**Examples for the DAM procurement and pricing of**

**RegUp/FRRS-Up, RegDn/FRRS-Dn, PFR, FFR1, FFR2, CR1, CR2, SR1 & SR2**

**5/2/2014**

**Revision Description:**

**5/2/2014:**

1. Removed reference to % contribution of FFR2 towards CR (missed cleanup item from 4/25 FAST meeting)
2. Added Scenario 5 to include RegUp, RegDn, & SR

**4/25/2014:**

1. Corrected the label for the ratio of FFR/PFR ratio to PFR/FFR i.e. this ratio defines how many MW of PFR is equivalent to 1 MW of FFR
2. Included in Scenarios 1,2,3,4, a Generation Resource G5 offering FFR1 only (e.g. Battery)
3. Changed the percentage contribution of FFR2 toward CR down to zero – based on answer to question 2 in list of consensus items
   1. In Scenarios 1, 2, 3, & 4, LR3 Maximum Power consumption (MPC) changed from 500 MW to 600 MW to keep the resulting energy and AS prices the same as was presented on 4/18/2014 FAST Work Session Meeting
4. Modified Scenarios 3, & 4 by increasing the Energy Bid amount from 40,000 to 40,001 to remove any ambiguity on power balance shadow price – this will show that the power balance shadow price is 9,000 $/MWh and is set by the Energy Bid. Does not change any of the resulting energy and AS prices
5. Crossed out all MCPC price options **except for Option 1** for FFR1, FFR2, & CR2 – based on answer to question 1 in list of consensus items
6. Added statement to indicate the input data shown in this document are for illustrative purpose only**.**

**Case Setup Scenarios 1-4:**

1. Five Generation Resources : G1, G2, G3, G4, & G5
2. Three Load Resources (AS offer exclusivity modeled by market participant bidding): LR1, LR2, & LR3
3. No congestion
4. Only Dispatch (procurement) and pricing part of DAM considered (no commitment, i.e. all Resources ONLINE)
5. All data shown in this document are for illustrative purpose ONLY. These numbers should NOT be taken as an indication of outcome of any study on the ERCOT system (e.g. the numbers in the AS plan have no relationship to the actual numbers that ERCOT will post – they are for illustrative purposes only).
6. Scenarios 1-4 are examples illustrating the procurement and interaction between energy, PFR, FFR and CR. RegUp, RegDn, and SR requirements are assumed to be zero MW.

**AS Plan for Scenarios 1-4: Assume RegUp, RegDn, & SR requirements are zero MW**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PFR Requirement (MW) | FFR Requirement (MW) | FFR Max Requirement (MW) | FFR1 Max Requirement (MW) | PFR/FFR Ratio | CR Requirement (MW) | CR1 Min Requirement (MW) |
| 1,400 | 800 | 800 | 100 | 2 | 700 | 200 |

**Energy Bid for Scenarios 1-4:**

|  |  |
| --- | --- |
| Demand Bid (MWh) | Bid Price ($/MWh) |
| 40,000 | 9,000 |

**Generation Resource Limits, Energy Offer, AS Offer for Scenarios 1-4:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Generation Resource | LSL (MW) | HSL (MW) | EOC ($/MWh) | PFR ($/MW) | CR ($/MW) | FFR1 ($/MW) |
| G1 | 0 | 5,000 | 7,000 | 20 | 19 | - |
| G2 | 0 | 15,000 | 50 | 15 | 14 | - |
| G3 | 0 | 20,000 | 20 | 10 | 9 | - |
| G4 | 0 | 10,000 | 10 | - | - | - |
| G5 | 0 | 20 | - | - | - | 2 |

**Load Resource Limits, AS Offer for Scenarios 1-4:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Load Resource | Type | LPC (MW) | MPC (MW) | FFR ($/MW) | CR ($/MW) |
| LR1 | FFR1 | 0 | 200 | 3 | - |
| LR2 | FFR2 | 0 | 1,000 | 6 | - |
| LR3 | CR | 0 | 600 | - | 4 |

