Summary of No-Load and Incremental Energy Offer M15 Changes

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General Manual Restructuring

- The following restructuring changes were made
  - Sections x.1 “Heat Input and Rates” and Sections x.2 “Performance Factors” were consolidated into one section named “Heat Input/Rates and Performance Factors”
  - Sections x.3 “Fuel Cost Policies and Guidelines” were moved into section x.2 (Old Performance Factor Section)
  - Sections x.3 (Old Fuel Cost Section) were renamed “Incremental Energy Cost”
  - Section 2.9 “Ten Percent Adder” was added.

- Revised No-Load Cost definition

No-Load Cost ($/hour) is the hourly cost required to theoretically operate a synchronized unit at zero MW. It consists primarily of the cost of fuel, as determined by the unit's no load heat (adjusted by the performance factor) times the fuel cost. It also includes operating costs, maintenance adders, emissions allowances and taxes~~create the starting point of a monotonically increasing incremental offer curve for a generating unit. The calculated No-Load Cost may have to be adjusted to ensure that the slope of the Generator Offer Curve is monotonically increasing~~.

- Revised Incremental Energy Cost definition

The incremental energy cost is the cost in dollars per MWh of providing an additional MWh from a synchronized unit.. It consists primarily of the cost of fuel, as determined by the unit's incremental heat rate (adjusted by the performance factor) times the fuel cost. It also includes operating costs, maintenance adders, emissions allowances, taxes, tax credits, and energy market opportunity costs~~per MWh to produce all of the energy segments above the Economic Minimum level (minimum generation level with the unit available for economic dispatch). No-Load Costs are not included in the incremental costs. It is calculated by summing the cost of each segment of energy in the unit's incremental cost curve up to the generation level. This cost is a dollar per hour ($/MWh) rate~~.

- Revised Heat Input definition and formula

Heat Input equals a point on the heat input curve (in MMbtu/hr) describing the resource's operational characteristics for converting the applicable fuel input (MMBtu) into energy (MWh). Heat Input curves, also called input/output curves, represent the amount of fuel used to produce energy. Heat input curves are developed based on net energy production. Heat input curves can be developed using historical data, performance test data or Original Equipment Manufacturer (OEM) documentation.~~are typically obtained via plant performance testing or from the original equipment manufacturer~~.

Observed fuel heat input and electric output data during normal operation or a performance test provide a direct measure of the heat input curve. A linear regression of the heat input on the energy output can provide an estimated polynomial curve. In the typical case, the heat input curve is a second order polynomial that applies to the entire operating output range of the unit.

$$Heat\ Input\ \left(\frac{MMBtu}{hour}\right) = A + B * Unit\ Output\ (MWh) + C * Unit\ Output^2\ (MWh)$$

Where A, B, and C are e the polynomial coefficients calculated through a linear regression.

When based on historical data, heat input curves must be developed using data points during times in which the resource was operating above its physical minimum level (e.g. do not include data points when the resource was in starting, soaking or shutdown mode).

- Revised Incremental Heat Rate equation

The Incremental heat rate is the relationship between an additional MW of output and the heat input necessary to produce it. Graphically, the incremental heat rate can be determined from the ratio of the change in fuel input to the change in unit MW output; which is the slope of the input/output curve. Mathematically, the incremental heat rate curve can be expressed as the first derivative of the heat rate curve (input heat versus MW output).

$$Incremental\ Heat\ Rate = \Delta MMBtu/\Delta MWhB + 2*C*Unit\ Output\ (MWh)$$

$$= (Change\ in\ Fuel\ Going\ in)/(Change\ in\ Energy\ Coming\ Out)$$

$$= (d_y/d_x)\,Total\ Heat\ Rate$$

- Performance Factor Definition Changes highlighted in Yellow

The Performance Factor shall be calculated on either the total fuel consumed or a monthly spot check test basis. The Performance Factor for nuclear and steam units shall be reviewed (and updated if changed) at least once every twelve months. Market Sellers can choose to update the heat input curve instead of using performance factors. When that choice is made the performance factor is set to one (1). The Performance Factors for combustion turbine ("CT"), diesel units, and combined-cycle ("CC") units shall be updated at least once during:

- Twelve months, or
- The year in which a unit reaches 1,000 accumulated running hours since its last Performance Factor update, whichever represents a longer period, not to exceed five years.

Requests for exemptions from these periods should be submitted to PJM and the MMU for evaluation pursuant to Section 2.3. The overall Performance Factor can be modified by a seasonal Performance Factor to reflect ambient conditions. Performance factors have to be calculated for the entire year, by month or by season (e.g. summer/winter). Performance factors cannot be applied inconsistently (i.e. applied during the summer months and not during the winter months).

