Discussion Examples for Sequential and Combined IFM -RUC

Scott Harvey

Member California ISO Market Surveillance Committee

Folsom California

August 14, 2019

Sequential and Combined IFM-RUC Designs

These slides develop examples of the operation of alternative Option 1 sequential IFM RUC designs, comparing their operation to an Option 2 combined IFM RUC design with the goal of illustrating several important differences.

- It is envisioned that these slides will not be presented at the August 19 California ISO Market Surveillance Committee meeting. Instead, the discussion on August 19 could take into account the implications of the differences illustrated in these slides.
- While we have identified five options for sequential IFM RUC designs, these examples focus on three of these options.

Sequential IFM-RUC Designs

We have identified five alternative versions of an option 1 Sequential IFM-RUC designs.

- Option 1A: Separate IFM and RUC passes with flexible capacity scheduled in the IFM pass, and RUC capacity scheduled in a separate RUC pass. This corresponds to the current design.
- Option 1B: IFM pass which schedules flexible capacity to meet a projected combination of RUC – FMM uncertainty and IFM to RUC uncertainty, based on the historical differences between IFM cleared generation and FMM net load forecast. There would be a separate RUC evaluation that would test the deliverability and adequacy of the scheduled flexible capacity in meeting the RUC load forecast. This is the sequential IFM design described in CAISO materials.

FTI CONSULTING

Sequential IFM-RUC Designs

- Option 1C: IFM pass which schedules flexible capacity to meet projected RUC forecast – FMM uncertainty and the actual difference between IFM cleared generation and the RUC load net load forecast. There would be a separate RUC evaluation that would test the deliverability of the scheduled flexible capacity in meeting the RUC load forecast.
- Option 1D: The IFM would consist of separate bid load and forecast load unit commitment and dispatch pass, with flexible capacity and energy cleared in the bid load pass and additional capacity above that dispatched in the bid load pass cleared as reliability capacity (RCU) in the forecast load pass.

Sequential IFM-RUC Designs

- Option 1E: The IFM would have separate bid load and forecast load unit commitment and dispatch passes as under Option 1D, followed by a final bid load dispatch pass in which any long start resources committed in the forecast load pass would be blocked on at minimum load and dispatched to meet bid load and provide flexible capacity. The difference between the energy and flexible capacity cleared in the bid load redispatch pass and the dispatch in the forecast load pass would be cleared as reliability capacity (RCU).

All five versions of these “sequential IFM RUC” designs, co-optimize the scheduling of energy, flexible capacity (imbalance reserves), and other ancillary services. The only element that is potentially sequential is the scheduling of reliability capacity (RUC capacity).

Combined IFM-RUC Designs

The essence of the option two design is that instead of first clearing the IFM against bid load, then evaluating the system's ability to meet forecast load, and potentially committing and scheduling additional resources in a separate RUC process, the combined design commits and schedules resources to minimize the combined cost of both meeting bid load and having the resources available that would be needed to meet forecast load.

- The combined solution therefore must solve two distinct load flows to analyze transmission constraints and enforces two distinct load balance equations.
- The market solves for a single unit commitment of long start physical resources to meet these two loads. As the CAISO develops this approach it may identify other links between the operation of physical resources dispatched to meet bid load and/or forecast load that need to enforced in order to meet reliability needs.

Sequential IFM-RUC Designs

These examples illustrate eight observations regarding designs 1B, 1D and 2.

1. The requirement that forecast load be met with flexible capacity that is dispatchable in a 15 minute time frame increases the cost of meeting load and prices under option 1B. This requirement is not an inherent feature of Option 1B and relaxing it to allow forecast load be met with reliability capacity dispatchable in an hourly timeframe leads to prices and schedules that are more consistent with the optimum.

2. Because Option 1B schedules resources to meet forecast load based on flexible capacity zones, rather than the location at which forecast load must be met, there is a potential that option 1B will schedule either flexible capacity or reliability capacity at locations where it cannot be dispatched to meet forecast load.

Sequential IFM-RUC Designs

3. Because the amount of flexible or reliability scheduled to meet forecast load under option 1B is based on historical data, it will inevitably either often be too low, requiring that additional capacity be scheduled in the RUC pass, essentially reverting to option 1A, the current design; or it will often schedule too much capacity, inefficiently inflating costs and prices.
4. Option 1D will schedule the appropriate amount of reliability capacity at locations where it can be dispatched to meet forecast load, but requires 2 passes.

FTI™ CONSULTING

Sequential IFM-RUC Designs

5. If there are no long start resources that need to be committed, Option 1D will generally produce schedules for energy, flexible capacity and reliability capacity that are very similar to option 2. However, there will generally be at least small inconsistencies between the prices of energy and flexible capacity determined in the IFM pass and the price of reliability capacity determined in the forecast load pass. Under tight high load conditions these price inconsistencies can be large if a material amount of reliability capacity needs to be scheduled. Such large potential pricing inconsistencies would likely introduce inefficient bidding incentives during these conditions.
6. Option 2, the combined IFM RUC will schedule the resources needed to meet forecast load at locations at which it can be dispatched to meet forecast load with settlement prices that will be consistent with offers, bids and schedules.

Sequential IFM-RUC Designs

7. The ISO's load forecast will impact IFM prices for energy and flexible capacity as well as reliability capacity under option 2. Precisely because these prices are consistent with bids, offers and schedules, a high load forecast can lead to high energy and flexible capacity prices.

8. Under all of these designs, if reliability capacity can only be scheduled to meet forecast load on internal resources, and hence imports of energy but not of reliability capacity can be scheduled on the interties to meet forecast load, this restriction would have the potential to result in very high prices under tight market conditions if the ISO's load forecast requires scheduling imported energy. It would therefore be desirable to develop a design under any of the options that allows reliability capacity to be scheduled in the interties. This option, however, introduces many complications regarding performance obligations and settlements.

Example Overview

- The examples have California load and generation at two locations, A and B, with a potentially binding transmission constraint between these locations.
- It is assumed that locations A and B are within the same ancillary service zone so capacity at either location could be used to meet the flexible capacity requirement.
- Import supply is also available to meet load at B.

Example Overview

- Units available to meet incremental load at A and B have minimum load blocks. The minimum load blocks of resources that are scheduled for energy in the IFM are shaded red, as is the amount of incremental energy output above minimum load that clears in the IFM.
- The amount of flexible capacity (FRU) cleared in the IFM or reliability capacity (RCU) cleared to meet forecast load is also shown in red.
- We initially assume that none of the resources at A or B are long start resources, assuming that they can be started and ramped to full load within an hour.
- We then relax this assumption and assume that all of the resources with minimum load blocks are long start units.

Example Overview

These slides contain two examples. The first example is a base case, moderate load example.

The second example is a high load high gas price scenario in which imports must be scheduled to meet the RUC load forecast.

- We consider two versions of the high load example.
- In the first version, energy imports can be scheduled to meet forecast load, but all reliability capacity must be scheduled on units internal to the CAISO.
- In the second version, imports of reliability capacity can be scheduled to meet forecast load, in addition to energy imports scheduled to meet bid load.

Example Overview

Both the base case and high load examples cover a single hour and do not include virtual bids.

- The intent is to keep the examples simple so we can focus on how particular elements of these designs would operate.
- The units available to meet incremental load at A and B have minimum load blocks, but we initially assume that they are not long start resources and can be started and ramped to full load within an hour.

Example Overview

The base case example illustrates the operation of sequential and combined IFM-RUC day-ahead market designs on a day in which there is no need to procure high cost imports to meet CAISO load.

- Sequential option 1B produces different schedules and higher prices than the other approaches because flexible capacity, rather than reliability capacity, must be scheduled to meet forecast load .
- Sequential option designs 1D and 1E produce schedules corresponding to those in the combined IFM-RUC design and similar, but slightly different prices. The prices determined in the scheduling pass under options 1D and 1E have small inconsistencies resulting from the sequential determination of energy and reliability capacity schedules.

Example Overview

The second example is a high gas price, high load scenario. We work through two versions of this example.

- In the first version, only energy imports and reliability capacity on internal capacity can be scheduled to meet forecast load in excess of IFM cleared load.
- In the second version, forecast load can be met either with reliability capacity scheduled on internal resources or with imports of reliability capacity.

The sequential option 1D and 1E designs produce schedules that are very similar to the combined IFM RUC design in the both versions of the high load case but the sequential design produces materially different prices for energy and flexible capacity, than the option 2 design, particularly in the first version of the high load case.

FTI CONSULTING

Base Case Example

The base case example portrays the operation of sequential options 1B, 1D and 1E as well as the combined IFM-RUC design.

- Option 1A would produce the same IFM schedules as option 1D and have RUC schedules instead of reliability capacity schedules.

- Options 1B and 1C are the same in these examples because we assume that the option 1B solution covers the actual RUC load forecast, although this is not necessarily the case.

Base Case Example

The base case example assumes that the CAISO would schedule 500 megawatts of flexible capacity in the IFM in addition to any capacity scheduled to meet forecast load.

- Under Option 1B and 1C, additional flexible capacity would be scheduled to meet forecast load.
- Under Option 1D, 1E and option 2, only 500 megawatts of flexible capacity would be scheduled. Any additional capacity needed to meet forecast load would be scheduled as reliability capacity.

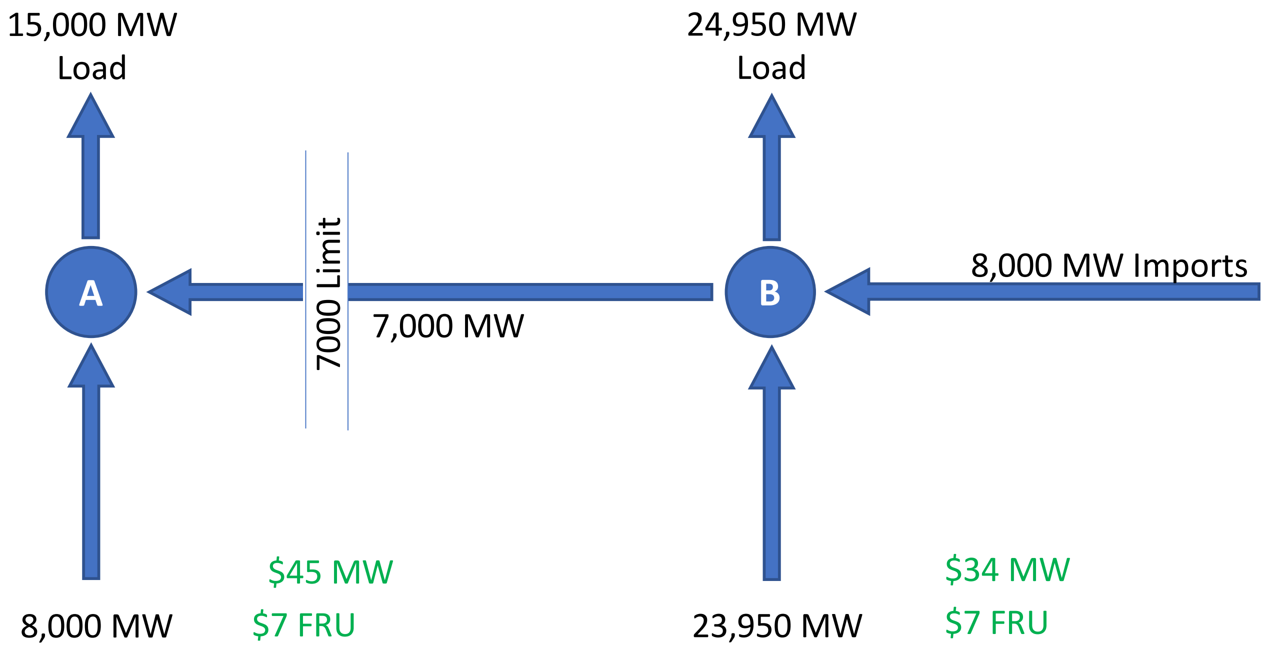
Reliability capacity differs from flexible capacity in the time frame in which it can be dispatched to meet load. Reliability capacity can be dispatched to meet load within an hour while flexible capacity can be dispatched to meet load within 15 minutes. Most resources can therefore provide more reliability capacity than flexible capacity.