**Scenarios 1-4: Assume RegUp, RegDn, & SR requirements are zero MW**

1. Base Case
   1. Lots of capacity
   2. No opportunity costs in clearing prices for energy and AS
2. Reduce G2 capacity (from Base Case) to 11,500 MW to force procurement of CR from more expensive G1.
   1. Opportunity cost of CR impacts prices
3. Reduce G2 capacity (from Base Case) to 6,600 MW to force procurement of energy, PFR, CR from more expensive G1.
   1. Opportunity prices of energy impacts prices
4. Reduce G2 capacity (from Base Case) to 6,600 MW to force procurement of energy, PFR, CR from more expensive G1. Also reduce Energy Offer price of G1 from 7000 to 100 (still the most expensive energy offer)
   1. Opportunity prices of energy impacts price
   2. Demonstrates MCPC for FFR (depending on option) can exceed VOLL

**Observations - Scenarios 1-4:**

1. MCPC for FFR1 and FFR2 needs to be limited to VOLL as it can lead to excessive values of FFR1 and FFR2 MCPC . This occurs in some scenarios due to the multiplication of the shadow price SPPFR+FFR by the equivalencing ratio of FFR to PFR.

**Scenario 1: Base Case**

**Yellow highlights are results/outputs of DAM**

**AS Plan: Assume RegUp, RegDn, & SR requirements are zero MW**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PFR Requirement (MW) | FFR Requirement (MW) | FFR Max Requirement (MW) | FFR1 Max Requirement (MW) | PFR/FFR Ratio | CR Requirement (MW) | CR1 Min Requirement (MW) |
| 1,400 | 800 | 800 | 100 | 2 | 700 | 200 |

**Energy Bid:**

|  |  |  |
| --- | --- | --- |
| Demand Bid (MWh) | Bid Price ($/MWh) | Bid Award (MW) |
| 40,000 | 9,000 | 40,000 |

**Generation Resource Limits, Energy Offer, AS Offer:**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation  Resource | LSL (MW) | HSL (MW) | EOC ($/MWh) | PFR ($/MW) | CR ($/MW) | FFR1 ($/MW) | Energy Award (MW) | PFR Award (MW) | CR Award (MW) | FFR1 Award (MW) | HSL Capacity Utilization (%) |
| G1 | 0 | 5,000 | 7,000 | 20 | 19 | - | 0 | 0 | 0 |  | 0 % |
| G2 | 0 | 15,000 | 50 | 15 | 14 | - | 10,000 | 1,400 | 200 |  | 77 % |
| G3 | 0 | 20,000 | 20 | 10 | 9 | - | 20,000 | 0 | 0 |  | 100 % |
| G4 | 0 | 10,000 | 10 | - | - | - | 10,000 | - |  |  | 100 % |
| G5 | 0 | 20 | - | - | - | 2 |  |  |  | 20 | 100% |

**Load Resource Limits, AS Offer:**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Load Resource | Type | LPC (MW) | MPC (MW) | FFR ($/MW) | CR ($/MW) | FFR Award (MW) | CR Award (MW) | MPC Capacity Utilization (%) |
| LR1 | FFR1 | 0 | 200 | 3 | - | 80 | - | 40 % |
| LR2 | FFR2 | 0 | 1,000 | 6 | - | 700 | - | 70 % |
| LR3 | CR | 0 | 600 | - | 4 | - | 500 | 83 % |

