Price Effects of Real-Time Market Pricing Run Parameters

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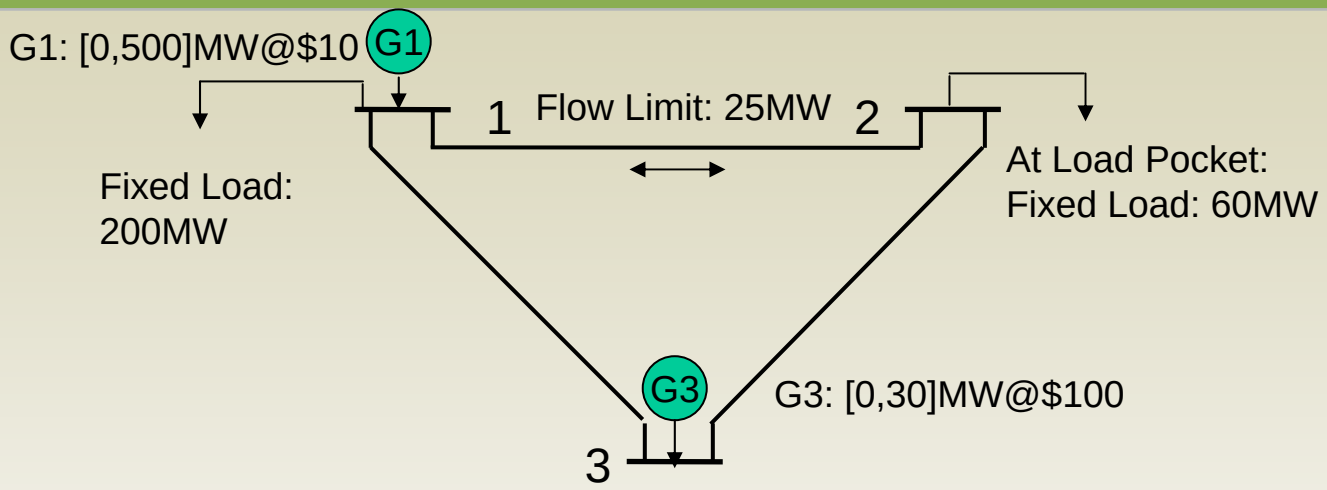
Topics of Presentation

- Pricing outcomes using the Energy Bid Cap, currently $500/MWh, as pricing run parameter in RTM on the relaxed transmission constraint.
- Pricing outcomes using the Energy Bid Cap, currently $500/MWh, as pricing run parameter in RTM on the relaxed power balance constraint.

Pricing Outcome in Pricing Run under Transmission Constraint Relaxation

- Under transmission constraint relaxation in scheduling run, shadow price of relaxed constraints in pricing run will be as low as possible but no less than the pricing run parameter nor less than the last economic signal prior to constraint relaxation in scheduling run.
- “Last economic signal” with respect to a relaxed transmission constraint means the (highest) shadow price of the constraint determined by the economic bids for resolving constraint violation right before relaxation.
- The CAISO has proposed to change the early proposed $1500 to the Energy Bid Cap, currently $500, as the RTM pricing run parameter.
- Next two examples demonstrate such results under RTD (Real-Time Dispatch).

Example 1: Real Time Price Effects under Relaxation of Transmission Constraint into Load Pocket