Section 2.1 (Cont'd)

- Restructuring changes – No change to content
  - Heat Rate Definition was just relocated after Incremental Heat Rate equation
  - Performance Factor Section 2.2.1 through 2.2.4 were moved to Section 2.1.2 through 2.1.5

Section 2.2

- Restructuring changes – No changes to content
  - Moved Fuel Cost Policy Section 2.3 to Section 2.2

- New Incremental Energy Cost definition

The incremental energy cost is the cost in dollars per MWh of providing an additional MWh from a synchronized unit.. It consists primarily of the cost of fuel, as determined by the unit's incremental heat rate (adjusted by the performance factor) times the fuel cost. It also includes operating costs, maintenance adders, emissions allowances, taxes, tax credits, and energy market opportunity costs. A Market Seller may submit sloped or blocked loaded offers into PJM's Markets Gateway system. The formula for calculating the a sloped, stepped, or block loaded incremental offer are show in Section 2.3.1 and 2.3.2 below.~~A Market Seller may only~~

- Sloped Offer Incremental Energy Cost

2.3.1 ~~Submission of and/or Modifications to Fuel Cost Policies~~Sloped Offer Incremental Energy Cost

The sloped function is the continuous first derivative of the heat input function. Units offered using a sloped function must select the "use offer slope" option in Markets Gateway. Generators offered using a sloped function must start their incremental offer curve with a zero MW segment. The incremental heat rate at zero MW is the y axis intercept of the incremental heat rate function (the incremental heat rate when MW = 0.).

Incremental Energy Cost in dollars per MWh for a sloped offer can be calculated by:

$$Incremental\ Energy\ Cost\ (Slope\ Offer) = Incremental\ Heat\ Rate * Total\ Fuel\ Related\ Cost\ \left(\frac{\$}{MMBtu}\right) + Maintenance\ Adder\ (\$/MWh) + Operating\ Cost\ Adder\ \left(\frac{\$}{MWh}\right) + Opportunity\ Cost\ Adder\ (\$/MWh)$$

Incremental Heat Rate – See Section 2.1

- Total Fuel Related Cost – See Section 2.2.3
- Maintenance Adder – See Section 2.6
- Operating Cost Adder – See Section 2.6.8
- Opportunity Cost Adder – See Section 12

- # Stepped Offer Incremental Energy Cost

2.3.2 Stepped Load Offer Incremental Energy Cost

The stepped incremental heat rate curve is derived from heat input curves, and direct measurements at different discrete output levels. Units offered using a stepped function must not select the "use offer slope" option in Markets Gateway. Generators offered using a stepped function should submit a nonzero first MW segment.

Incremental Energy Cost in dollars per MWh for a block loaded offer can be calculated by:

$$Incremental\ Energy\ Cost\ (Stepped\ Offer) =$$

$$[Incremental\ Heat\ Rate(i) - Incremental\ Heat\ Rate(i-1)]/[MWh(i) - MWh(i-1)]$$

$$*Total\ Fuel\ Related\ Cost\ (\$/MMBtu) + Maintenance\ Adder\ (\$/MWh)$$

$$+ Operating\ Cost\ Adder\ (\$/MWh) + Opportunity\ Cost\ Adder\ (\$/MWh)$$

- Incremental Heat Rate – See section 2.1
  - Incremental Heat Rate (i) is the incremental heat rate at the end of the block
  - Incremental Heat Rate (i-1) is the incremental heat rate at the beginning of the block
  - MWh(i) is the the MWh at the end of the block
  - MWH(i-1) is the MWH at the beginning of the block
- Total Fuel Related Cost – See Section 2.2.3
- Maintenance Adder – See Section 2.6
- Operating Cost Adder – See Section 2.6.8
- Opportunity Cost Adder – See Section 12

- Block Load Incremental Energy Offer

2.3.3 Block Load Offer Incremental Energy Cost

Block Load offers are used when a unit offers only one incremental energy step. The average heat rate of a block loaded offer is equal to the total heat input needed to run the unit divided by the total output. When using an average heat rate all the fuel cost is in the incremental offer so when using a block offer the No-load cost must be set to zero.