Option 1B Sequential IFM Design

In this example we assume that the amount of flexible capacity (FRU) scheduled is equal to the target level of flexible capacity plus the actual difference between the bid load cleared in the IFM and the CAISO load forecast.

- This would be a completely fortuitous outcome if the flexible capacity (FRU) cleared in the IFM were based on the historical distribution of differences between IFM cleared generation and the FMM net load forecast.
- The difference between cleared IFM generation and the RUC net load forecast could be much higher or lower on a given day than any fixed historical target value.

Option 1B Sequential Design – IFM Dispatch



Option 1B Sequential Design

20,000 MW @ 0
600 Min @ $30 0 FRU
D 2,400 MW @ $28 900 FRU @ $1
1,600 MW 800 FRU

4,000 MW @ 0
2,750 MW @ $20 500 FRU @ $1

200 Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
500 MW 300 FRU

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

X 300 MW Min @ $45 0 FRU
450 MW @ $40 100 FRU @ $8
450 MW 0 FRU

Y 300 MW Min @ $50 0 FRU
450 MW @ $45 100 FRU @ $9
200 MW 0 FRU

Z 300 MW Min @ $55 0 FRU
450 MW @ $50 100 FRU @ $10
0 MW

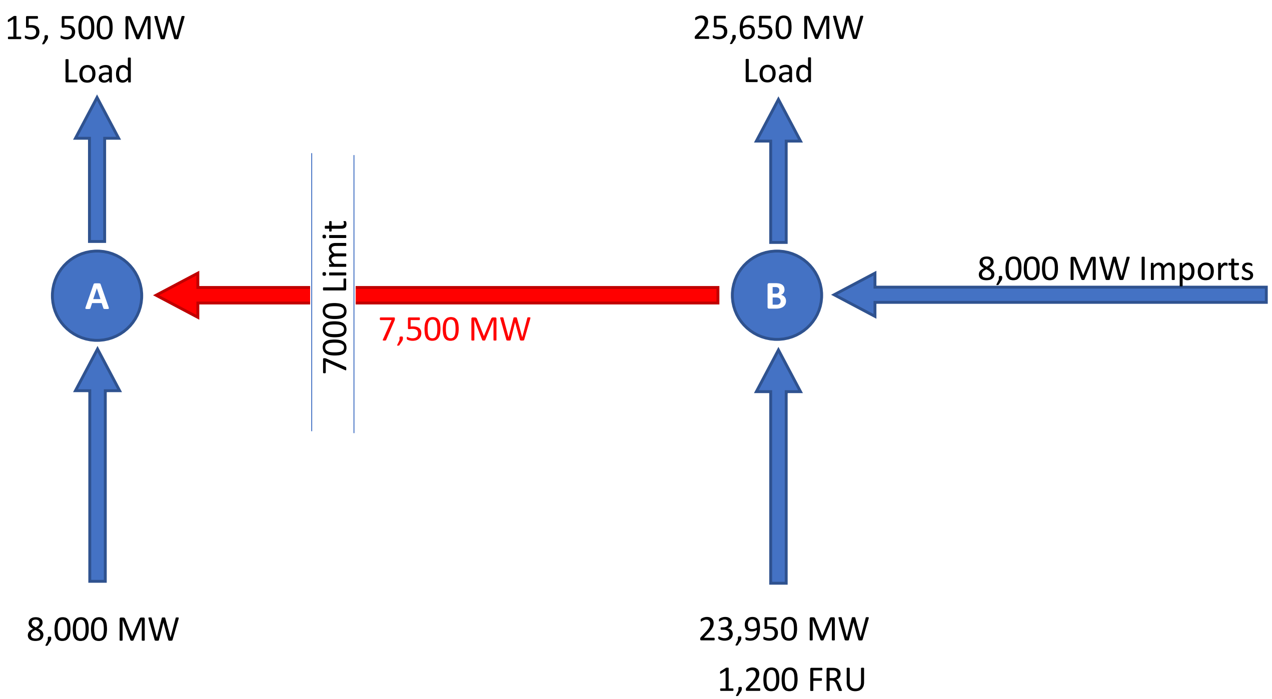
200 Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
500 MW 300 FRU

200 Min @$36 0 FRU
G 800 MW @ $34 300 FRU @ $2
150 MW 300 FRU

200 Min @ $41 0 FRU
H 800 MW @ $43 300 FRU @ $2
0 MW

FTI CONSULTING

Option 1B Sequential Design – RUC Dispatch



Option 1B Sequential Design

Because forecast load would be met with a general regional flexible capacity requirement (FRU) under the sequential design option 1B approach, the high cost of scheduling flexible capacity at A would cause the capacity needed to meet forecast load at A to be scheduled as flexible capacity at B.

- Flexible capacity at B, however, could not be dispatched to meet load at A due to the transmission constraint.
- This would require that additional capacity be committed at A using exceptional dispatch in the subsequent RUC evaluation.
- This would have the effect that flexible capacity would be scheduled at both A and B to meet the same forecast load at A.

FTI CONSULTING

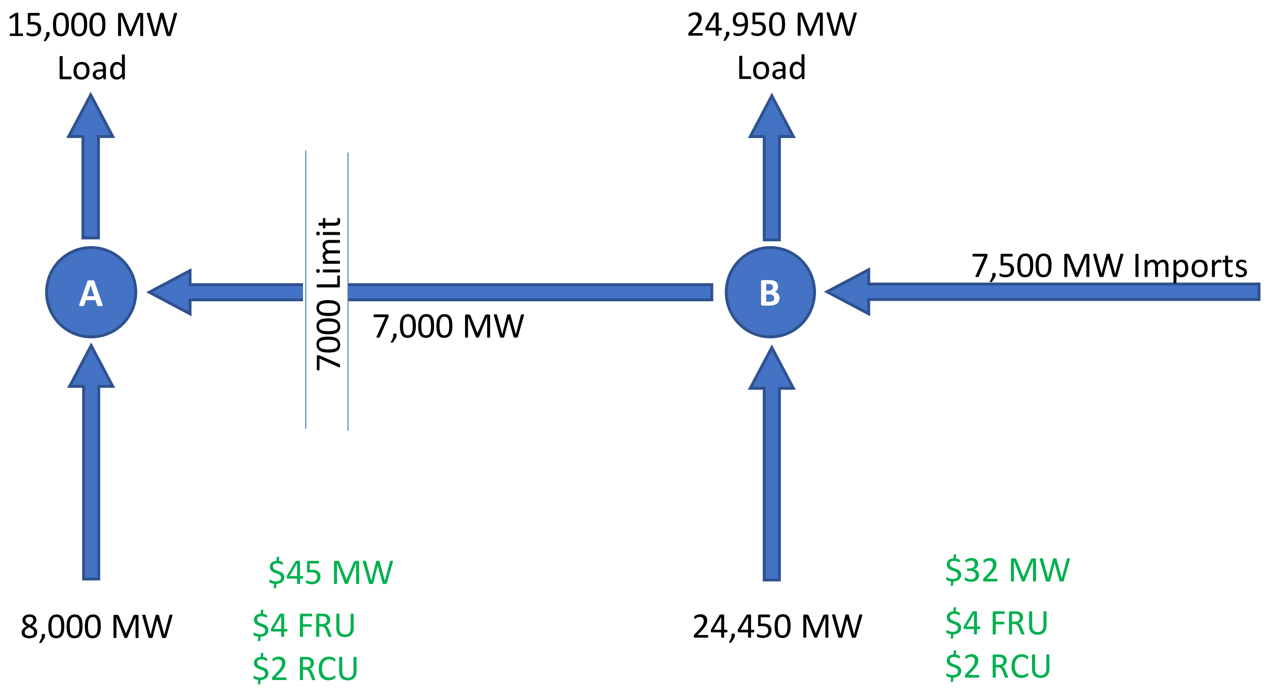
Option 1B2 Sequential Design

The requirement that forecast load in excess of bid load be met with flexible capacity, rather than reliability capacity, is not an inherent feature of design 1B.

- If this requirement were eliminated and forecast load could be met with reliability capacity that could be committed and dispatched within an hour, both the cost of meeting load and market prices would be reduced.
- This is illustrated in the slides that follow. It will be seen that the schedules and prices produced by option 1B2 are more in line with those produced by option 1D and option 2. Hence, it would still be the case that too much capacity would be scheduled at B, where it could not be dispatched to meet forecast load at A.