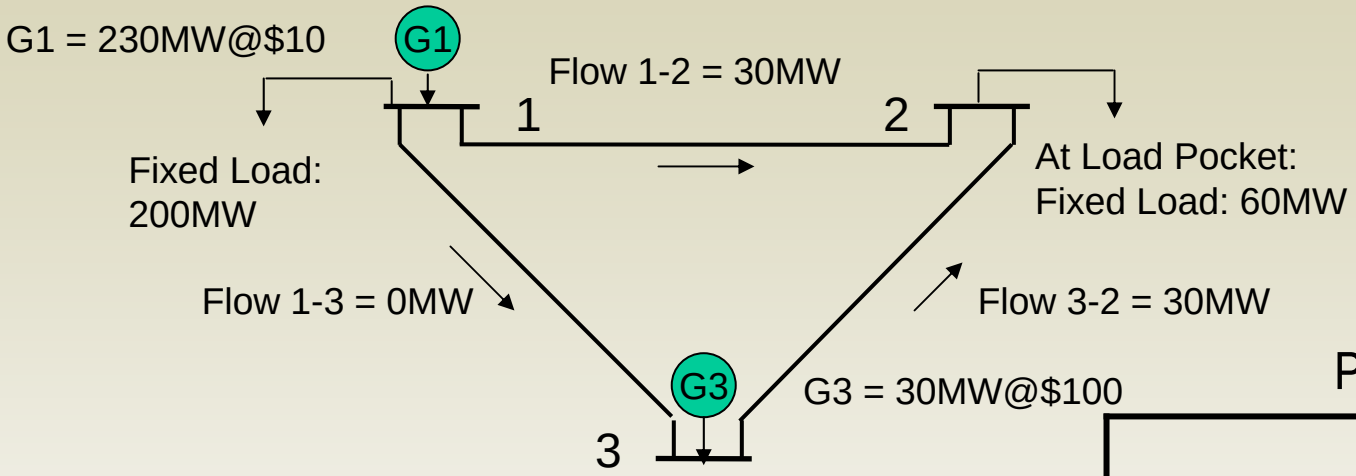


- Flow constraint for line 1–2, load pocket at bus 2 and small generating capacity for G3. All 3 lines are equal in reactance and lossless.
- Fixed RT Load and small G3 capacity cause 5MW constraint relaxation and resulting flow on line 1→2 is 30MW.
- Additional capability of G3 could reduce the flow violation by 1/3MW per MW supply shift from G1 to G3.

Scheduling Run Results

G1	230MW
G3	30MW
Flow 1 → 2	30MW (5MW relaxation)
Flow 1 → 3	0MW
Flow 3 → 2	30MW

Example 1: Real Time Price Effects under Relaxation of Constraint into Load Pocket – Continued

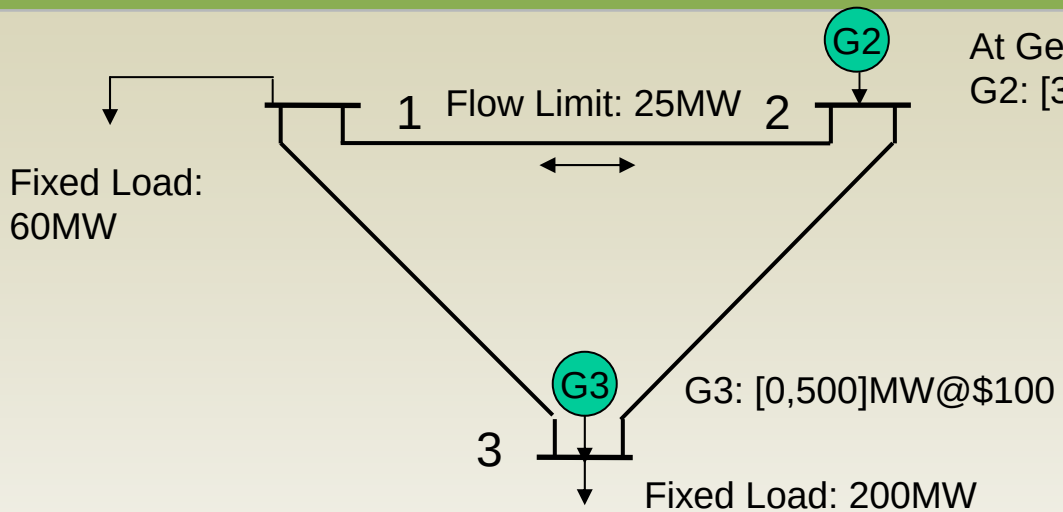


- Pricing run results compare pricing parameters of $500 and $1500.
- G1 is marginal setting LMP1 at $10 in both cases.
- Because 1 MW supply shift from G1 to G3 reduces 1→2 flow by 1/3 MW, we calculate LMP3 under $500 pricing parameter value as follows: 3*(LMP3-LMP1) = $500
- $500 parameter value in comparing with the early proposed $1500 reduces LMP2, LMP3 and LAP price.

Pricing Run Results

	$500 for Parameter	$1500 for Parameter
LMP1	$10	$10
LMP2	$343.33	$1010
LMP3	$176.67	$510
LAP Price	$86.92	$240.77
Shadow Price	$500	$1500
Marginal Resources	G1, slack variables	G1, slack variables

Example 2: Real Time Price Effects under Relaxation of Transmission Constraint out of Generation Pocket