**Constraints:**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraints | Equation | Shadow Price ($/MW) | Comments |
| Power Balance | EnergySupply - EnergyDemand = 0 | 50 | * G2 EOC is marginal and sets energy price * The Energy bid is fully awarded |
| Combined PFR/FFR  Procurement | PFR Award + Ratio \*( FFR1+FFR2) Award >= PFR Req. + Ratio \* FFR Req. | 15 | * Ratio=2 * The right hand side of the equation is 1400 + 2\*800 = 3000 * G2 PFR Offer is marginal * G2 capacity is **not fully** utilized. There is **no opportunity** cost for energy or other AS incorporated into this constraint’s shadow price |
| Max FFR  Procurement | ( FFR1+FFR2) Award <= FFR Max Req. | -26 | * Shadow price is negative * The right had side of the equation is 800 |
| Max FFR1  Procurement | FFR1 Award <= FFR1 Max Req. | -1 | * Shadow price is negative * The right had side of the equation is 100 |
| CR  Procurement | CR1 Award + CR2 Award >= CR Req. | 4 | * The right had side of the equation is 700 * LR3 CR Offer is marginal |
| Min CR1  Procurement | CR1 Award >= CR1 Req. | 10 | * The right had side of the equation is 200 * G2 CR Offer is marginal * G2 capacity is **not fully** utilized. There is **no opportunity** cost for energy incorporated into this constraint’s shadow price |

**MCPCs:**

|  |  |  |
| --- | --- | --- |
| AS MCPC | Equation | $/MW |
| PFR | SPPFR+FFR | 15 $/MW  Note: This is the marginal Offer price for PFR from Gen |
| FFR1 | R\*SPPFR+FFR | 2\*15 = 30 $/MW |
| FFR2 | R\*SPPFR+FFR | 2\*15 = 30 $/MW |
| CR1 | SPCR+ SPCR1 | 4 + 10 = 14 $/MW  Note: This is the marginal Offer price for CR from Gen |
| CR2 | SPCR+ SPCR1 | 4 + 10 = 14 $/MW |

**Scenario 2: Base Case changed - G2 HSL = 11,500 MW**

Red highlights are changes to input from Base Case

Yellow highlights are results/outputs of DAM

**AS Plan: Assume RegUp, RegDn, & SR requirements are zero MW**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PFR Requirement (MW) | FFR Requirement (MW) | FFR Max Requirement (MW) | FFR1 Max Requirement (MW) | PFR/FFR Ratio | CR Requirement (MW) | CR1 Min Requirement (MW) |
| 1,400 | 800 | 800 | 100 | 2 | 700 | 200 |

**Energy Bid:**

|  |  |  |
| --- | --- | --- |
| Demand Bid (MWh) | Bid Price ($/MWh) | Bid Award (MW) |
| 40,000 | 9,000 | 40,000 |

**Generation Resource Limits, Energy Offer, AS Offer:**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation  Resource | LSL (MW) | HSL (MW) | EOC ($/MWh) | PFR ($/MW) | CR ($/MW) | FFR1 ($/MW) | Energy Award (MW) | PFR Award (MW) | CR Award (MW) | FFR1 Award (MW) | HSL Capacity Utilization (%) |
| G1 | 0 | 5,000 | 7,000 | 20 | 19 | - | 0 | 0 | 100 |  | 2 % |
| G2 | 0 | 11,500 | 50 | 15 | 14 | - | 10,000 | 1,400 | 100 |  | 100 % |
| G3 | 0 | 20,000 | 20 | 10 | 9 | - | 20,000 | 0 | 0 |  | 100 % |
| G4 | 0 | 10,000 | 10 | - | - | - | 10,000 | - |  |  | 100 % |
| G5 | 0 | 20 | - | - | - | 2 |  |  |  | 20 | 100% |

**Load Resource Limits, AS Offer:**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Load Resource | Type | LPC (MW) | MPC (MW) | FFR ($/MW) | CR ($/MW) | FFR Award (MW) | CR Award (MW) | MPC Capacity Utilization (%) |
| LR1 | FFR1 | 0 | 200 | 3 | - | 80 | - | 40 % |
| LR2 | FFR2 | 0 | 1,000 | 6 | - | 700 | - | 70 % |
| LR3 | CR | 0 | 600 | - | 4 | - | 500 | 83 % |