FTI CONSULTING

Option 1B2 Sequential Design – IFM Dispatch



FTI CONSULTING

Option 1B2 Sequential Design

4,000 MW @ 0
2,750 MW @ $20 500 FRU @ $1

X 300 MW Min @ $45 0 FRU
450 MW @ $40 100 FRU @ $8
450 MW 0 FRU

Y 300 MW Min @ $50 0 FRU
450 MW @ $45 100 FRU @ $9
200 MW 0 FRU

Z 300 MW Min @ $55 0 FRU
450 MW @ $50 100 FRU @ $10
0 MW

20,000 MW @ 0
600 Min @ $30 0 FRU
D 2,400 MW @ $28 900 FRU @ $1
2,400 MW 000 FRU

200 Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
600 MW 200 FRU

200 Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
450 MW 300 FRU 50 RCU

200 Min @$36 0 FRU
G 800 MW @ $34 300 FRU @ $2
0 MW 1000 RCU

200 Min @ $41 0 FRU
H 800 MW @ $43 300 FRU @ $2
0 MW 150 RCU

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

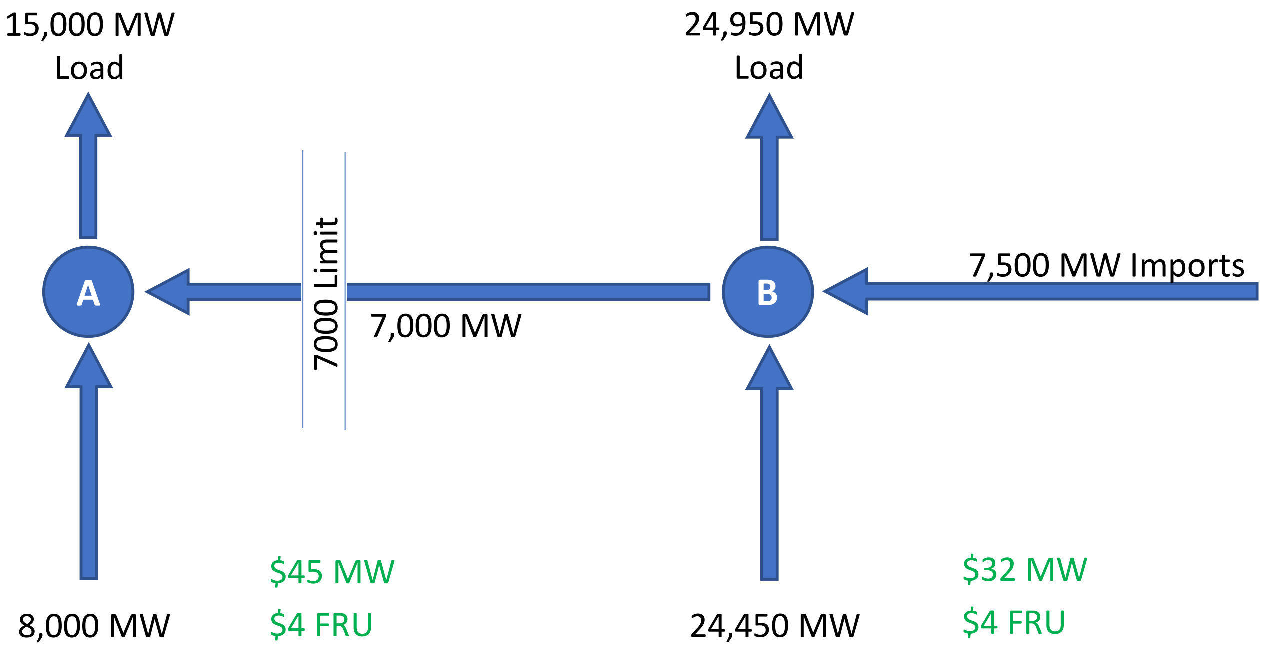
Option ID Sequential IFM Design

Under the option 1D design, there would be a separate IFM unit commitment and dispatch pass to meet cleared bid load and a forecast load unit commitment and dispatch pass to meet the CAISO net load forecast.

- In this example we assume that reliability capacity (RCU) is scheduled to meet forecast load using FRU offer prices.
- The example also assumes that resources would be able to use an hour of ramp to provide reliability capacity, and that all of the resources at A and B could start and ramp to full load within an hour.

FTI CONSULTING

Option 1D Sequential Design – IFM Dispatch



FTI CONSULTING

Option 1D Sequential Design – IFM Dispatch

4,000 MW @ 0
2,750 MW @ $20 500 FRU @ $1

X 300 MW @ $45 0 FRU
450 MW @ $40 100 FRU @ $8
450 MW 0 FRU

Y 300 MW @ $50 0 FRU
450 MW @ $45 100 FRU @ $9
200 MW 0 FRU

Z 300 MW @ $55 0 FRU
450 MW @ $50 100 FRU @ $10

20,000 MW @ 0
600 MW Min @ $30 0 FRU
D 2,400 MW @ $28 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
600 MW 200 FRU

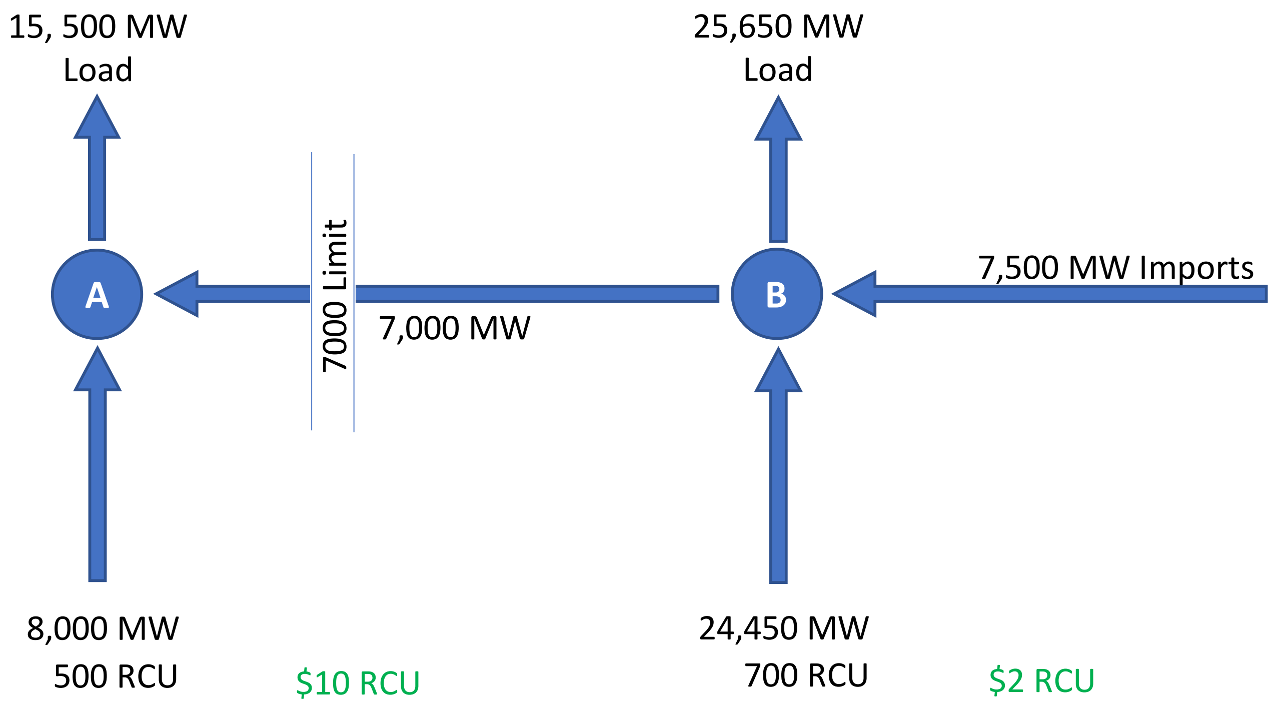
200 MW Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
450 MW 300 FRU

200 MW Min @ $36 0 FRU
G 800 MW @ $34 300 FRU @ $2

200 Min @ $45 0 FRU
H 800 MW @ $43 300 FRU @ $2

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

Option 1D Sequential Design – Forecast Load Dispatch



FTI CONSULTING

Option 1D Sequential Design – Forecast Load Dispatch

4,000 MW @ 0
2,750 MW @ $20 500 FRU @ $1

X 300 MW @ $45 0 FRU
450 MW @ $40 100 FRU @ $8
450 MW 0 FRU 0 RCU

Y 300 MW @ $50 0 FRU
450 MW @ $45 100 FRU @ $9
200 MW 0 FRU 250 RCU

Z 300 MW @ $55 0 FRU
450 MW @ $50 100 FRU @ $10
0 MW 0 FRU 250 RCU

20,000 MW @ 0
600 MW Min @ $30 0 FRU
D 2,400 MW @ $28 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
600 MW 200 FRU 0 RCU

200 MW Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
450 MW 300 FRU 50 RCU

200 MW Min @$36 0 FRU
G 800 MW @ $3 300 FRU @ $2
0 MW 0 FRU 650 RCU

200 Min @$41 0 FRU
H 800 MW @ $43 300 FRU @$2

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

Option 1D Sequential Design

The price of RUC energy would be $10 at A and $2 at B. The price of reliability capacity (RCU) at B ($2) would be lower than the price of flexible capacity ($4) at B because none of the capacity scheduled to provide reliability capacity could provide flexible capacity due to ramp constraints.

- Because A and B are assumed to be in the same flexible capacity zone, the price of flexible capacity (FRU) would be $4 at A while the price of reliability capacity (RCU) would be locational and clear at $8 at A.
- Because the IFM and forecast load market solutions are sequential there is a slight inconsistency in the prices of energy and reliability capacity. Resource Y at node A earns no margin on its energy output scheduled in the IFM, but earns a 1$ margin on the reliability capacity scheduled in the forecast load pass.

FTI CONSULTING

Option 1D Sequential Design

Incremental load would be met at a cost of $32 under the Option 1D sequential design, compared to $34 under the option 1B design.

- The difference is due to the fact that option 1D would schedule reliability capacity rather than flexible capacity to meet the forecast load target.
- This would require less out of merit dispatch and enable incremental load to be met at lower cost.

Option 1D Sequential Design

Suppose, on the other hand, that the resources at B were long start resources. In this case, the resources would need to be committed day-ahead in order to be able to meet forecast load in real-time.

- Resources committed in the forecast load pass would only receive the reliability capacity compensation to cover their gas scheduling costs.

- Under the option 1D sequential design, the start-up and minimum load costs of such long start resources would need to be covered by real-time bid cost guarantee payments.

Option 1E Sequential Design

If there is a potential for long start resources to be committed in the forecast load pass, a slight variation on the option 1D design would follow the forecast load unit commitment and dispatch pass with a final dispatch step to meet IFM load at least cost with the unit commitment fixed based on the forecast load pass.

- This would be similar to the New York ISO forecast load design in which there is a final bid load dispatch pass.
- Any long start units committed in the forecast load pass would receive an energy schedule covering their minimum load block, and the IFM schedules of other resources would be reduced to reflect this output.