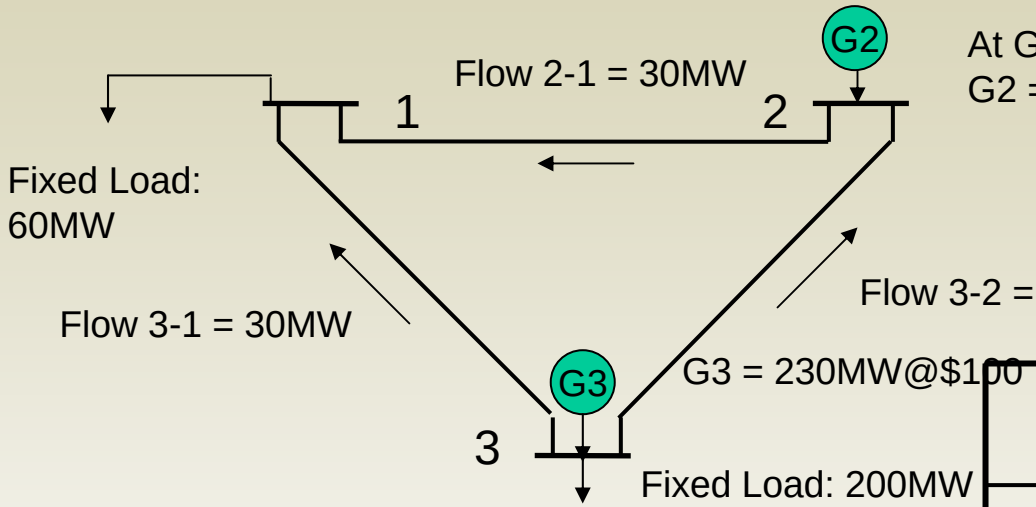


- Generation pocket at bus 2 and 30MW non-zero minimum generation for G2
- Fixed RT Load and G2 min gen limit cause 5MW relaxation of transmission constraint and resulting 2 → 1 MW flow is 30MW.
- Min gen on G2 is hard constraint. However, for min gen of G2 at some lower value, flow violation can be further reduced at a rate of 1/3MW per MW supply shift from G2 to G3.

Scheduling Run Results

G2	30MW
G3	230MW
Flow 2 → 1	30MW (5MW relaxation)
Flow 3 → 1	30MW
Flow 3 → 2	0MW

Example 2: Real Time Price Effects under Relaxation of Constraint out of Gen Pocket - Continued



- Pricing run results are compared between the use of pricing parameters of $500 and $1500.
- G3 is marginal setting LMP3 at $100 for both cases.
- Because 1 MW supply shifting from G2 to G3 reduces 2 →1 flow by 1/3 MW, we calculate LMP2 under $500 parameter value as follows: 3*(LMP3-LMP2) = $500
- $500 parameter value in comparing with the early proposed $1500 reduces LMP1 and LAP price and causes LMP2 less negative.

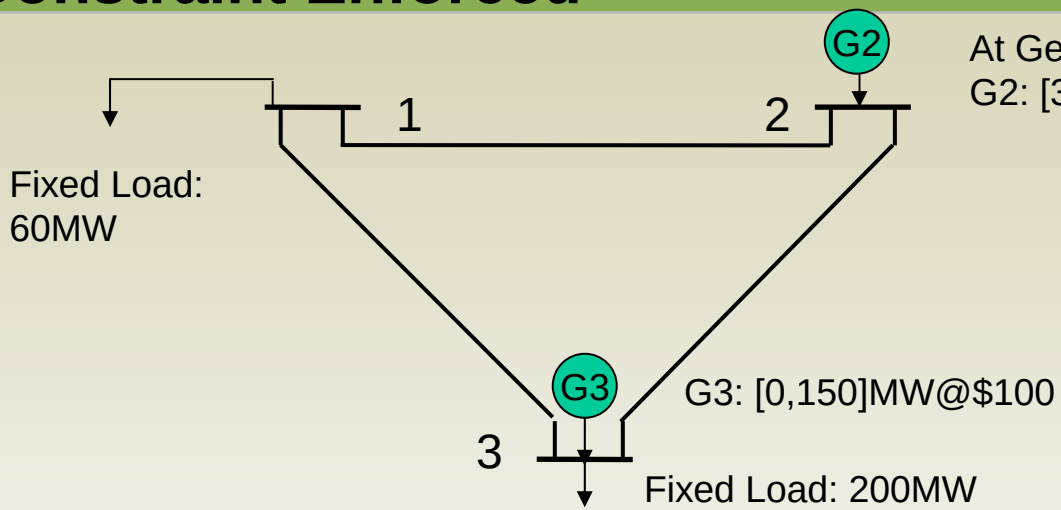
Pricing Run Results

	$500 for Parameter	$1500 for Parameter
LMP1	$266.67	$600
LMP2	-$66.67	-$400
LMP3	$100	$100
LAP Price	$138.46	$215.38
Shadow Price	$500	$1500
Marginal Resource	Slack Variable, G3	Slack Variable, G3