**Constraints:**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraints | Equation | Shadow Price ($/MW) | Comments |
| Power Balance | EnergySupply - EnergyDemand = 0 | 55 | * G2 EOC is marginal for energy * Energy price set by combination of energy offer price of G2 and opportunity cost of CR (between G1 & G2) * The Energy bid is fully awarded |
| Combined PFR/FFR  Procurement | PFR Award + Ratio \*( FFR1+FFR2) Award >= PFR Req. + Ratio \* FFR Req. | 20 | * Ratio=2 * The right hand side of the equation is 1400 + 2\*800 = 3000 * G2 PFR Offer is marginal * G2 capacity is **fully** utilized. There is **opportunity** cost for CR (between G1 & G2) incorporated into this constraint’s shadow price |
| Max FFR  Procurement | ( FFR1+FFR2) Award <= FFR Max Req. | -36 | * Shadow price is negative * The right had side of the equation is 800 |
| Max FFR1  Procurement | FFR1 Award <= FFR1 Max Req. | -1 | * Shadow price is negative * The right had side of the equation is 100 |
| CR  Procurement | CR1 Award + CR2 Award >= CR Req. | 4 | * The right had side of the equation is 700 * LR3 CR Offer is marginal |
| Min CR1  Procurement | CR1 Award >= CR1 Req. | 15 | * The right had side of the equation is 200 * G1 CR Offer is marginal * G1 capacity is **not fully** utilized. There is **no opportunity** cost for energy incorporated into this constraint’s shadow price |

**MCPCs:**

|  |  |  |
| --- | --- | --- |
| AS MCPC | Equation | $/MW |
| PFR | SPPFR+FFR | 20 $/MW  Note: This is the marginal Offer price for PFR from Gen plus opportunity cost of CR |
| FFR1 | R\*SPPFR+FFR | 2\*20 = 40 $/MW |
| FFR2 | R\*SPPFR+FFR | 2\*20 = 40 $/MW |
| CR1 | SPCR+ SPCR1 | 4 + 15 = 19 $/MW  Note: This is the Offer price for CR from Gen |
| CR2 | SPCR+ SPCR1 | 4 + 15 = 19 $/MW |

**Scenario 3: Base Case changed - G2 HSL = 6,600 MW**

Red highlights are changes to input from Base Case

Yellow highlights are results/outputs of DAM

**AS Plan: Assume RegUp, RegDn, & SR requirements are zero MW**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PFR Requirement (MW) | FFR Requirement (MW) | FFR Max Requirement (MW) | FFR1 Max Requirement (MW) | PFR/FFR Ratio | CR Requirement (MW) | CR1 Min Requirement (MW) |
| 1,400 | 800 | 800 | 100 | 2 | 700 | 200 |

**Energy Bid:**

|  |  |  |
| --- | --- | --- |
| Demand Bid (MWh) | Bid Price ($/MWh) | Bid Award (MW) |
| 40,001 | 9,000 | 40,000 |

**Generation Resource Limits, Energy Offer, AS Offer:**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation  Resource | LSL (MW) | HSL (MW) | EOC ($/MWh) | PFR ($/MW) | CR ($/MW) | FFR1 ($/MW) | Energy Award (MW) | PFR Award (MW) | CR Award (MW) | FFR1 Award (MW) | HSL Capacity Utilization (%) |
| G1 | 0 | 5,000 | 7,000 | 20 | 19 | - | 3,400 | 1,400 | 200 |  | 100 % |
| G2 | 0 | 6,600 | 50 | 15 | 14 | - | 6,600 | 0 | 0 |  | 100 % |
| G3 | 0 | 20,000 | 20 | 10 | 9 | - | 20,000 | 0 | 0 |  | 100 % |
| G4 | 0 | 10,000 | 10 | - | - | - | 10,000 | - |  |  | 100 % |
| G5 | 0 | 20 | - | - | - | 2 |  |  |  | 20 | 100% |

