2.8 Regulation Service

Regulation is the capability of a specific resource with appropriate telecommunications, control and response capability to increase or decrease its output in response to a regulating control signal to control for frequency deviations'

The cost-based regulation offer is split into two portions:

The Regulation Capability portion ~~capturing~~consists of the f~~F~~uel c~~C~~ost i~~I~~ncrease and u~~U~~nit s~~S~~pecific h~~H~~eat r~~R~~ate d~~D~~egradation due to o~~O~~perating at l~~L~~ower l~~L~~oads and ~~cihri~~t~~T~~he margin risk adder~~ may only be added to the Regulation Capability portion~~;

The Regulation Performance portion ~~representing and~~consists of the c~~C~~ost i~~I~~ncrease in VOM, cost increase due to heat rate increase during non-steady state operation and, where applicable, e~~E~~nergy l~~L~~osses for e~~E~~nergy s~~S~~torage ~~Devices. The~~devices. ~~t~~The $/MW value determined in the performance offer- will be converted to $/ΔMW by multiplying the value by the annual ratio of ΔMW/MW for the applicable signal for that offer as described in Manual 11.

Regulation Capability costs to provide Regulation Service from a unit shall include the following components up to but not exceeding:

$$\text{Regulation Capability Regulation Costs } (\$\,/\,\text{MW}) \leq$$

$$(\text{Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at Lower Loads}) \cancel{+ \text{Cost Increase due to Heat Rate Increase during nonsteady state operation}}$$

$$\cancel{(\text{above heat rate factor not to exceed } 0.35\%)} + \text{Margin Risk Adder}$$

Regulation Performance costs to provide Regulation s~~S~~ervice from a unit shall include the following components up to but not exceeding:

$$\text{Regulation Performance } \cancel{\text{Regulation}} \text{ Costs } (\$\,/\,\Delta\text{MW}) \leq$$

$$\{\text{Cost Increase in VOM} + \text{Cost Increase due to Heat Rate Increase during nonsteady state operation}$$

$$(\text{above heat rate factor not to exceed } 0.35\%) +$$

$$(\text{Energy Storage Unit } \cancel{\text{Fuel Cost Increase for Energy Storage Devices only}}\text{Losses})\}/\ \Delta\text{MW/MW}$$

Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at lower loads:

The costs (in $/MWh of Regulation) to provide Regulation service from units shall not exceed the fuel cost increase due to operating the unit at lower loads than at the optimal economic dispatch level load and the unit specific heat rate degradation from operating at lower loads, resulting from operating the unit at lower MW output incurred from the provision of Regulation over the entire generator MW range of providing Regulation service.

Cost Increase due to Heat Rate increase during non-steady state:

The cost (in $/~~delta~~ MW~~h~~h of Regulation) increase due to the heat rate increase resulting from operating the unit at a non steady-state condition. This heat rate loss factor rate shall not exceed 0.35% of the top Regulation load MW heat rate value.

Margin/Risk Adder:

Margin Risk Adder shall not exceed $12.00 per MWh of Regulation service provided.

Energy Storage Unit Losses:

Energy Storage Unit Losses can only be greater than zero for energy storage type devices and calculated in accordance with the guidance provided in section 11.8.

Cost increase in VOM:

The cost increase (in $/~~delta~~ MW~~h~~h of Regulation) of variable operations and maintenance (VOM) cost resulting from operating the unit at lower MW output incurred from the provision of Regulation. VOM costs shall be calculated by the following methods and shall not exceed those levels below:

For non-hydro units that have been providing Regulation service for less than 10 years, or all hydro units regardless of the historical years of Regulation service, the following variable operation and maintenance (VOM) costs can be applied by unit type up to the following:

- Super-critical Steam: $10.00 per MW~~h~~h of Regulation
- Sub-critical Steam: $3.50 per MW~~h~~h of Regulation
- Combined Cycle: $2.50 per MW~~h~~h of Regulation
- Combustion Turbine: $2.00 per MW~~h~~h of Regulation
- Hydro: $1.00 per MW~~h~~h of Regulation
- Energy Storage: Based on OEM estimates initially and actual as history is available.