Incremental Energy Cost in dollars per MWh for a block loaded offer can be calculated by:

$$Incremenatal\ Energy\ Cost\ (Block\ Offer) =$$

$$(Average\ Heat\ Rate\left(\frac{MMBtu}{MWh}\right)$$

$$or\ Heat\ Input\ @EcoMAx\ (MMBtu)\ /EcoMax\ (MWh)$$

$$*Total\ Fuel\ Related\ Cost\ (\$/MMBtu)\ +\ Maintenance\ Adder\ (\$/MWh)$$

$$+\ Operating\ Cost\ Adder\ (\$/MWh)\ +\ Opportunity\ Cost\ Adder\ (\$/MWh)$$

- Total Fuel Related Cost – See Section 2.2.3
- Maintenance Adder – See Section 2.6
- Operating Cost Adder – See Section 2.6.8
- Opportunity Cost Adder – See Section 12

Section 2.3 (Cont'd)

- Need to add rule that Sloped offers must start at non-zer0 MW and must not select "Use Offer Slope in MG

- New No-Load Definition

No-Load Cost ($/hour) - The hourly cost required to theoretically operate a synchronized unit at zero MW. It consists primarily of the cost of fuel, as determined by the unit's no load heat (adjusted by the performance factor) times the fuel cost. It also includes operating costs, maintenance adders, emissions allowances and taxes~~create the starting point of a monotonically increasing incremental offer curve for a generating unit~~.

- Changes to No-Load Fuel

2.5.2 No-Load Fuel

All Market Sellers shall develop No-Load Costs for their units. The no-load heat input may be determined by collecting heat input values as a function of output and performing a regression analysis. The heat input values as a function of output may be either created from heat rate test data or the initial design heat input curve for an immature unit.

For units that use a different starting fuel (e.g. coal units), the fuel in the No-Load cost calculation cannot be the fuel used during startup and synchronization, but must be the fuel used during normal operation.

- # New No-Load Calculation

2.5.3 No Load Calculation

The initial estimate of a unit's **No-Load Cost ($/Hr)** is the No-Load fuel Cost multiplied by the Performance Factor, multiplied by the (Total Fuel-Related Cost (TFRC))

$$NoLoadCost(\$/Hour) =$$

$$(NoLoadFuel)*(Performance\ Factor*Total\ Fuel\ Related\ Cost)$$

$$+Maintennce\ Adder\left(\frac{\$}{hour}\right)+Operating\ Cost\ Adder\left(\frac{\$}{hour}\right)$$

- Performance Factor – See Section 2.1
- Total Fuel Related Cost – See Section 2.2.3
- Maintenance Adder – See Section 2.6
- Operating Cost Adder – See Section 2.6.8

~~The unit's generator offer curve must comply with PJM's monotonically increasing curve requirement. In some instances, the calculated No-Load Cost may have to be adjusted to ensure that the slope of the generator offer curve is monotonically increasing. The No-Load Cost adjustment is limited to a maximum difference of $1/MWh between the unit's first and second incremental cost offers.~~

Units that only operate block loaded (i.e. no dispatchable range) must be offered using an average heat rate and zero no load cost. All the hourly costs of operating the unit must be included in the incremental energy offer.

- Deleted alternative No-Load Cost calculation

~~As an alternative to adjusting the No-Load Cost, No-Load Cost may also be calculated by subtracting the incremental cost (unit's Economic Minimum cost-offer value multiplied by MW value) at the unit's Economic Minimum point from the total cost (from the heat input at Economic Minimum value) at the unit's Economic Minimum point.~~

$$NoLoadCost(\$/Hour) = (EconomicMinimumHeatInput * PerformanceFactor * (TFRC + VOM) - (EconomicMinimumIncrementalCost(\$/MWh) * EconomicMinimum(MW))$$

~~Note that if the unit of Variable Operations and Maintenance (VOM) cost is in terms of dollars per Equivalent Service Hours (ESH), the equation changes to:~~

$$NoLoadCost(\$/Hour) = (EconomicMinimumHeadInput * PerformanceFactor * TFRC) + VOM - (EconomicMinimumIncrementalCost(\$/MWh) * EconomicMinimum(MW))$$

~~When using No-Load Fuel to calculate No-Load Cost, the Market Seller must submit block average cost and cannot select "Use Offer Slope" when entering cost information into Markets Gateway. When using the alternative incremental cost method to calculate No-Load Cost, the Market Seller must submit incremental cost and select "Use Offer Slope" when entering cost information into Markets Gateway.~~

- Added Ten Percent Adder Section

2.9 Ten Percent Adder

In accordance with the Operating Agreement, Market Sellers can include a ten percent adder in their start-up, no-load, and incremenatl energy offers. The ten percent adder is limited in the following situations:

- For incremental energy offers less than $2,000/MWh the ten percent adder is limited to the lesser of 10% or $100 MWh, the sum of which shall not exceed $2,000/MWh
- And for incremental energy offers greater than $2,000/MWh, the ten percent adder is limted to $0/MWh.