**Load Resource Limits, AS Offer:**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Load Resource | Type | LPC (MW) | MPC (MW) | FFR ($/MW) | CR ($/MW) | FFR Award (MW) | CR Award (MW) | MPC Capacity Utilization (%) |
| LR1 | FFR1 | 0 | 200 | 3 | - | 80 | - | 40 % |
| LR2 | FFR2 | 0 | 1,000 | 6 | - | 700 | - | 70 % |
| LR3 | CR | 0 | 600 | - | 4 | - | 500 | 83 % |

**Constraints:**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraints | Equation | Shadow Price ($/MW) | Comments |
| Power Balance | EnergySupply - EnergyDemand = 0 | 9,000 | * Energy Bid is marginal and sets energy price * Energy Bid partially awarded (40,000 MWh) |
| Combined PFR/FFR  Procurement | PFR Award + Ratio \*( FFR1+FFR2) Award >= PFR Req. + Ratio \* FFR Req. | 2,020 | * Ratio=2 * The right hand side of the equation is 1400 + 2\*800 = 3000 * G1 PFR Offer is marginal * G1 capacity is **fully** utilized. Opportunity cost for energy **incorporated** into this constraint’s shadow price |
| Max FFR  Procurement | ( FFR1+FFR2) Award <= FFR Max Req. | -4,036 | * Shadow price is negative * The right had side of the equation is 800 |
| Max FFR1  Procurement | FFR1 Award <= FFR1 Max Req. | -1 | * Shadow price is negative * The right had side of the equation is 100 |
| CR  Procurement | CR1 Award + CR2 Award >= CR Req. | 4 | * The right had side of the equation is 700 * LR3 CR Offer is marginal |
| Min CR1  Procurement | CR1 Award >= CR1 Req. | 2,015 | * The right had side of the equation is 200 * G1 CR Offer is marginal * G1 capacity is **fully** utilized. Opportunity cost for energy **incorporated** into this constraint’s shadow price |

**MCPCs:**

|  |  |  |
| --- | --- | --- |
| AS MCPC | Equation | $/MW |
| PFR | SPPFR+FFR | 2,020 $/MW  Note: This is the marginal Offer price for PFR from Gen plus opportunity cost of energy |
| FFR1 | R\*SPPFR+FFR | 2\*2020 = 4,040 $/MW |
| FFR2 | R\*SPPFR+FFR | 2\*2020 = 4,040 $/MW |
| CR1 | SPCR+ SPCR1 | 4 + 2015 = 2,019 $/MW  Note: This is the marginal Offer price for CR from Gen plus opportunity cost of energy |
| CR2 | SPCR+ SPCR1 | 4 + 2015 = 2,019 $/MW |

**Scenario 4: Base Case changed - G2 HSL = 6,600 MW, G1 Energy Offer = 100 $/MWh**

Red highlights are changes to input from Base Case

Yellow highlights are results/outputs of DAM

**AS Plan: Assume RegUp, RegDn, & SR requirements are zero MW**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PFR Requirement (MW) | FFR Requirement (MW) | FFR Max Requirement (MW) | FFR1 Max Requirement (MW) | PFR/FFR Ratio | CR Requirement (MW) | CR1 Min Requirement (MW) |
| 1,400 | 800 | 800 | 100 | 2 | 700 | 200 |

**Energy Bid:**

|  |  |  |
| --- | --- | --- |
| Demand Bid (MWh) | Bid Price ($/MWh) | Bid Award (MW) |
| 40,001 | 9,000 | 40,000 |