Exhibit 4: VOM for All Hydro Units or Non-Hydro Units providing service for less than 10 years

For non-hydro units that have been providing Regulation service for more than 10 years, the VOM rates above can be utilized only if the annual VOM dollar amounts resulting from those rates and included in Regulation cost based offers, are subtracted from the escalated 10 or 20 year historical total VOM accounts and the Regulation MWh based on the average of the last three years.

Energy Storage Units that participate only in regulation service shall include all their VOM in the Cost increase in VOM adder in Regulation cost offers.

~~Margin/Risk Adder:~~

~~Margin Risk Adder shall not exceed $12.00 per MWh of Regulation service provided.~~

For example, a 100 MW sub-critical coal fired steam unit that has been providing Regulation service for 30 years. The unit averaged 5,000 MWh of Regulation service over the last three years and the escalated 20 year historical total VOM = $10,000,000.

Annual VOM costs to subtract

= ($3.50 per Regulation MWh * 5,000 MWh) * 20 years

= $17,500 per year * 20 years

= $350,000

20-year balance of historical total VOM accounts

= $10,000,000 - $350,000

= $ 9,650,000

Actual Regulation VOM incremental costs submitted and evaluated pursuant to the Cost and Methodology Approval Process.

Exhibit 5: Example of VOM for Non-Hydro Units providing Regulation for more than 10 years:

For Example for a Sub-critical Coal-Fired Steam Unit providing Regulation Service for the last seven years:

~~**Unit Operating Mode**~~	~~**Output**~~	~~**Heat Rate**~~
~~Steam Unit Highest Regulating Operating Load:~~	~~100 MW~~	~~9,000 BTU/kWh~~
~~Steam Unit Regulation Band:~~	~~10 MW~~	
~~Lowest Regulating Operating Load~~	~~40 MW~~	~~12,500 BTU/kWh~~

Data Submitted by Participant	Value	Units
Fuel	$1.50	$/MBTU
Heat Rate @ EcoMax	9,000.0	Btu/KWh
Heat Rate @ RegMin	12,500.0	Btu/KWh
VOM	$3.50	$/MW of Regulation
EcoMax	100.0	MW
RegMin	40.0	MW
Unit Reg Band	10.0	MW
Margin Adder	$12.00	$/MW of Regulation

Heat Rate Adjustment (Operating Range)	Value	Units
Unit Base Load Heat Rate Fuel Input	360.0	MBTU/Hr
Unit Reduced Load Heat Rate Fuel Input	500.0	MBTU/Hr
Difference	140.0	MBTU/Hr

$$\text{Unit Base Load Heat Rate Fuel Input} = \text{Unit Base Load Heat Rate} * \text{RegMin} * \frac{1\text{MBTU}}{1{,}000{,}000\ \text{BTU}} * 1{,}000\ \text{kW/MW}$$

$$\text{Unit Base Load Heat Rate Fuel Input} = 9{,}000\frac{\text{BTU}}{\text{kWh}} * 40\ \text{MW} * \frac{1\text{MBTU}}{1{,}000{,}000\ \text{BTU}} * 1{,}000\ \text{kW/MW} = 360\ \text{MBTU/Hr}$$

$$\text{Unit Reduced Load Heat Rate Fuel Input} = \text{Unit Reduced Load Heat Rate} * \text{RegMin} * \frac{1\text{MBTU}}{1{,}000{,}000\ \text{BTU}} * 1{,}000\ \text{kW/MW}$$

$$\text{Unit Base Load Heat Rate Fuel Input} = 12{,}500\frac{\text{BTU}}{\text{kWh}} * 40\ \text{MW} * \frac{1\text{MBTU}}{1{,}000{,}000\ \text{BTU}} * 1{,}000\ \text{kW/MW} = 500\ \text{MBTU/Hr}$$

$$\text{Difference} = \text{Unit Base Load Heat }\cancel{\text{Rate}}\text{Input} - \text{Unit Reduced Load Heat }\cancel{\text{Rate}}\text{Input}$$

$$\text{Difference} = 500\frac{\text{MBTU}}{\text{hr}} - 360\frac{\text{MBTU}}{\text{hr}} = 140\frac{\text{MBTU}}{\text{hr}}$$