Option 1E Sequential Design – Forecast Load Dispatch

4,000 MW @ 0
2,750 MW @ $20 500 FRU @ $1

X 300 MW @ $45 0 FRU
450 MW @ $40 100 FRU @ $8
350 MW 0 FRU 100 RCU

Y 300 MW @ $50 0 FRU
450 MW @ $45 100 FRU @ $9
0 MW 0 FRU 400RCU

Z 300 MW @ $55 0 FRU
450 MW @ $50 100 FRU @ $10
0 MW 0 FRU 0 RCU

20,000 MW @ 0
600 MW Min @ $30 0 FRU
D 2,400 MW @ $28 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
800 MW 0 FRU 0 RCU

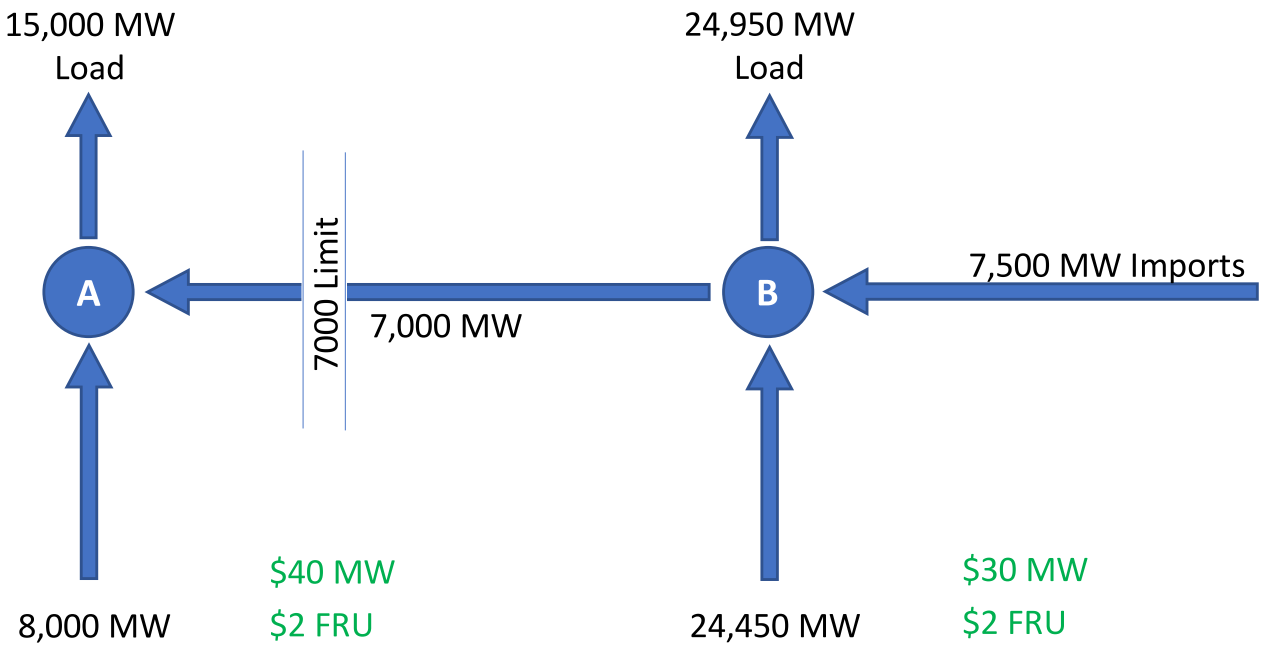
200 MW Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
50 MW 300 FRU 450 RCU

200 MW Min @$36 0 FRU
G 800 MW @ $3 300 FRU @ $2
0 MW 200 FRU 250 RCU

200 Min @$41 0 FRU
H 800 MW @ $43 300 FRU @$2

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

Option 1E Sequential Design – Final IFM Dispatch



Option 1E Sequential Design – Final IFM Dispatch

4,000 MW @ 0
2,750 MW @ $20   500 FRU @ $1

X 300 MW @ $45   0 FRU
450 MW @ $40   100 FRU @ $8
350 MW   0 FRU 100 RCU

Y 300 MW @ $50   0 FRU
450 MW @ $45   100 FRU @ $9
0 MW   0 FRU   0 RCU

Z 300 MW @ $50   0 FRU
450 MW @ $55   100 FRU @ $10
0 MW   0 FRU   0 RCU

20,000 MW @ 0
600 MW Min @ $30 0 FRU
D 2,400 MW @ $28 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
800 MW   0 FRU

200 MW Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
50 MW 300 FRU

200 MW min @ $36 0 FRU
G 800 MW @ $34 300 FRU @ $2
0 MW   200 FRU

200 Min @ $41 0 FRU
H 800 MW @ $43 300 FRU @$2

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

FTI CONSULTING

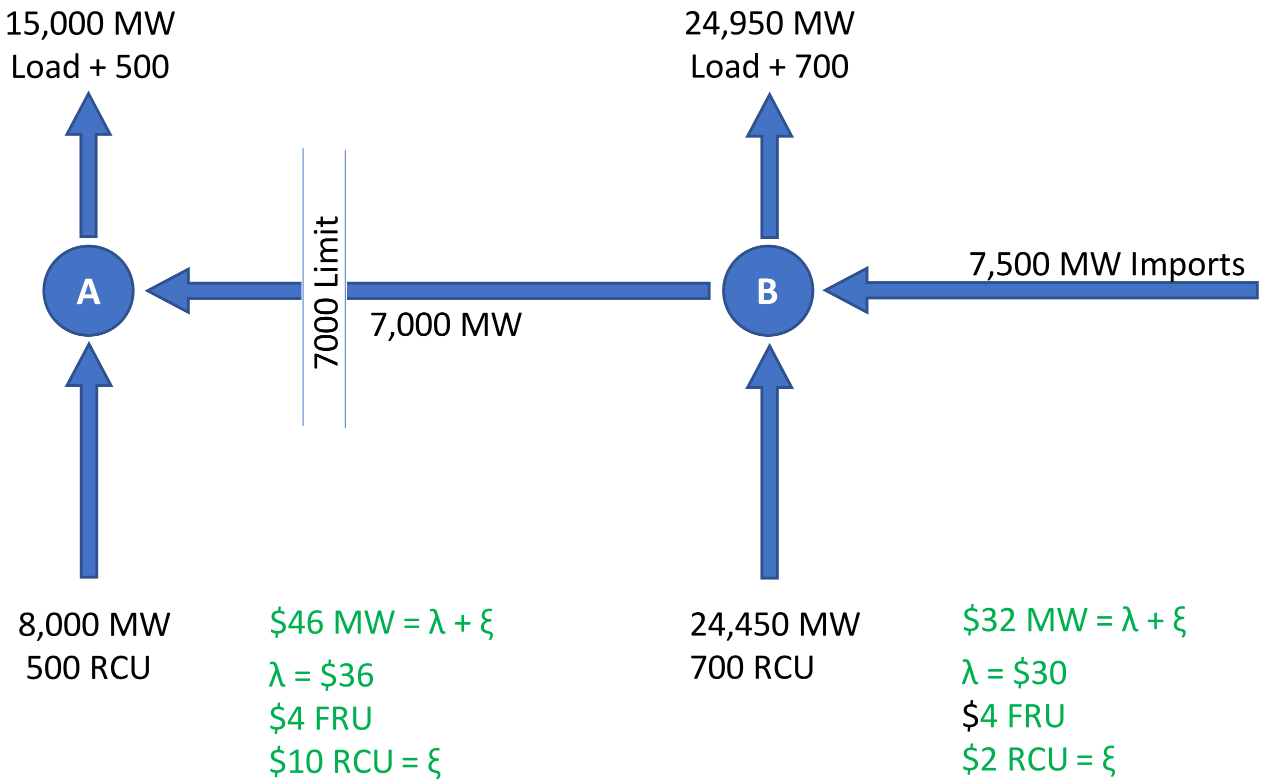
Option 1E Sequential Design

The option 1E Sequential Design could result in lower energy and flexible capacity clearing prices relative to the option 1D design if there are long start resources committed at minimum load in the forecast load pass.

- In this example, the price of energy under option 1E is lower than under the option 1D design at both A and B, because the long start resources are committed at minimum load in clearing energy and flexible capacity schedules. The price of flexible capacity is also lower under option 1E than under 1D.
- As under option 1D there is a slight pricing inconsistency under option 1E due to the sequential dispatch. Resource X at location A earns a $1 margin on capacity scheduled to provide RCU in the RCU pass, but earns no margin on the capacity cleared for energy in the final dispatch pass.

Option 2 Combined IFM RUC Design

Option 2 Combined IFM RUC Design



Option 2 Combined IFM RUC Design

4,000 MW @ 0
2,750 MW @ $20   500 FRU @ $1

X 300 MW @ $45   0 FRU
450 MW @ $40   100 FRU @ $8
450 MW   0 FRU 0 RCU

Y 300 MW @ $50   0 FRU
450 MW @ $45   100 FRU @ $9
200 MW   0 FRU   250RCU

Z 300 MW @ $55   0 FRU
450 MW @ $50   100 FRU @ $10
0 MW   0 FRU   250RCU

20,000 MW @ 0
600 MW Min @ $30 0 FRU
D 2,400 MW @ $28 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
600 MW 200 FRU 0 RC

200 MW Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
450 MW 300 FRU 50 RCU

200 MW min @$36 0 FRU
G 800 MW @ $34 300 FRU @ $2
0 MW 0FRU 650RCU

200 MW Min @$41 0 FRU
H 800 MW @ $43 300 FRU @$2

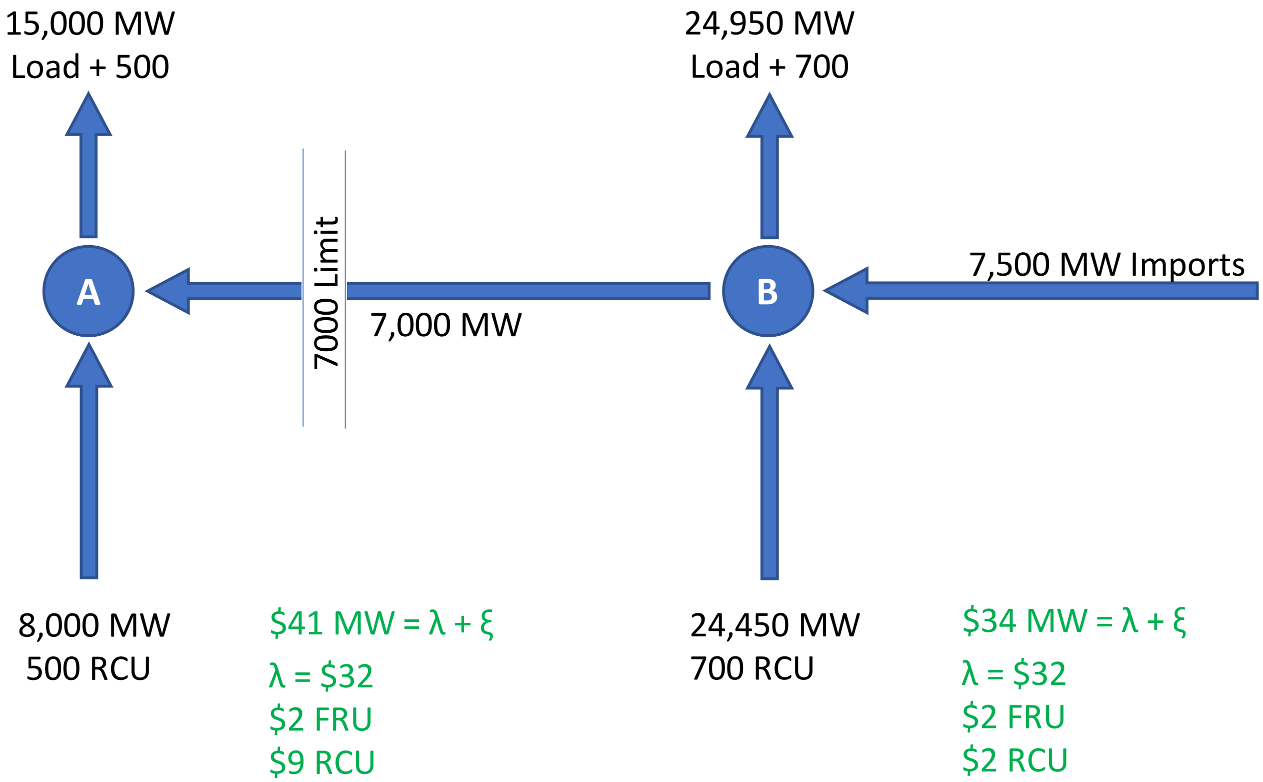
2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

Option 2 Combined IFM RUC Design

If there are no long start resources and no need to schedule high cost imports to meet forecast load, the combined IFM RUC design solution for the base case example yields the same IFM schedules for energy, flexible capacity and RUC capacity, as the option 1D sequential IFM RUC design.