**Generation Resource Limits, Energy Offer, AS Offer:**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation  Resource | LSL (MW) | HSL (MW) | EOC ($/MWh) | PFR ($/MW) | CR ($/MW) | FFR1 ($/MW) | Energy Award (MW) | PFR Award (MW) | CR Award (MW) | FFR1 Award (MW) | HSL Capacity Utilization (%) |
| G1 | 0 | 5,000 | 100 | 20 | 19 | - | 3,400 | 1,400 | 200 |  | 100 % |
| G2 | 0 | 6,600 | 50 | 15 | 14 | - | 6,600 | 0 | 0 |  | 100 % |
| G3 | 0 | 20,000 | 20 | 10 | 9 | - | 20,000 | 0 | 0 |  | 100 % |
| G4 | 0 | 10,000 | 10 | - | - | - | 10,000 | - |  |  | 100 % |
| G5 | 0 | 20 | - | - | - | 2 |  |  |  | 20 | 100% |

**Load Resource Limits, AS Offer:**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Load Resource | Type | LPC (MW) | MPC (MW) | FFR ($/MW) | CR ($/MW) | FFR Award (MW) | CR Award (MW) | MPC Capacity Utilization (%) |
| LR1 | FFR1 | 0 | 200 | 3 | - | 80 | - | 40 % |
| LR2 | FFR2 | 0 | 1,000 | 6 | - | 700 | - | 70 % |
| LR3 | CR | 0 | 600 | - | 4 | - | 500 | 83 % |

**Constraints:**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraints | Equation | Shadow Price ($/MW) | Comments |
| Power Balance | EnergySupply - EnergyDemand = 0 | 9,000 | * Energy Bid is marginal and sets energy price * Energy Bid partially awarded (40,000 MWh) |
| Combined PFR/FFR  Procurement | PFR Award + Ratio \*( FFR1+FFR2) Award >= PFR Req. + Ratio \* FFR Req. | 8,920 | * Ratio=2 * The right hand side of the equation is 1400 + 2\*800 = 3000 * G1 PFR Offer is marginal * G1 capacity is **fully** utilized. Opportunity cost for energy **incorporated** into this constraint’s shadow price |
| Max FFR  Procurement | ( FFR1+FFR2) Award <= FFR Max Req. | -17,836 | * Shadow price is negative * The right had side of the equation is 800 |
| Max FFR1  Procurement | FFR1 Award <= FFR1 Max Req. | -1 | * Shadow price is negative * The right had side of the equation is 100 |
| CR  Procurement | CR1 Award + CR2 Award >= CR Req. | 4 | * The right had side of the equation is 700 * LR3 CR Offer is marginal |
| Min CR1  Procurement | CR1 Award >= CR1 Req. | 8,915 | * The right had side of the equation is 200 * G1 CR Offer is marginal * G1 capacity is **fully** utilized. Opportunity cost for energy **incorporated** into this constraint’s shadow price |

**MCPCs:**

|  |  |  |
| --- | --- | --- |
| AS MCPC | Equation | $/MW |
| PFR | SPPFR+FFR | 8,920 $/MW  Note: This is the marginal Offer price for PFR from Gen plus opportunity cost of energy |
| FFR1 | R\*SPPFR+FFR | 2\*8920 = 17,840 $/MW  Note: Exceeds VOLL |
| FFR2 | R\*SPPFR+FFR | 2\*8920 = 17,840 $/MW  Note: Exceeds VOLL |
| CR1 | SPCR+ SPCR1 | 4 + 8915 = 8919 $/MW  Note: This is the marginal Offer price for CR from Gen plus opportunity cost of energy |
| CR2 | SPCR+ SPCR1 | 4 + 8915 = 8919 $/MW |

**Scenario 5: Example with RegUp/FRRS-Up, RegDn/FRRS-Dn, PFR, FR1, FFR2, CR1, CR2, SR1, SR2**

**Yellow highlights are results/outputs of DAM**

**AS Plan:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RegUp  Requirement  (MW) | FRRS-Up Max MW | RegDn  Requirement  (MW) | FRRS-Dn Max MW | SR  Requirement  (MW) | SR1 Min  Requirement  (MW) |  |
| 200 | 50 | 100 | 30 | 100 | 50 |  |
|  | | | | | | |
| PFR Requirement (MW) | FFR Requirement (MW) | FFR Max Requirement (MW) | FFR1 Max Requirement (MW) | PFR/FFR Ratio | CR Requirement (MW) | CR1 Min Requirement (MW) |
| 1,400 | 800 | 800 | 100 | 2 | 700 | 200 |