Heat Rate Adjustment (Non-Steady State Operation)	Value	Units
Top Operating Point Heat Rate	9,000.0	BTU/kWh
Heat Rate Loss Factor (Max per M15)	0.35%	
Heat Rate Loss	3.15	MBTU/Hr

$$\text{Heat Rate Loss} = (\text{Economic Maximum Heat Rate} * 0.35\%) * \frac{1\text{MBTU}}{1{,}000{,}000\ \text{BTU}} * 1{,}000\frac{\text{kW}}{\text{MW}} * \text{Economic Maximum MW}$$

$$\text{Heat Rate Loss} = (9{,}000\text{BTU/kWh} * 0.35\%) * \frac{1\text{MBTU}}{1{,}000{,}000\ \text{BTU}} * 1{,}000\frac{\text{kW}}{\text{MW}} * 100\ \text{MW} \cancel{= 3150 * 0.001} = 3.15\ \text{MBTU/Hr}$$

(a) Heat Rate Adjusment (Operating Range)	Value	Units
Fuel Cost Adder - Operating Range	$3.50	$/Hr/MW of Regulation

Fuel Cost Adder

$$= \left((\text{Difference} * \text{Fuel Cost}) \middle/ (\text{Economic Maximum MW} - \text{Regulation Minimum MW}) \right)$$

$$\text{Fuel Cost Adder} = \left((140\ \text{MBTU/Hr} * \$1.50/\text{MBTU}) \middle/ (100\ \text{MW} - 40\ \text{MW}) \right) \cancel{= \frac{210}{60}}$$

$$= \$3.50\ /\text{Hr/MW}$$

(b) Margin/Risk Adder	Value	Units
Margin/Risk Adder	$12.00	$/Hr/MW of Regulation

MAXIMUM CAPABILITY OFFER	Value	Units
~~a+b~~Heat Rate Adjustment(Operating Range) + Margin Adder	15.5	$/Hr/MW of Regulation

Historic Mileage Ratio	Value
Ratio	5

** This value is an example substitute for the annual average value for RegA.

(c) Heat Rate Adjustment (Non Steady-State Operation)	Value	Units
Fuel Cost Adder - Non Steady-State Operation	$0.50	$/Hr/MW of Regulation

$$\text{Fuel Cost Adder} = \frac{(\text{Heat Rate Loss} * \text{Fuel Cost})}{\text{Regulation Band MW}}$$

$$\text{Fuel Cost Adder} = \frac{(3.15\ \text{MBTU/Hr} * \$1.50/\text{MBTU})}{10\ \text{MW}} \cancel{= \frac{5}{10}} = \$0.50/\text{Hr/MW}$$

(d) VOM Adder	Value	Units
Regulation VOM Adder	$3.50	$/Hr/MW of Regulation

MAXIMUM PERFORMANCE OFFER	Value	Units
(c+d)/Historic Mileage Ratio	$ 0.80	$/ΔMW

$$\text{Maximum Performance Offer} = [\text{Fuel Cost Adder(Non Steady State Operation)} + \text{Regulation VOM Adder}]/\ \text{Historic Mileage Ratio}$$

$$\text{Fuel Cost Adder} = [\$0.50/\text{Hr/MW} + \$3.50/\text{Hr/MW}]\ /\ 5\ \Delta\text{MW/MW} = \$0.80/\text{Hr/MW of Regulation}$$