Pricing Outcome in Pricing Run under Power Balance Constraint Relaxation

- Under power balance constraint relaxation for supply shortfall in scheduling run, shadow price of constraint in pricing run, also known as the system LAP price, will be as low as possible but no less than the pricing run parameter nor less than the last economic signal prior to constraint relaxation in scheduling run.
- The CAISO has proposed to change the early proposed $1500 to the Energy Bid Cap, currently $500, as the RTM pricing run parameter.
- Next two examples demonstrate that pricing run shadow prices are set by the parameter value.
- In conjunction with transmission constraint relaxation and/or the binding of resource ramping constraint, shadow price of power balance constraint could possibly rise above the parameter value. Final example demonstrates such pricing outcome.

Example 3: Real Time Price Effects under Relaxation of Power Balance Constraint with no Transmission Constraint Enforced

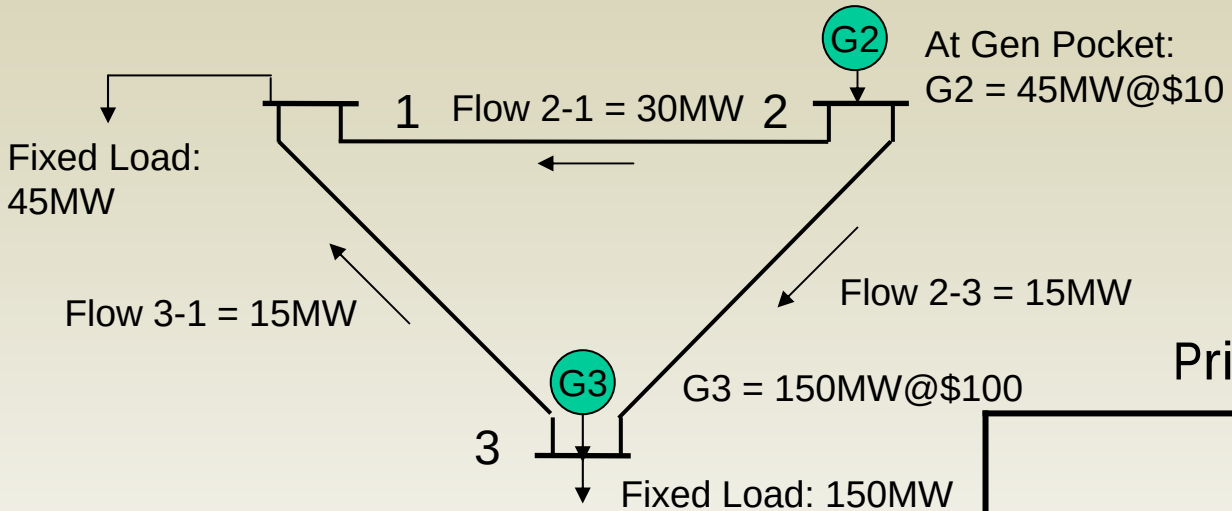


- Bid max of G2 and G3 are reduced respectively to 45 and 150MW from previous example resulting in supply deficiency. Transmission constraint on line 1-2 not enforced.
- Total energy supply of 195MW could not meet 260MW total fixed load.
- Power balance constraint is relaxed by 65MW, representing a proportional reduction of loads by 25% each.

Scheduling Run Results

G2	45MW
G3	150MW
Flow 2 → 1	30MW
Flow 3 → 1	15MW
Flow 2 → 3	15MW
Total Load Served	195MW (65MW relaxation)

Example 3: Real Time Price Effects under Relaxation of Power Balance Constraint with no Transmission Constraint Enforced - Continued