**Energy Bid:**

|  |  |  |
| --- | --- | --- |
| Demand Bid (MWh) | Bid Price ($/MWh) | Bid Award (MW) |
| 40,000 | 9,000 | 40,000 |

**Generation Resource Limits, Energy Offer, AS Offer:**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation  Resource | LSL (MW) | HSL (MW) | EOC ($/MWh) | RegUp  ($/MW) | PFR ($/MW) | CR ($/MW) | SR ($/MW) | RegDn  ($/MW) | FFR1 ($/MW) | FRRS-Up  ($/MW) |
| G1 | 0 | 5,000 | 7,000 | 22 | 20 | 19 | 16 |  | - | 0 |
| G2 | 0 | 15,000 | 50 | 15 | 15 | 13 | 10 | 12 | - | 10,000 |
| G3 | 0 | 25,000 | 20 | 12 | 10 | 7 | 4 | 8 | - | 20,000 |
| G4 | 0 | 10,000 | 15 |  | - | - |  |  | - | 10,000 |
| G5 | 0 | 20 | - |  | - | - |  |  | 8 | 8 |

**Generation Resource Energy and Ancillary Service Awards::**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation  Resource | Energy Award (MW) | RegUp  Award  (MW) | PFR Award (MW) | CR Award (MW) | SR  Award  (MW) | RegDn  Award  (MW) | FFR1 Award (MW) | FRRS-Up  Award  (MW) | HSL Capacity Utilization (%) |
| G1 | 0 | 0 | 0 | 0 | 0 |  |  |  | 0 % |
| G2 | 5,000 | 180 | 1,400 | 200 | 50 | 0 |  |  | 47 % |
| G3 | 25,000 | 0 | 0 | 0 | 0 | 80 |  |  | 100 % |
| G4 | 10,000 |  |  |  |  |  |  |  | 100 % |
| G5 |  |  |  |  |  |  | 0 | 20 | 100% |

**Load Resource Limits, AS Offer:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Load Resource | Offer-Type | LPC (MW) | MPC (MW) | FFR ($/MW) | CR ($/MW) | SR  ($/MW) | FRRS-Dn  ($/MW) |
| LR1 | FFR1 | 0 | 200 | 3 | - |  |  |
| LR2 | FFR2 | 0 | 1,000 | 6 | - |  |  |
| LR3 | CR2 | 0 | 600 | - | 4 |  |  |
| LR4 | SR2 | 0 | 700 |  |  | 2 |  |
| CLR-1 | FRRS-Dn | 0 | 20 |  |  |  | 8 |

**Load Resource Ancillary Service Awards:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Load Resource | FFR1  Award (MW) | FFR2 Award  (MW) | CR2  Award (MW) | SR2  Award  (MW) | FRRS-Dn  Award  (MW) | MPC  Capacity  Utilization  (%) |
| LR1 | 100 |  |  |  |  | 50 % |
| LR2 |  | 700 |  |  |  | 70 % |
| LR3 |  |  | 500 |  |  | 83 % |
| LR4 |  |  |  | 50 |  | 7 % |
| CLR-1 |  |  |  |  | 20 | 100 % |