~~Base Prices~~	
~~Fuel Cost (TFRC):~~	~~$1.50/MBTU~~

~~Heat Rate Adjustment (Operating Range)~~	
~~Unit Base Load Heat Rate Fuel Input =~~	~~9,000 * 40 / 1000 = 360.0 MBTU/Hr~~
~~Unit Reduced Load Heat Rate Fuel Input =~~	~~12,500 * 40 / 1000 = 500.0 MBTU/Hr~~
~~Difference =~~	~~140.0 MBTU/Hr~~
~~Heat Rate Adjustment (Non Steady-State Operation)~~	
~~Top Operating Point Heat Rate =~~	~~9,000 Btu/kWh~~
~~Heat Rate Loss Factor =~~	~~0.35%~~
~~Heat Rate Loss =~~	~~(9,000*0.35%) * 100 MW / (1000 kW/MW)~~
	~~= 3.15 MBTU/Hr~~
~~Total Regulation Cost:~~	
~~(a) Heat Rate Adjustment (Operating Range)~~	
~~Fuel Cost Adder – Operating Range =~~	~~140.0 MBTU/Hr * $1.50/MBTU / 60 MW Operation Band~~
	~~= $3.50/Hr/MW of Regulation~~
~~(b)Heat Rate Adjustment (Non Steady-State Operation)~~	
~~Fuel Cost Adder–Non Steady-State Operation~~	~~= 3.15 MBTU/Hr * $1.50 MBTU / 10 MW Regulation Band~~
	~~= $0.47/Hr/MW of Regulation~~
~~(c) VOM Adder~~	
~~Regulation VOM Adder~~	~~$3.50/Hr/MW of Regulation (for a Steam Unit)~~
~~(d) Margin/Risk Adder~~	
~~Margin/Risk Adder =~~	~~$12.00/Hr/MW of Regulation~~
~~Total Regulation Cost~~	
~~Total Regulation Cost =~~	~~(a) Fuel Cost Adder (Operating Range) + (b) Fuel Cost Adder (Non Steady-State Operation) + (c) VOM Adder + (d) Margin/Risk Adder~~
~~Total Regulation Cost =~~	~~$3.50 + $0.47 +3.50+ $12.00~~
~~Total Regulation Cost =~~	~~$19.47/Hr/MW of Regulation~~

Exhibit 6: Regulation Maximum Allowable Cost Adder Example

Section 11: Energy Storage

11.8 Regulation Cost

Note: The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types. The following additional information only pertains to battery and flywheels units.

~~For a~~ Battery or Flywheel Units shall calculate Energy Storage unit Losses in accordance with the equation below. ~~to be consistent with other PJM units within this manual, the term~~The "Cost Increase due to Heat Rate Increase during non-steady state operation" ~~is used to account for the energy losses experienced by an energy storage device while providing regulation service. T~~and the "Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at lower loads" shall be equal to zero.

If a Unit Owner wishes to change its method of calculating these losses, the PJM Member shall submit a cost policy to the PJM MMU pursuant to the Cost and Methodology Approval Process. The approved method of calculation may be implemented upon approval and may be updated no more frequently than once every 12 months. If any action by a government or regulatory agency external to a Unit Owner that results in a need for the Unit Owner to change its method of cost calculation, the affected PJM Member may submit a request, or notification as appropriate, to the PJM MMU for evaluation, pursuant to the Cost and Methodology Approval Process.

Energy Storage Unit ~~Fuel Cost Increase~~Losses ($/MW) – shall be the calculated average of seven (7) days of rolling hourly periods where the real time bus LMP ($/MWh) at the plant node is multiplied by the net energy consumed (MWh) when regulating divided by the regulation offer (MW). The seven (7) days of rolling hourly periods shall consist of the unit's last 168 hour periods with accepted regulation offers. The following equation governs energy storage unit's fuel cost increase:

$$\text{Energy Storage Unit } \cancel{\text{Fuel Cost Increase}}\text{Losses}(\$/\text{MW})$$
$$= \left| \text{Average of 7 Days}\left\{\frac{\left(\text{Hourly LMP }\left(\frac{\$}{\text{MWh}}\right) * \text{Hourly Net Energy Consumed}(\text{MWh})\right)}{\text{Hourly Accepted Regulation Offers (MW)}}\right\} \right|$$

~~Capability costs to provide Regulation sService from a unit shall include the following components up to but not exceeding:~~

$$\cancel{\text{Capability Regulation Costs } (\$ / \text{MW}) \leq}$$

$$\cancel{\text{Margin Risk Adder}}$$

~~Performance costs to provide Regulation sService from a unit shall include the following components up to but not exceeding:~~

$$\cancel{\text{Performance Regulation Costs } (\$ / \Delta\text{MW}) \leq}$$

$$\cancel{\text{Cost Increase in VOM} + (\text{Energy Storage Unit Fuel Cost Increase})}$$