- The price of energy at A is slightly lower than under sequential option 1B because RCU, rather than flexible capacity is scheduled to meet the load forecast, requiring less of the out of merit dispatch that raises the cost of incremental energy under option 1B.
- The price of energy at A is slightly higher under Option 2 than under sequential options 1D or 1E because the energy price is determined jointly with the scheduling of reliability capacity (RCU), and reflects the opportunity cost of providing reliability capacity.

Option 2 Combined IFM RUC Design-Long Start Units



Option 2 Combined IFM RUC – Long Start Units

4,000 MW @ 0
2,750 MW @ $20   500 FRU @ $1

X 300 MW @ $45   0 FRU
450 MW @ $40   100 FRU @ $8
350 MW   0 FRU 100 RCU

Y 300 MW @ $50   0 FRU
450 MW @ $45   100 FRU @ $9
0 MW   0 FRU   400 RCU

Z 300 MW @ $50   0 FRU
450 MW @ $55   100 FRU @ $10
0 MW   0 FRU   0RCU

20,000 MW @ 0
600 MW Min @ $30 0 FRU
D 2,400 MW @ $28 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $32 0 FRU
E 800 MW @ $30 300 FRU @ $2
800 MW 0 FRU 0 RCU

200 MW Min @ $34 0 FRU
F 800 MW @ $32 300 FRU @ $2
50 MW 300 FRU 450 RCU

200 MW min @ $36 0 FRU
G 800 MW @ $34 300 FRU @ $2
0 MW 200 FRU 250 RCU

200 Min @ $41 0 FRU
H 800 MW @ $43 300 FRU @$2

2,000 MW @ 0
2,000 MW @ $20
2,500 MW @ $29
1,000 MW @ $31
500 MW @ $33
500 MW @ $45

FTI CONSULTING

Option 2 Combined IFM RUC Design

The need to commit long start resources at minimum load to supply reliability capacity causes energy and flexible capacity prices to fall.

- The need to commit long start resources does not change the outcome that the price of energy is higher at A in the combined IFM RUC design than in the sequential IFM RUC designs.
- This is because the price of energy reflects the opportunity cost of providing reliability capacity.

CRR Settlements

If CRRs are settled against the day-ahead energy market price (λ) in the combined IFM RUC design, the congestion rents allocated to customers at A in the example would be lower under the option 2 combined IFM RUC design than under sequential design options 1A, B, C, D or E.

- The design for allocating residual congestion rents and RCU charges to power consumers under the combined IFM RUC design could therefore lead to some cost shifts relative to the current market.
- However, there may be alternative ways to settle CRRs that will avoid material, predictable costs shifts.
- The congestion calculations assume that under option 2 all real-time load pays the price of reliability capacity for their real-time energy consumption.

CRR Settlements

The example assumes 7000 B to A FTRs

Base Case	Congestion Rents	FTR Payment	Total Payments	Residual
Option 1B	$77,000	$11	$77,000	0
Option 1D	$91,000	$13	$91,000	0
Option 2	$98,000	$ 6	$42,000	$56,000

FTRs settled based on the shadow price of the energy load balance constraint may leave a material congestion rent residual if reliability capacity cost varies by location.

High Gas Price High Load Case

High Gas Price High Load Case

This example uses the same resources as the base case, but assumes that gas prices are much higher, so resource and import offer prices are much higher.

- In addition, in this example there is not enough capacity available in the CAISO to meet the load forecast without scheduling high cost imports.
- One minor change in the example is that the flexible capacity requirement is reduced to 475 megawatts. This reduction avoids price indeterminacies that would confuse the example.

High Gas Price High Load Case

As explained in the introduction, we work through two versions of this example.

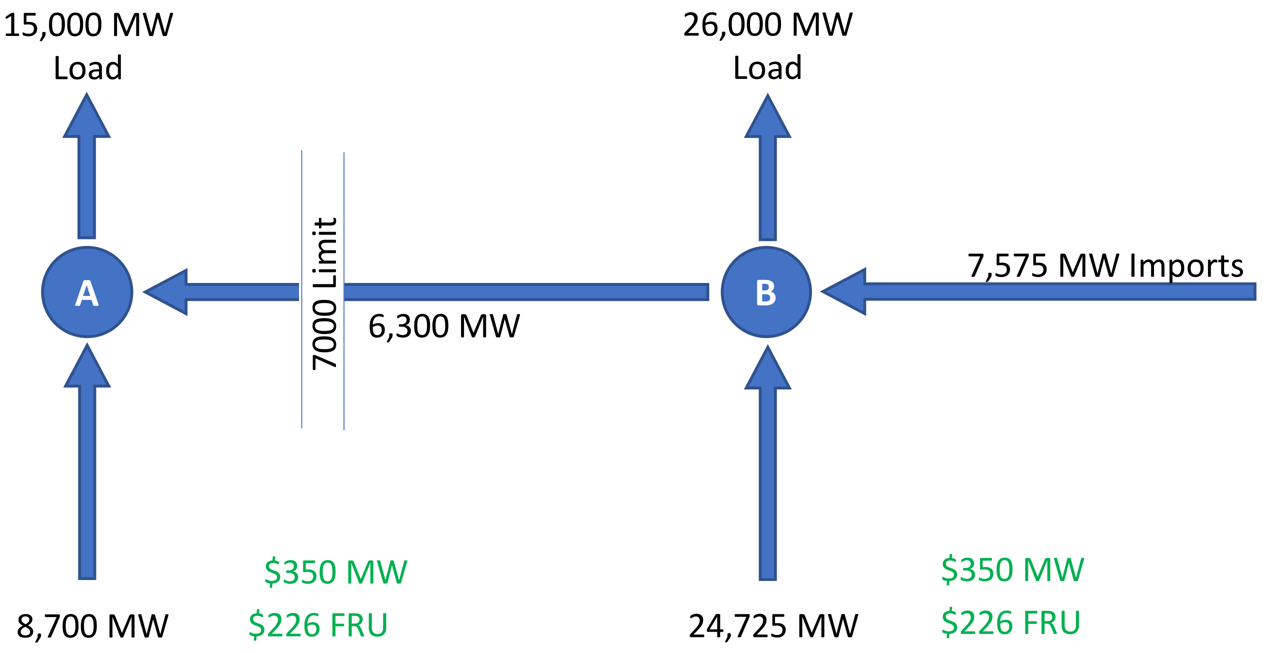
- In the first version, imports cannot be used to supply reliability capacity in the IFM, imports can only be scheduled to provide energy. This version results in very high energy, flexible capacity and reliability capacity prices.
- In the second version, both imports and internal generation can be used to supply reliability capacity to meet forecast load.
    - The example shows that this flexibility materially reduces the production cost of meeting load, and prices.
    - The second version of the design raises questions about whether such an approach would be workable from a reliability and market standpoint.

High Gas Price, High Load Case – Version 1

Option 1B Sequential IFM Design

FTI CONSULTING

Option 1B Sequential Design – IFM Dispatch



Option 1B Sequential Design – IFM Dispatch

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

A 300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
350 MW 100 FRU

B 300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
350MW 100 FRU

C 300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
350 MW 100 FRU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 1200 FRU @ $1
1325 MW 1075 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
500 MW 300 FRU

200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
500 MW 300 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
500MW 300 FRU

200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
500 MW 300 FRU

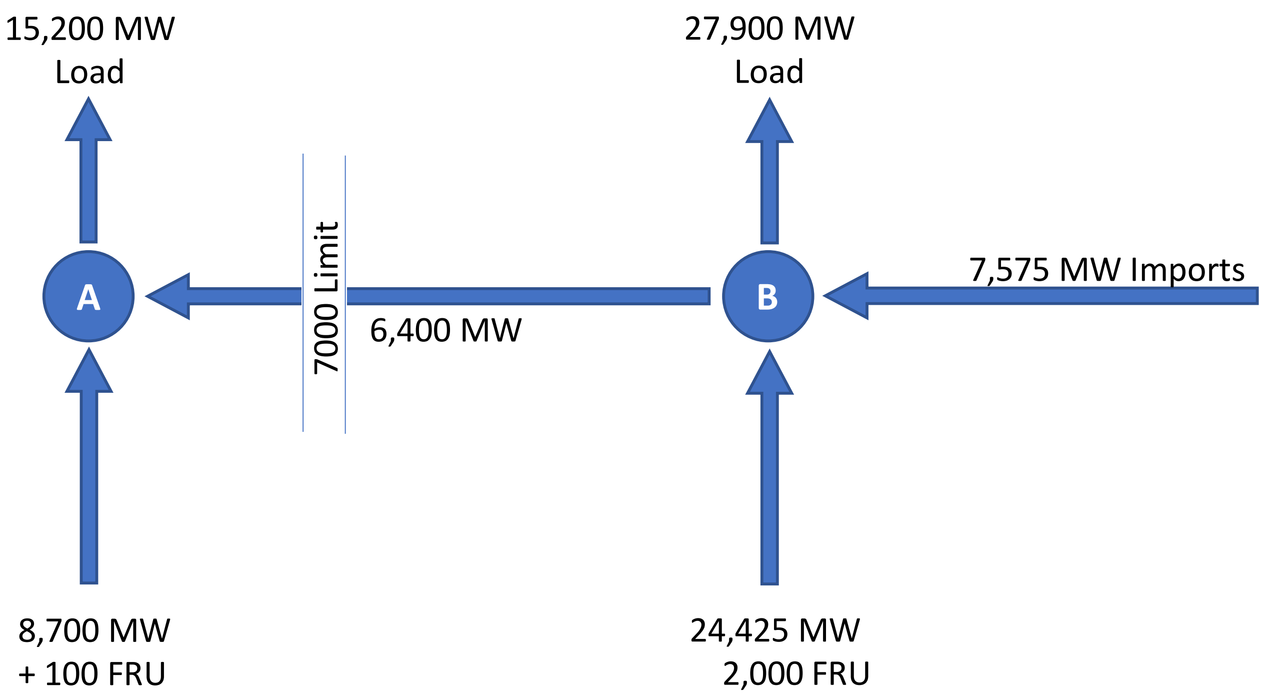
2,000 MW @ 0
2,000 MW @ $220
2,500 MW @ $230
1,000 MW @$250
1000 MW @ 350
75 MW
500 MW @ $450

Option 1B Sequential Design

The example assumes that the amount of flexible capacity scheduled is enough to meet the flexible capacity requirement and to meet forecast load.