**Constraints:**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraints | Equation | Shadow Price ($/MW) | Comments |
| Power Balance | EnergySupply - EnergyDemand = 0 | 50 | * G2 EOC is marginal and sets energy price * The Energy bid is fully awarded |
| Combined PFR/FFR  Procurement | PFR Award + Ratio \*( FFR1+FFR2) Award >= PFR Req. + Ratio \* FFR Req. | 15 | * Ratio=2 * The right hand side of the equation is 1400 + 2\*800 = 3000 * G2 PFR Offer is marginal * G2 capacity is **not fully** utilized. There is **no opportunity** cost for energy or other AS incorporated into this constraint’s shadow price |
| Max FFR  Procurement | ( FFR1+FFR2) Award <= FFR Max Req. | -24 | * Shadow price is negative * The right had side of the equation is 800 |
| Max FFR1  Procurement | FFR1 Award <= FFR1 Max Req. | -3 | * Shadow price is negative * The right had side of the equation is 100 |
| CR  Procurement | CR1 Award + CR2 Award >= CR Req. | 4 | * The right had side of the equation is 700 * LR3 CR Offer is marginal |
| Min CR1  Procurement | CR1 Award >= CR1 Req. | 9 | * The right had side of the equation is 200 * G2 CR Offer is marginal * G2 capacity is **not fully** utilized. There is **no opportunity** cost for energy incorporated into this constraint’s shadow price |
| RegUp  Procurement | RegUp Award + FRRS-Up Award >= RegUp Req. | 15 | * The right hand side of the equation is 200 * G2 RegUp Offer is marginal * G2 capacity is **not fully** utilized. There is **no opportunity** cost for energy incorporated into this constraint’s shadow price |
| Max FRRS-Up  Procurement | FRRS-Up Award <= FRRS-Up Max Req. | 0 | * The right hand side of the equation is 50 * Shadow Price is zero as the constraint is not binding. G5 cannot sell more than 20 MW and the limit is 50 MW |
| RegDn  Procurement | RegDn Award+FRRS-Dn Award >= RegDn Req. | 8 | * The right hand side of the equation is 100 * G3 RegDn Offer is marginal * G3 capacity is utilized. However, there is **no opportunity** cost for energy incorporated into this constraint’s shadow price. |
| Max FRRS-Dn  Procurement | FRRS-Dn Award <= FRRS-Dn Max Req. | 0 | * The right hand side of the equation is 30 * Shadow Price is zero as the constraint is not binding. CLR-1 cannot sell more than 20 MW and the limit is 30 MW |
| SR  Procurement | SR1 Award + SR2 Award >= SR Req. | 2 | * The right hand side of the equation is 100 * LR4 SR2 Offer is marginal * LR4 capacity is **not fully** utilized. |
| Min SR1  procurement | SR1 Award >= SR1 Req. | 8 | * The right hand side of the equation is 50 * G2 CR Offer is marginal * G2 capacity is **not fully** utilized. There is **no opportunity** cost for energy incorporated into this constraint’s shadow price |

**MCPCs:**

|  |  |  |
| --- | --- | --- |
| AS MCPC | Equation | $/MW |
| PFR | SPPFR+FFR | 15 $/MW  Note: This is the marginal Offer price for PFR from Gen |
| FFR1 | R\*SPPFR+FFR | 2\*15 = 30 $/MW |
| FFR2 | R\*SPPFR+FFR | 2\*15 = 30 $/MW |
| CR1 | SPCR+ SPCR1 | 4 + 10 = 14 $/MW  Note: This is the marginal Offer price for CR from Gen |
| CR2 | SPCR+ SPCR1 | 4 + 10 = 14 $/MW |
| RegUp | SPRegUp | 15 $/MW  Note: This is the marginal Offer price for RegUp from Gen |
| FRRS-Up | SPRegUp | 15 $/MW |
| RegDn | SPRegDn | 8 $/MW  Note: This is the marginal Offer price for RegDn from Gen |
| FRRS-Dn | SPRegDn | 8 $/MW |
| SR1 | SPSR+ SPSR1 | 2+8 = 10 $/MW  Note: This is the marginal Offer price for SR from Gen |
| SR2 | SPSR+ SPSR1 | 2+8 = 10 $/MW |