- # Added Ten Percent Adder Example

For example a Market Seller calculates the following incremental energy costs for the unit

MW	Incremental Cost ($/MWh)
100	800
200	1100
300	1950
400	2005

Then the allowable ten percent adder for each MW step would be

MW	Incremental Cost ($/MWh)	Calculated 10% Adder ($/MWh)	Limtation	Allowable 10% Adder ($/MWh)
100	800	$80	N/A	$80
200	1100	$110	Lessor of 10% or $100	$100
300	1950	$195	Sum shall not exceed $2000/MWh	$50
400	2010	$201	10% Adder = $0	$0

Section 3 - Nuclear

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 3.2 to and consolidated Section 3.1 to include Heat Input/Rate and Performance Factor
  - Moved Fuel Cost Section 3.3 to Section 3.2
  - Created Incremental Energy Cost Section 3.3

Section 4 – Fossil Steam

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 4.2 to and consolidated Section 4.1 to include Heat Input/Rate and Performance Factor
  - Moved Fuel Cost Section 4.3 to Section 4.2
  - Created Incremental Energy Cost Section 4.3

- Deleted Equivalent Service Hours (ESH Formula)

5.6.3 Equivalent Service Hours (ESH)

~~The equivalent service hours shall be calculated based on history:~~

$$Equivalent\ Service\ Hours = (Cyclic\ Starting\ Factor * Number\ of\ Starts) + Total\ Operating\ Hours\ at\ any\ load\ level + (Cyclic\ Peaking\ Factor * Number\ of\ Hours\ above\ Base\ load\ temperature\ limit)$$

CC CTs shall use OEM supplied values for cyclic starting factors and cyclic peaking factors and formulas even if the CT technology is no longer being built. Some OEMs use ESH to trigger when a major overhaul should be performed. These are typically found in OEM or LTSA documentation under “equivalent hours”, “equivalent starts”, “factored hours”, or “factored starts”.

Section 5 – Combined Cycle (Cont'd)

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 5.2 to and consolidated Section 5.1 to include Heat Input/Rate and Performance Factor
  - Moved Fuel Cost Section 5.3 to Section 5.2
  - Created Incremental Energy Cost Section 5.3

Section 6 – Combustion Turbine & Diesel Engine

- Revised No-Load Fuel definition
  - Deleted note in Section 6.1

~~For CT generating units, no-load fuel shall be the theoretical or actual fuel burn rate expressed in MMBtu/Hr at the point of electric bus synchronization.~~

  - Added to Section 6.5

For CT generating units, no-load fuel shall be the theoretical or actual fuel burn rate expressed in MMBtu/Hr at the point of electric bus synchronization.

Section 6 – Combustion Turbine & Diesel Engine (Cont'd)

- Deleted equivalent Service Hours (ESH) equation

~~The equivalent service hours shall be calculated based on history.~~

$$Equivalent\ Service\ Hours = (Cyclic\ Starting\ Factor * Number\ of\ Starts) + Total\ Operating\ Hours\ at\ any\ load\ level + (Cyclic\ Peaking\ Factor * Total\ Operating\ Hours\ above\ base\ load\ temperature\ limit)$$

CTs shall use OEM supplied values for cyclic starting factors and cyclic peaking factors and formulas even if the CT technology is no longer being built. Only OEM-specified cyclic starting and peaking factors can be applied to the Maintenance Adder of the unit's cost-based offer. If the OEM documentation does not specify a cyclic starting factor and/or cyclic peaking factor, then the cyclic starting factor and/or cyclic peaking factor shall be zero.

Section 6 – Combustion Turbine & Diesel Engine (Cont'd)

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 6.2 to and consolidated Section 6.1 to include Heat Input/Rate and Performance Factor
  - Moved Fuel Cost Section 6.3 to Section 6.2
  - Created Incremental Energy Cost Section 6.3

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 7.2 to and consolidated Section 6.1 to include Pumping Efficiency (Pumped Storage Hydro Only) and Performance Factor
  - Moved Fuel Cost Section 7.3 to Section 7.2
  - Created Incremental Energy Cost Section 7.3

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 9.2 to and consolidated Heat Input/Rates and Performance Factor
  - Moved Fuel Cost Section 9.3 to Section 9.2
  - Created Incremental Energy Cost Section 9.3

Section 10 – Solar Units

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 10.2 to and consolidated Heat Input/Rates and Performance Factor
  - Moved Fuel Cost Section 10.3 to Section 10.2
  - Created Incremental Energy Cost Section 10.3

Section 11 – Batteries and Flywheels

- Restructuring changes – No changes to content
  - Moved Performance Factor Section 11.2 to and consolidated Efficiency Factor and Performance Factor
  - Moved Fuel Cost Section 11.3 to Section 11.2
  - Created Incremental Energy Cost Section 11.3

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