- The need to meet forecast load with flexible capacity would require the same high level of import purchases that occurs in the option 1D forecast load dispatch and in the option 2 combined IFM RUC design, with the price of energy equal to $350 at A and B and flexible capacity prices of $226.
- The energy and flexible capacity schedules would be consistent with the prices.

Option 1B Sequential Design – RUC Dispatch



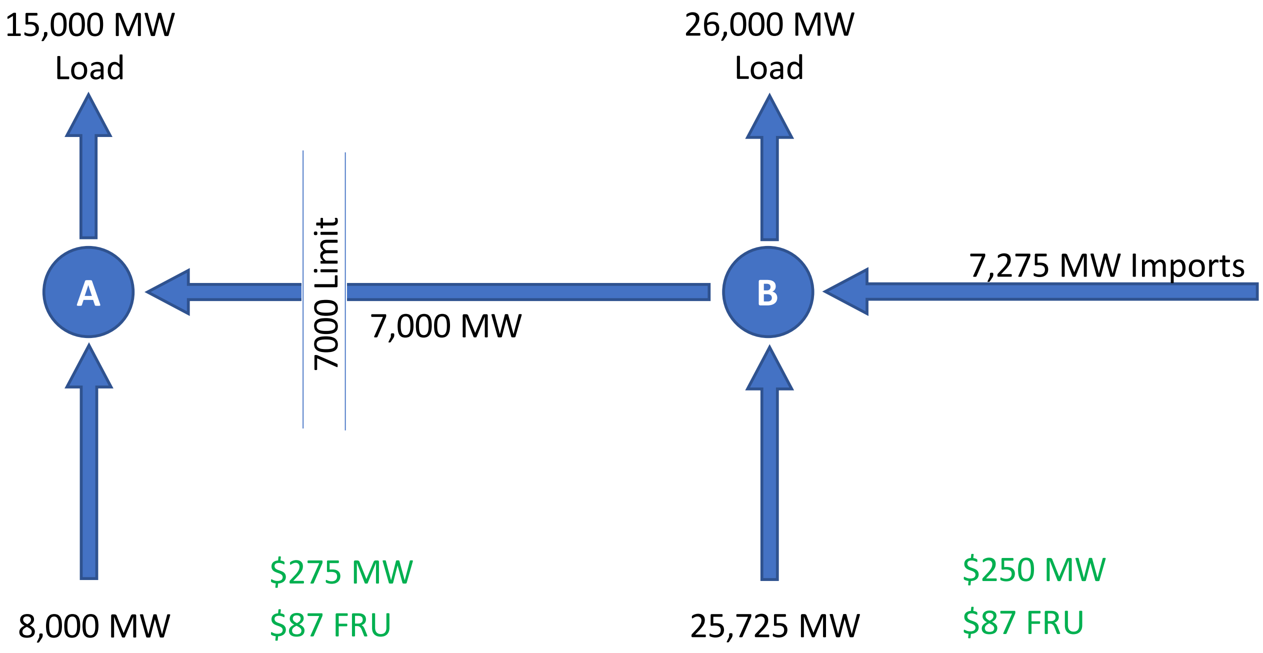
Option 1B Sequential Design

The transmission system would not be constrained between A and B in either the IFM dispatch or the RUC dispatch because high cost generation at A would be generating in the IFM pass in order to maintain flexible capacity on resources at B and would be generating in the RUC pass to displace high cost imports at the margin.

High Gas Price High Load Case Version 1

Option 1 D Sequential IFM Design

Option 1D Sequential Design – IFM Dispatch



Option 1D Sequential Design – IFM Dispatch

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

A 300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
350 MW 100 FRU

B 300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
300 MW 100 FRU

C 300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
0 MW 0 FRU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
800 MW 0 FRU

200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
800 MW 0 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
525MW 275 FRU

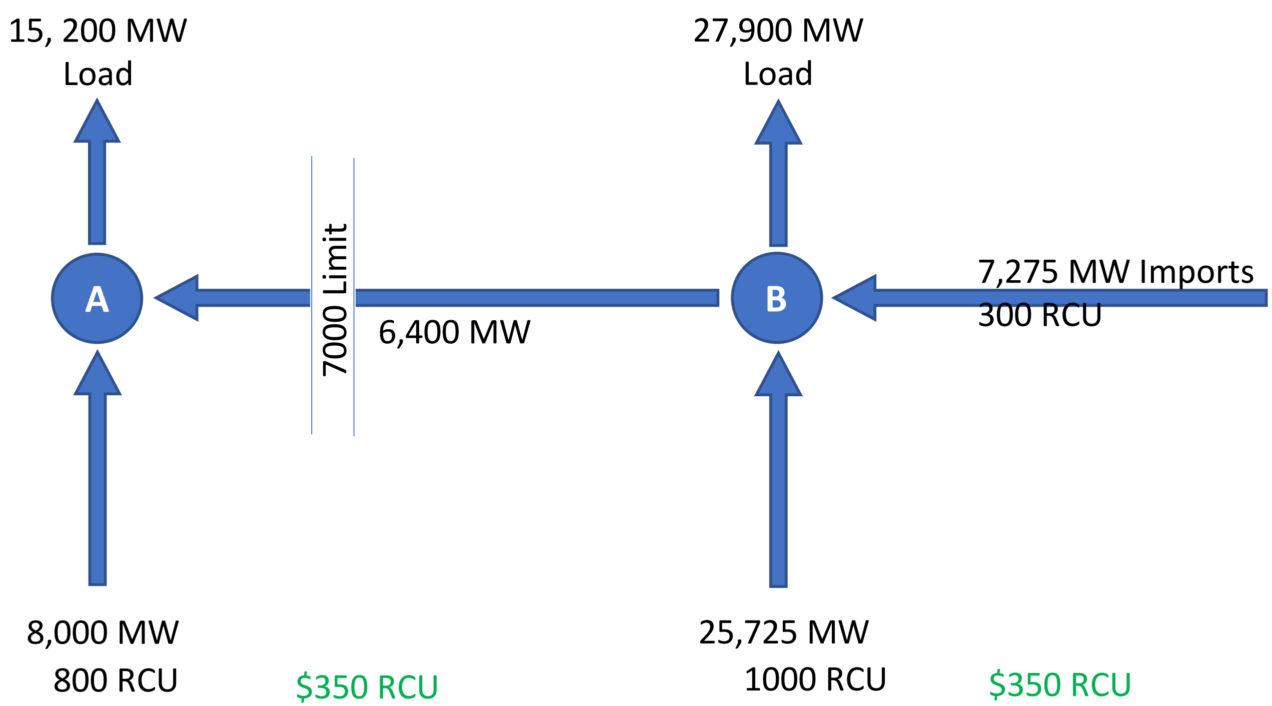
200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
0 MW

2,000 MW @ 0
2,000 MW @ $220
2,500 MW @ $230
1,000 MW @$250
775 MW
500 MW @ $350
500 MW @ $450

Option 1 D Sequential Design

The option 1D sequential design would result in materially lower energy and flexible capacity prices than option 1B.

Option 1D Sequential Design – Forecast Load Dispatch



FTI CONSULTING

Option 1D Sequential Design – Forecast Load Dispatch

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

X 300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
350 MW 100 FRU

Y 300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
300MW 100 FRU 50 RCU

Z 300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
750 RCU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
800 MW 0 FRU

200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
800 MW 0 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
525MW 275 FRU

200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
1000 RCU

2,000 MW @ 0
2,000 MW @ $220
2,500 MW @ $230
1,000 MW @$250
775 MW
200 MW RCU
500 MW @ $350
100 MW RCU
500 MW @ $450

FTI CONSULTING

Option 1D Sequential Design

There were small inconsistencies in the Option 1D prices between the IFM and forecast load passes in the base case example.

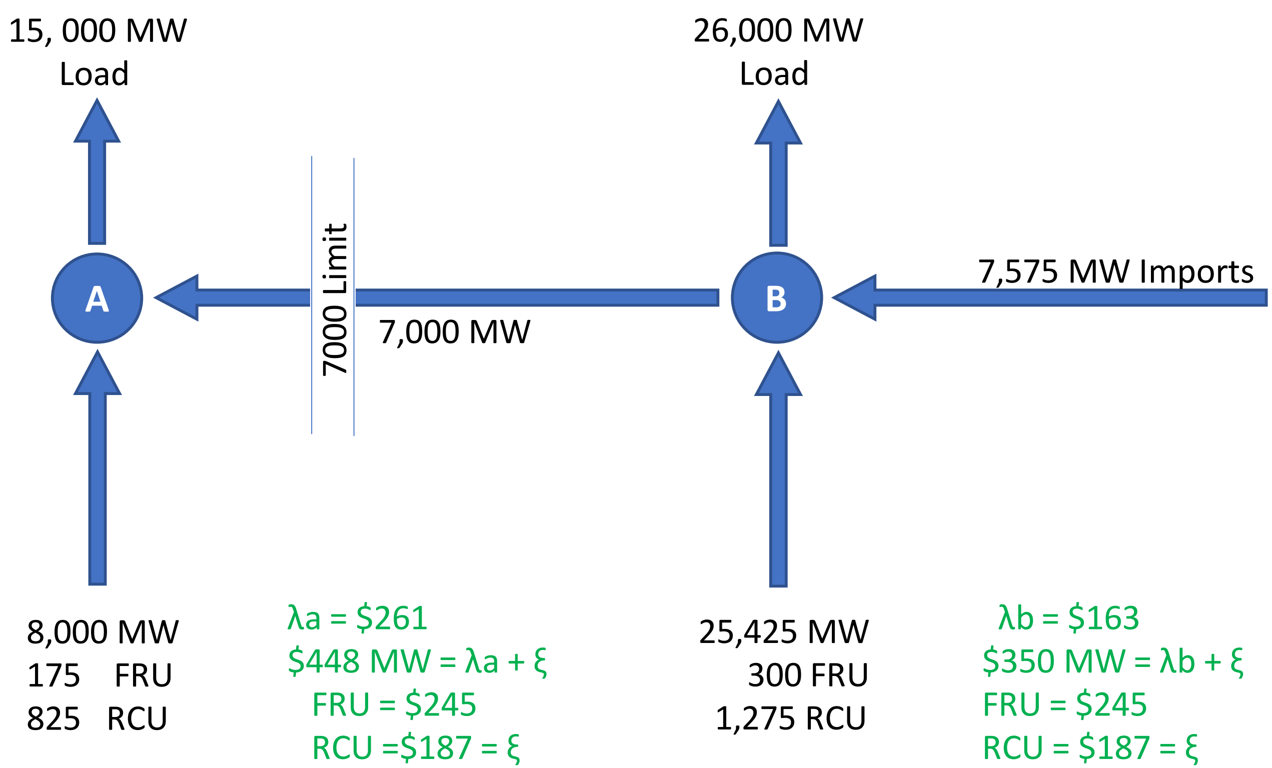
- In the high load example, these become very large price inconsistencies, with energy clearing at A and B at prices of $250 and $275 in the IFM pass, while reliability capacity clears at $350 in the forecast load pass.
- Similarly, flexible capacity clears at $87 in the IFM pass, while reliability capacity clears at $350 in the forecast load pass.