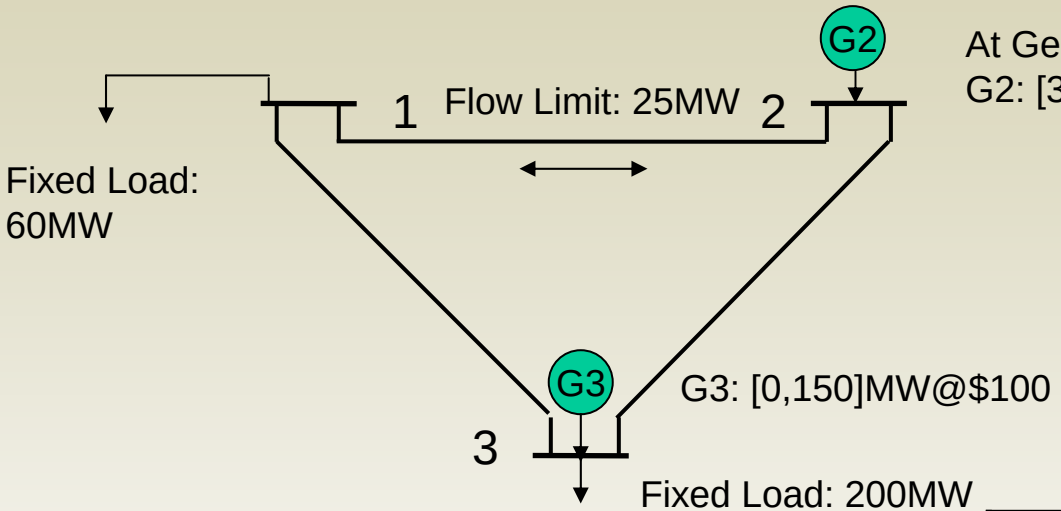


- Pricing results using $500 and $0 (for last economic signal prior to relaxation) as pricing parameter are presented for comparison.
- $500 parameter value raises the shadow price above the last economic signal for this example, setting LMPs for all buses and LAP price at $500.

Pricing Run Results

	$500 for Parameter	$0 for Parameter
LMP1	$500	$100
LMP2	$500	$100
LMP3	$500	$100
LAP Price	$500	$100
Shadow Price	$500	$100
Marginal Resource	Slack Variable	G3

Example 4: Pricing Outcomes under Simultaneous Relaxations of Power Balance and Transmission Constraints

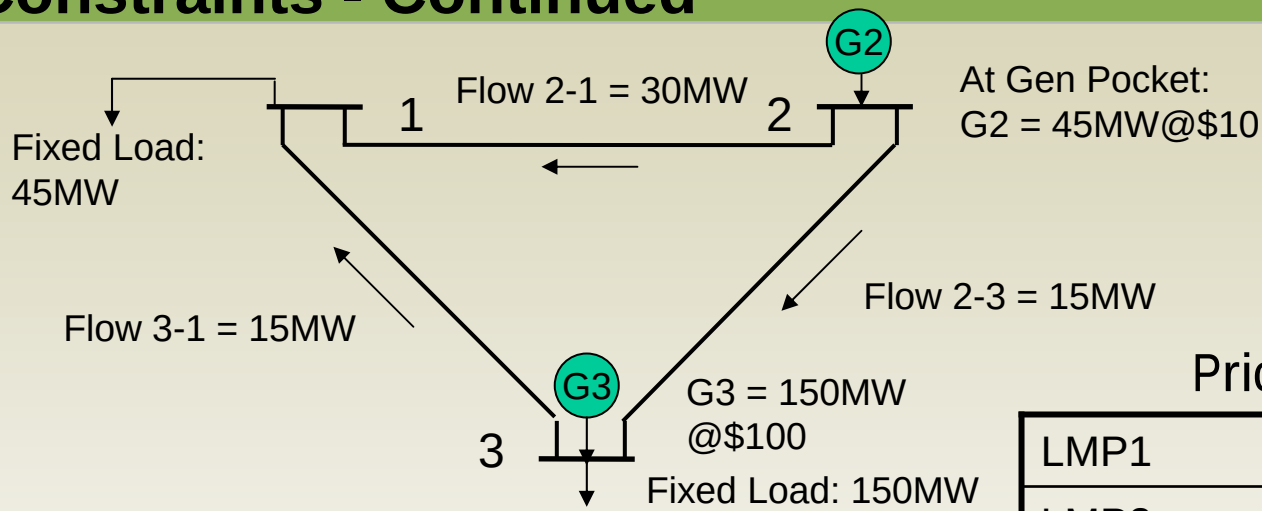


- Same setup as previous example but with flow limit of line 1-2 enforced.
- With $5000 and $6500 for scheduling run penalty prices respectively for transmission constraint and power balance constraint relaxations, transmission constraint is relaxed as much as possible to allow all available supply from G2 to serve loads.
- Power balance constraint is then relaxed by 65MW, to make up of the energy supply shortfall.

