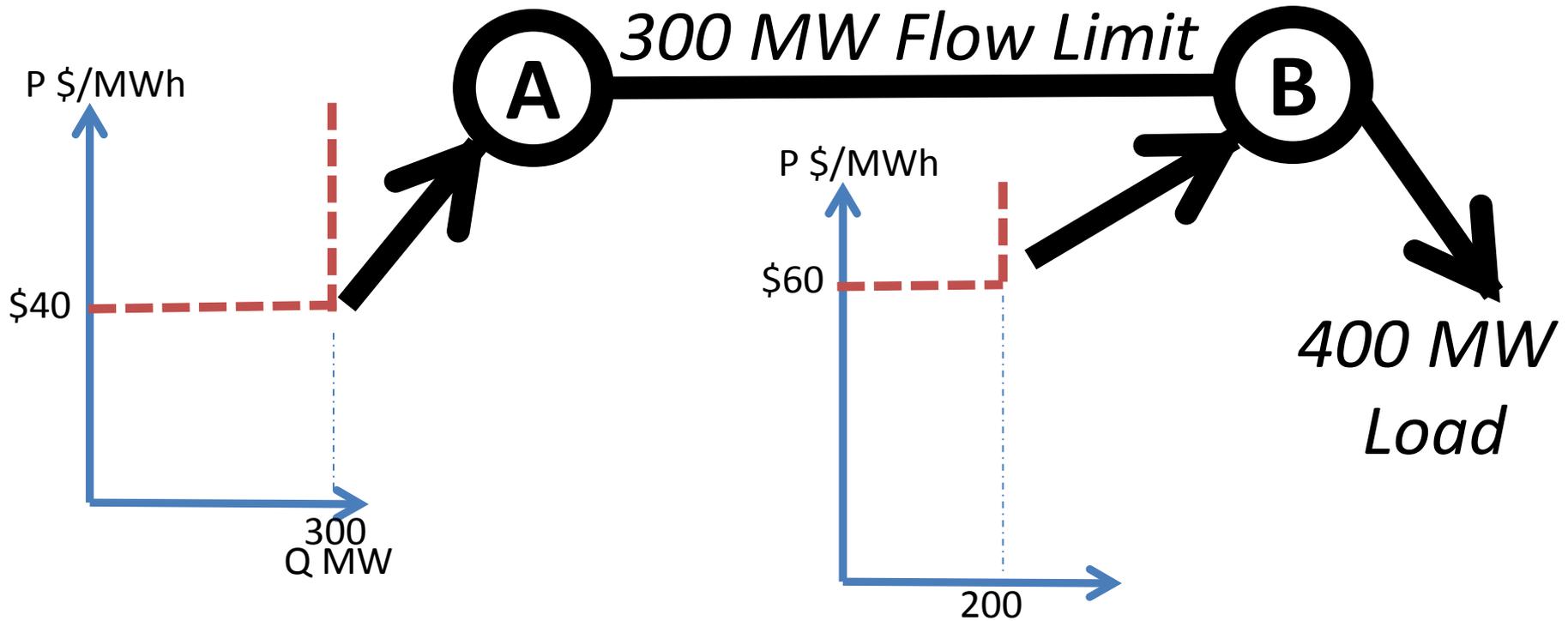
Because of A & line capacity coincide → multiple price solutions:

- LMP$_A$ = $40, Shadow price of line = $20
- LMP$_A$ = $60, Shadow price of line = $0

Permutation or artificial supply/load will yield unique prices.

Will favor either: Gen A (& counterflow CRR holders) …

… OR load (& with-flow CRR holders)

Conclusion

- Can eliminate degeneracy (multiple prices) via:
  - constraint permutation *or*
  - nonlinear penalty (artificial supply/demand)
- Depending on how permutation/penalty defined and which constraint is involved, can favor different parties (gen, load, CRR holders)
  - There's no *a priori* "neutral" resolution
  - Transparency of formulation and impacts desirable