The potential for such large price inconsistencies could materially impact bidding incentives.

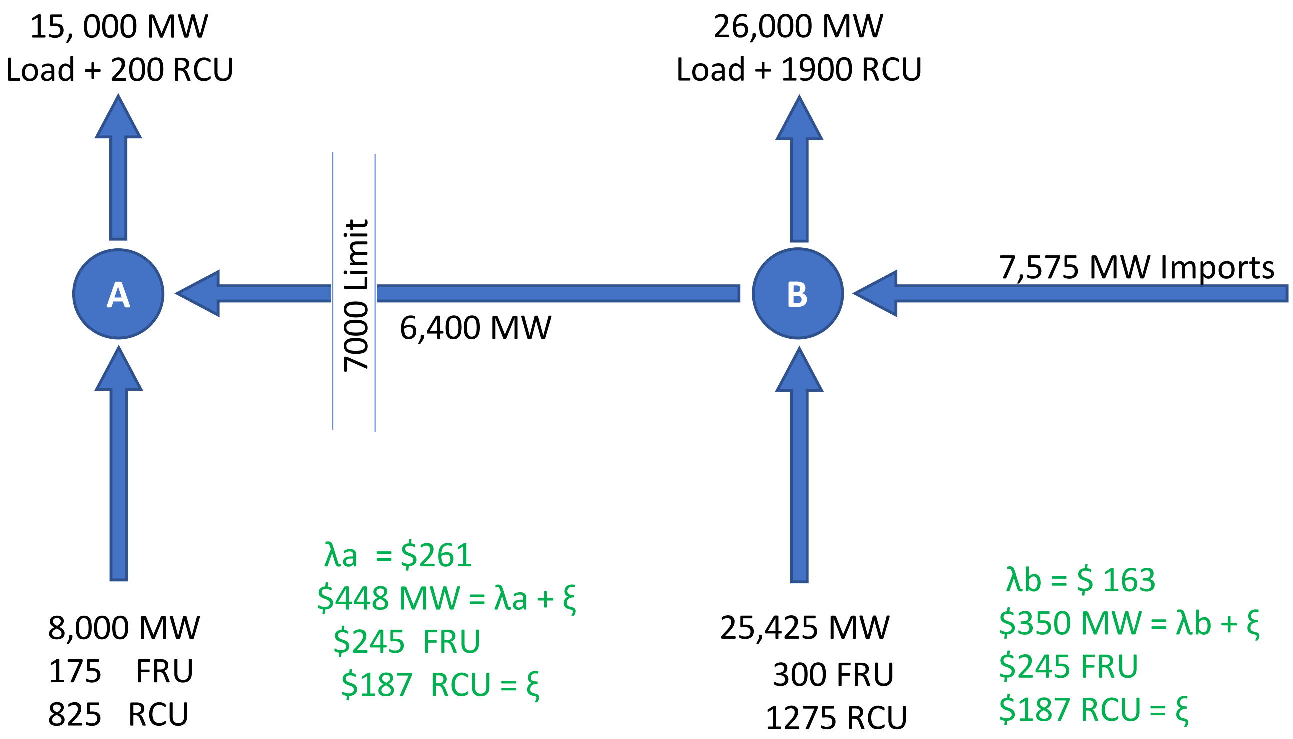
High Gas Price High Load Case – Version 1

Option 2 -- Combined IFM RUC Design

Option 2 Combined IFM RUC Design -- Bid Load Dispatch



Option 2 Combined IFM RUC Design – forecast load Dispatch



Option 2 Combined IFM RUC

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

X
300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
375 MW 75 FRU

Y
300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
275 MW 100 FRU 75 RCU

Z
300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
750 RCU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
800 MW 0 FRU

200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
800 MW 0 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
250MW 300 FRU 250 RCU

200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
1000MW RCU

2,000 MW @ 0
2,000 MW @ $220
2,500 MW @ $230
1,000 MW @$250
1000 MW
500 MW @ $350
75 MW
500 MW @ $450

FTI CONSULTING

Option 2 Combined IFM RUC Design

A striking feature of the option 2 combined IFM RUC design in this first version of the high load case is that the high CAISO load forecast results in much higher energy and flexible capacity prices than options 1B or 1D.

- The energy, flexible capacity and reliability capacity prices are all consistent with offer prices and schedules and no supplier that offers supply at its actual cost would have an incentive to change its bids in order to get more profitable schedules or higher prices.

CRR Settlements

The example assumes 7000 B to A FTRs.

High Load Case	Congestion Rents	FTR Payment	Total Payments	Residual
Option 1B	$ 0	$0	$0	$0
Option1D	$175,000	$25	$175,000	$0
Option 2	$686,000	$98	$686,000	$0

High Gas Price, High Load Case – Version 2

FTI CONSULTING

Version 2 High Load Case

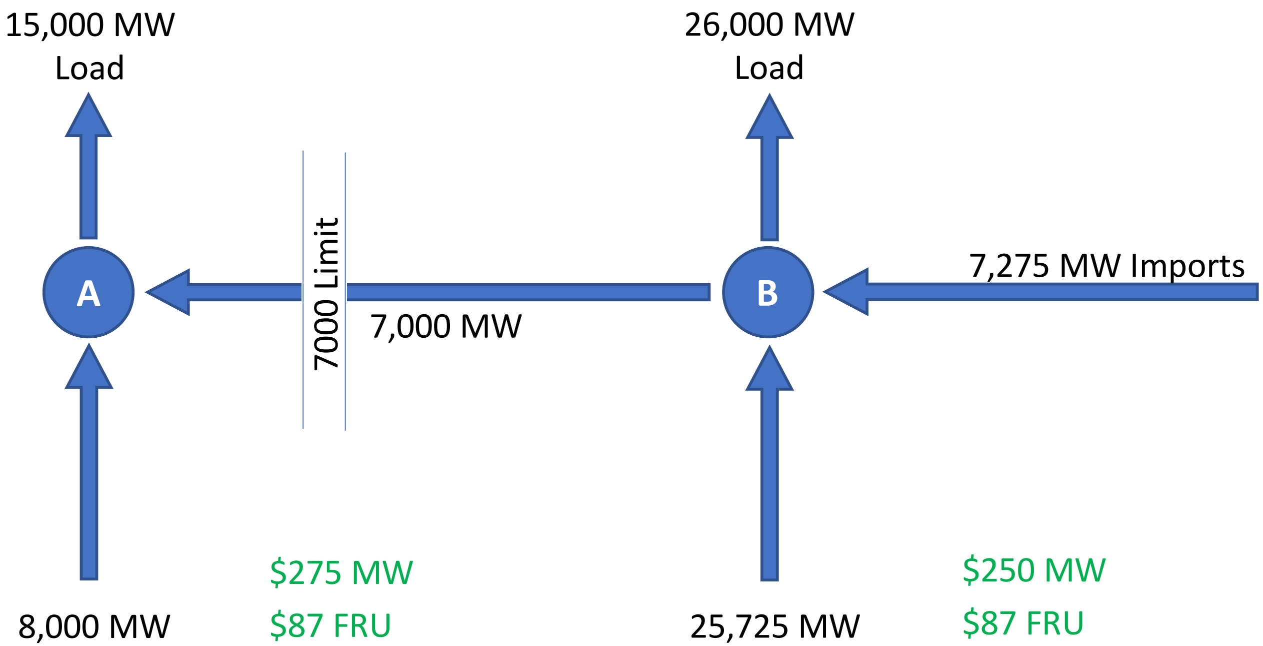
The high cost of meeting forecast load and the high cost of energy, flexible capacity and reliability capacity in the first version of the high load high gas price gas is in part due to the assumption that forecast load can only be met with reliability capacity scheduled on internal generation or by energy imports.

- We relax this assumption in the second version of the high load, high gas price gas to understand the cost and price impacts of an alternative design in which import supply can provide reliability capacity under options 1D or 2.
- The option 1B outcomes would not be changed by this assumption because option 1B assumes that forecast load would be met with flexible capacity.
- The option 1B outcomes would be changed by an assumption that flexible capacity could be cleared on the interties. We will not work through such an example in these slides in order to focus on the effects of the reliability capacity design choice.

High Gas Price High Load Case Version 2

Option 1 D Sequential IFM Design

Option 1D Sequential Design – IFM Dispatch



Option 1D Sequential Design – IFM Dispatch

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

A 300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
350 MW 100 FRU

B 300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
300MW 100 FRU

C 300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
0 MW 0 FRU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
800 MW 0 FRU

200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
800 MW 0 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
525MW 275 FRU

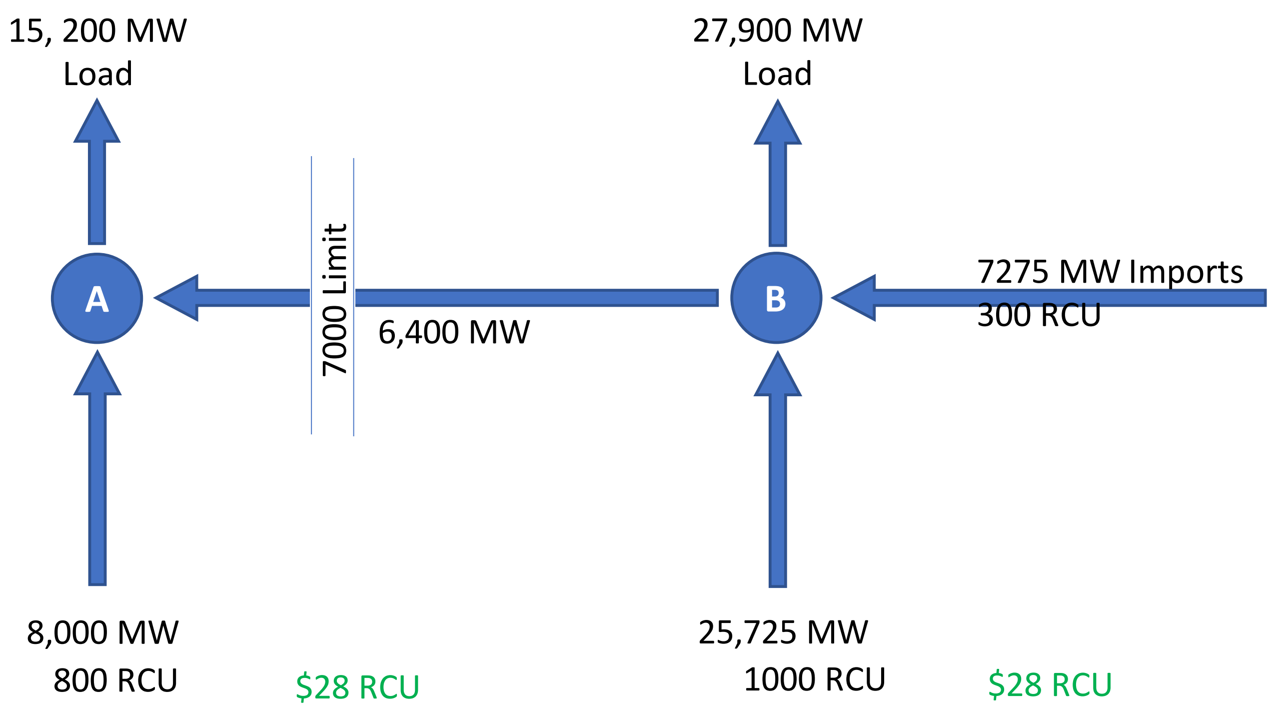
200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
0

2,000 MW @ 0
2,000 MW @ $220
2,500 MW @ $230
1,000 MW @$250
775 MW
500 MW @ $350
500 MW @ $450

Option 1 D Sequential Design

The option 1D sequential design IFM schedules and prices would be exactly the same if imports could be used to supply reliability capacity because reliability capacity is only scheduled in the forecast load pass under the Option 1D sequential design.