Scheduling Run Results

G2	45MW
G3	150MW
Flow 2 → 1	30MW (5MW relaxation)
Flow 3 → 1	15MW
Flow 2 → 3	15MW
Total Load Served	195MW (65MW relaxation)

Example 4: Real Time Price Effects on Simultaneous Relaxations of Power Balance and Transmission Constraints - Continued

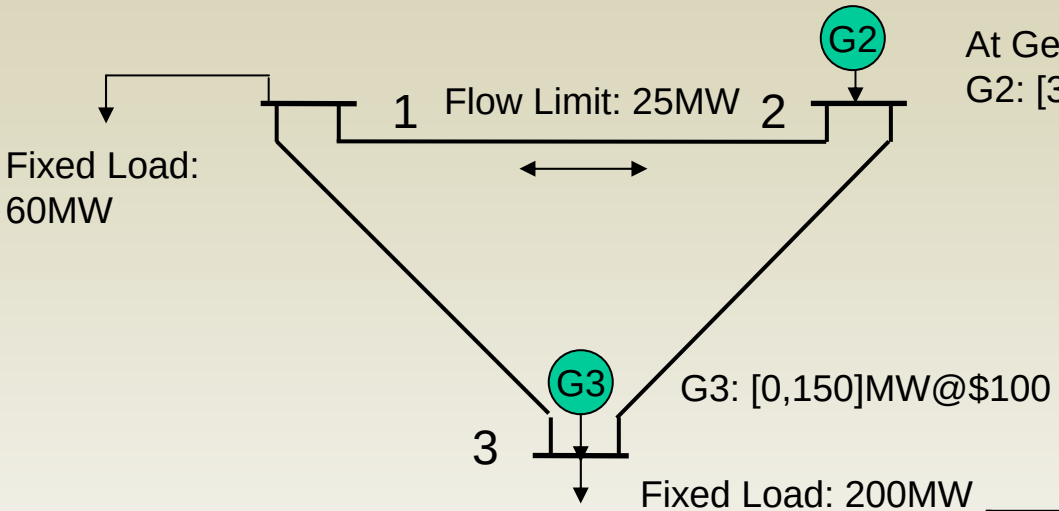


- $500 is used as pricing run parameter for the relaxations of both types of constraints.
- Slack variables of the two relaxed constraints are both marginal, setting shadow prices at parameter value.
- Comparing transmission constraint relaxation with no transmission constraint enforced in previous example, LMP1 is higher while LMP2 and LMP3 are lower. LAP Price remains at $500.
- LAP price could be above $500 depending on the transmission constraint location and resource bid prices.

Pricing Run Results

LMP1	$628.21
LMP2	$294.87
LMP3	$461.54
LAP Price	$500
Shadow Price of Transmission	$500
Shadow Price of Power Balance	$500
Marginal Resources	Both Slack Variables

Example 5: Real Time Price Effects on Simultaneous Relaxations of Power Balance and Transmission Constraints

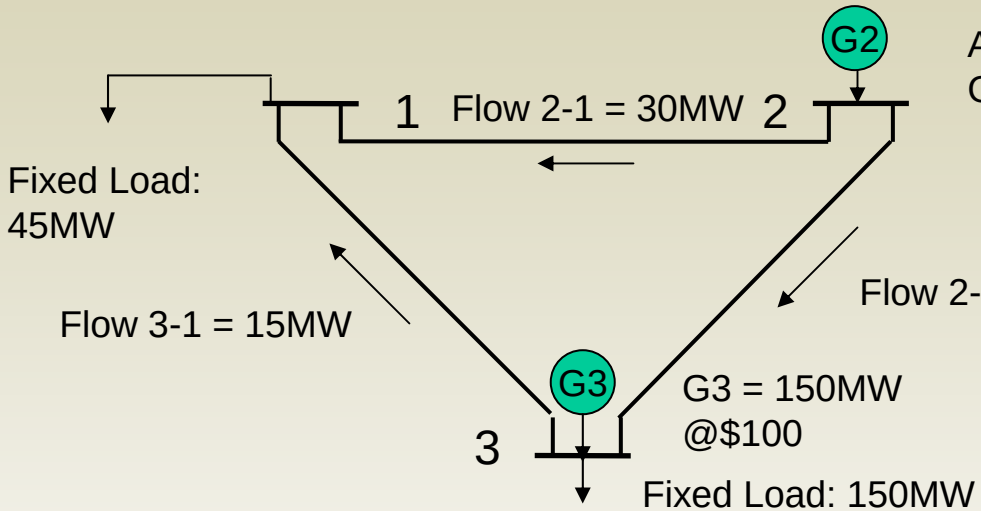


- Same setup as previous example but with bid price of G2 increased to $400
- Scheduling results are the same as the previous example

Scheduling Run Results

G2	45MW
G3	150MW
Flow 2 → 1	30MW (5MW relaxation)
Flow 3 → 1	15MW
Flow 2 → 3	15MW
Total Load Served	195MW (65MW relaxation)

Example 5: Real Time Price Effects on Simultaneous Relaxations of Power Balance and Transmission Constraints - Continued



- G2 is the marginal, setting LMP2 at $400. Slack variable of the transmission constraint is marginal, setting the constraint shadow price at $500.
- The two marginal resources set the shadow price of the power balance constraint, also known as the system LAP price, to $605.13, above the $500 pricing run parameter for this constraint.

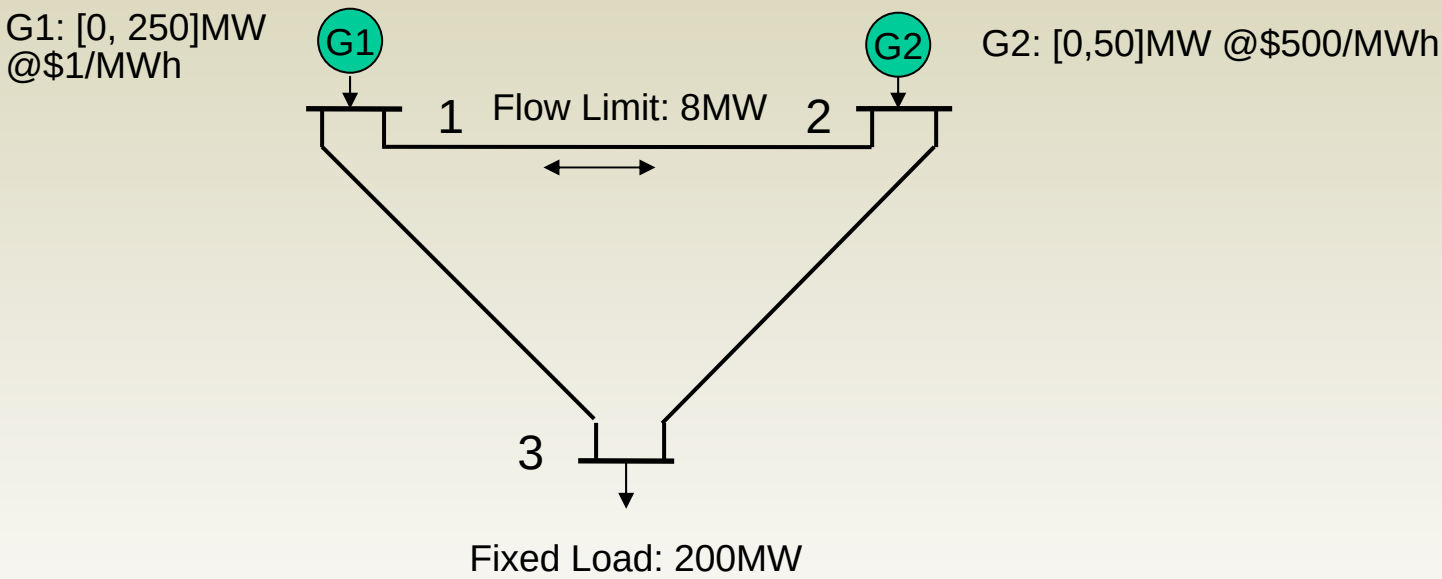
Pricing Run Results

LMP1	$733.33
LMP2	$400
LMP3	$566.67
LAP Price	$605.13
Shadow Price of Transmission	$500
Shadow Price of Power Balancing	$605.13
Marginal Resources	Slack Variable of Transmission Constraint, G2

Appendix

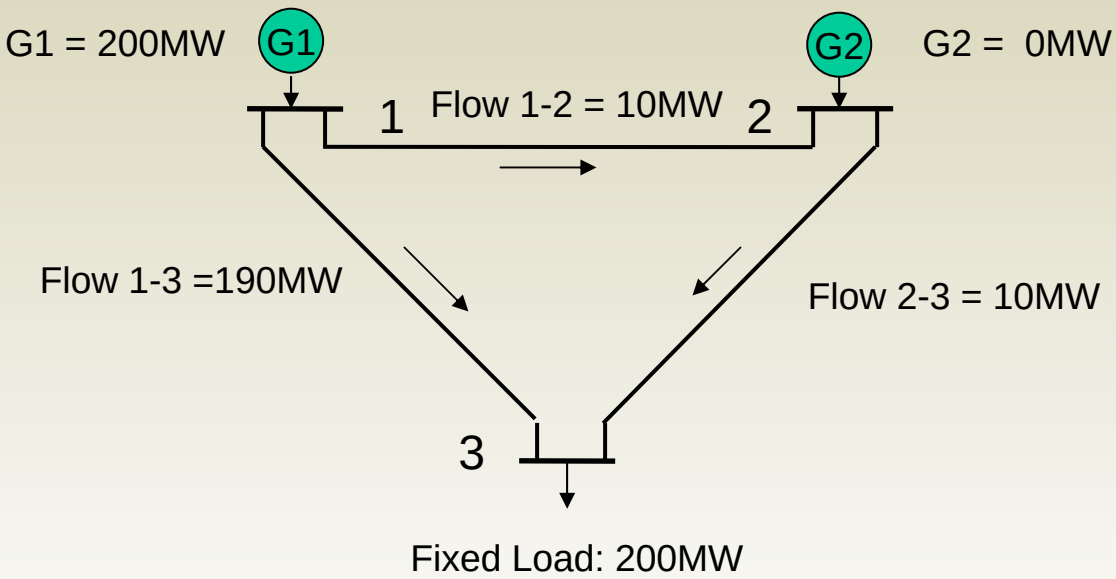
Appendix presents an example demonstrating very high shadow price for a binding transmission constraint but with much lower LMP differential across.