Option 1D Sequential Design – Forecast Load Dispatch



Option 1D Sequential Design – Forecast Load Dispatch

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

X 300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
350 MW 100 FRU

Y 300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
300MW 100 FRU 50 RCU

Z 300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
750 RCU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
800 MW 0 FRU

200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
800 MW 0 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
525MW 275 FRU

200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
1000 RCU

2,000 MW @ 0
2,000 MW @ $220
RCU @ 25
2,500 MW @ $230
RCU @ 26
1,000 MW @$250
RCU @ 27
775 MW
200 MW RCU
500 MW @ $350
RCU @ 28
100 MW RCU
500 MW @ $450
RCU @ 28

FTI CONSULTING

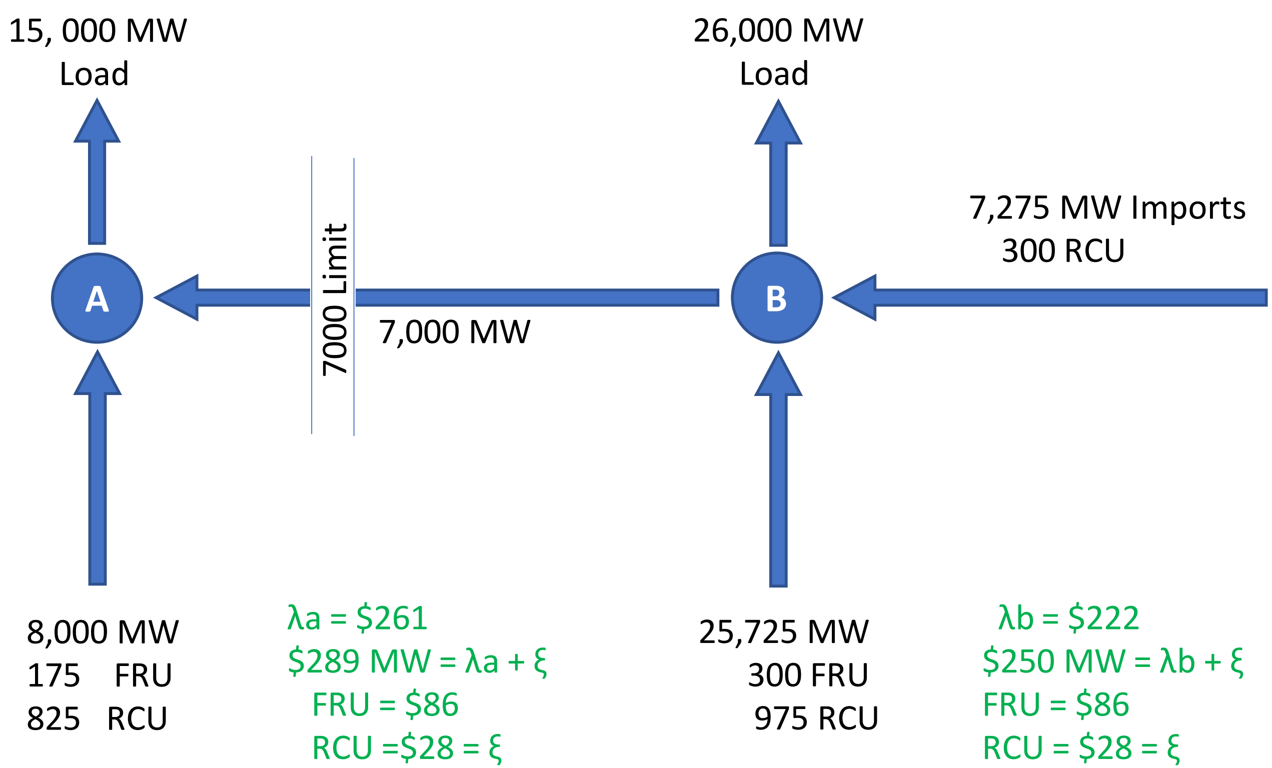
Option 1 D Sequential Design

Reliability capacity prices would be dramatically lower under option 1D if reliability capacity could be scheduled on the interties because the ISO could schedule reliability capacity at a cost of $28 instead of scheduling energy to meet forecast load at a cost of $350.

High Gas Price High Load Case – Version 2

Option 2 -- Combined IFM RUC Design

Option 2 Combined IFM RUC Design -- IFM Bid Load Dispatch



Option 2 Combined IFM RUC

4,000 MW @ 0
2,750 MW @ $60 500 FRU @ $1

X 300 MW @ $225 0 FRU
450 MW @ $215 100 FRU @ $12
375 MW 75 FRU

Y 300 MW @ $300 0 FRU
450 MW @ $275 100 FRU @ $14
275 MW 100 FRU 75 RCU

Z 300 MW @ $325 0 FRU
450 MW @ $300 100 FRU @ $15
750 RCU

20,000 MW @ 0
600 MW Min @ $125 0 FRU
D 2,400 MW @ $100 300 FRU @ $1
2,400 MW 0 FRU

200 MW Min @ $150 0 FRU
E 800 MW @ $125 300 FRU @ $10
800 MW 0 FRU

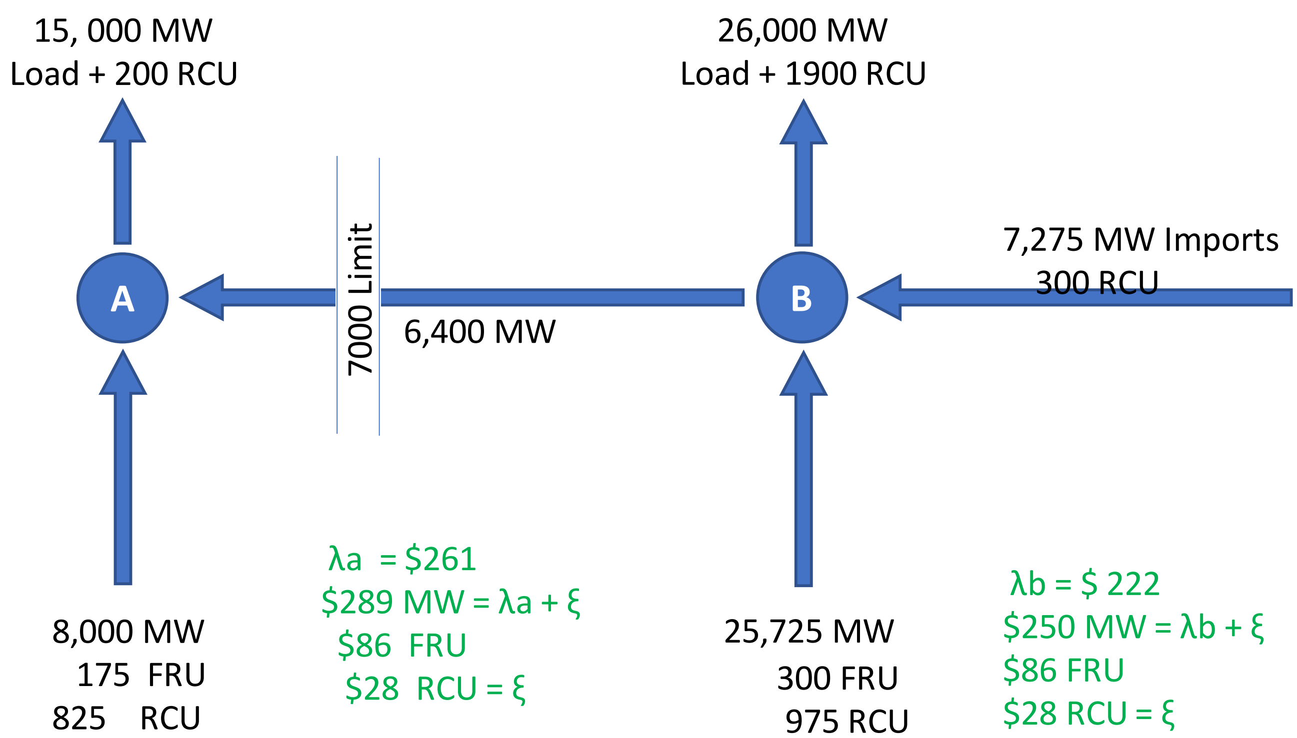
200 MW Min @ $180 0 FRU
F 800 MW @ $160 300 FRU @ $11
800 MW 0 FRU

200 MW Min @ $200 0 FRU
G 800 MW @ $175 300 FRU @ $12
525MW 300 FRU 0 RCU

200 MW Min @ $300 0 FRU
H 800 MW @ $275 300 FRU @ $13
1000MW RCU

2,000 MW @ 0
2,000 MW @ $220
RCU @ $25
2,500 MW @ $230
RCU @ $26
1,000 MW @$250
RCU @$27
775 MW 225RCU
500 MW @ $350
RCU @ $28
75 MW RCU
500 MW @ $450
RCU@ $28

Option 2 Combined IFM RUC Design – Forecast Load Dispatch



FTI CONSULTING

Option 2 Combined IFM RUC Design

It is noteworthy that if reliability capacity can be scheduled on the interties to meet forecast load, the price of energy, flexible capacity and reliability capacity would be much more similar between sequential option 1D and combined IFM RUC option 2.

- The combined IFM RUC option 2 produces more efficient prices and schedules than option 1 in either case, but the schedules and prices are much more similar if reliability capacity can be scheduled on the interties.