Example Demonstrates High Transmission Constraint Shadow Price But with Much Lower LMP Differential Across



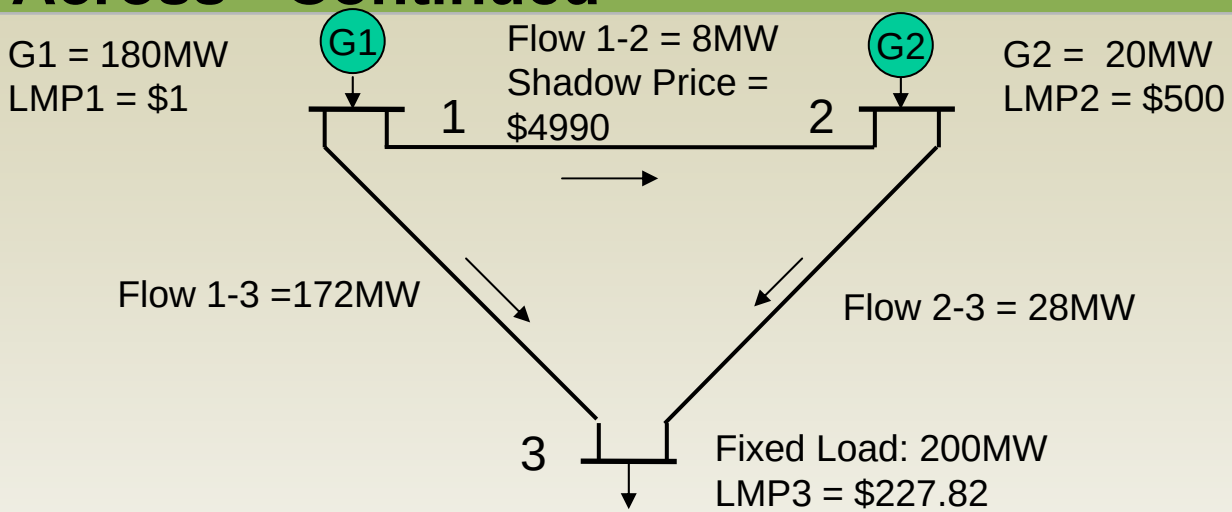
- The reactance ratios of the three transmission lines 1-2, 1-3 and 2-3 are 18 : 1 : 1 and the transmission lines are assumed loseless.

Example Demonstrates High Transmission Constraint Shadow Price But with Much Lower LMP Differential Across - Continued



- Without enforcing transmission constraint, optimal schedule: G1 = 200MW and G2 = 0MW
- G1 is the only marginal resource, setting LMPs of all buses at $1.

Example Demonstrates High Transmission Constraint Shadow Price But with Much Lower LMP Differential Across - Continued



- To resolve congestion, energy supply is shifted from inexpensive G1 to expensive G2. Due to high reactance ratio of 18:1:1 between line 1-2 and the other two lines, only 1/10MW of flow violation reduction is realized per MW supply shifting from G1 to G2. For flow violation 2MW, required MW shifting is 20MW. Adjustment between G1 and G2 is ineffective to resolve congestion.
- G1 and G2 are marginal, setting LMPs of their locations at $1 and $500 respectively.
- Shadow price of transmission constraint of line 1-2 is $4990. Per MW increase in line limitation, 10MW can be shifted from G2 to G1 for 10*($500-$1) = $4990 system cost saving.
- LMP3 for the fixed load is $250.5. For 1MW load increase at bus 3, 1MW increase from G1 to supply load will result in system cost increase by $1 and flow violation by 0.05MW. Shifting 10*0.05 MW supply from G1 to G2 to resolve congestion will cost the system additional $499*0.5 = $249.5