Start-Up Cost Offer Numerical Examples

Tom Hauske
Performance Compliance
Cost Development Subcommittee
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M15 Section 1.7.2 Start-up Cost

Start-up Costs are defined as the unit costs to bring the boiler, turbine and generator from shutdown conditions to the point after breaker closure which is typically indicated by telemetered or aggregated state estimator MWs greater than zero and is determined based on the cost of start fuel, total fuel-related cost, performance factor, electrical costs (station service), start maintenance adder, and additional labor cost if required above normal station manning. Start-up Costs can vary with the unit offline time being categorized in three unit temperature conditions: hot, intermediate and cold. Start-up Cost is a dollar cost and is incurred once each time the unit operates regardless of the period of operation. See Start-up Cost in Section 2.4.

M15 Section 2.4 Start-up Cost

Start-up Cost ($) - The unit costs required to bring the boiler, turbine, and generator from shut-down conditions to the point after breaker closure which is typically indicated by telemetered or aggregated state estimator MWs greater than zero and is determined based on the cost of start fuel, total fuel-related cost, Performance Factor, electrical costs (station service), start maintenance adder, and additional labor cost if required above normal station manning levels.

Start-up Cost ($/Start) =

Start Fuel Consumed (MMBtu/Start) * TFRC ($/MMBtu) * Performance Factor

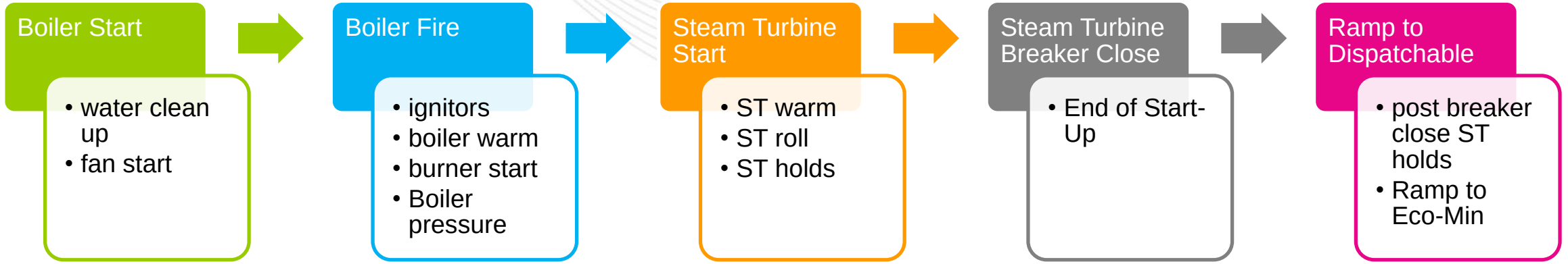
+ (Station Service (MWh) * Station Service Rate ($/MWh))

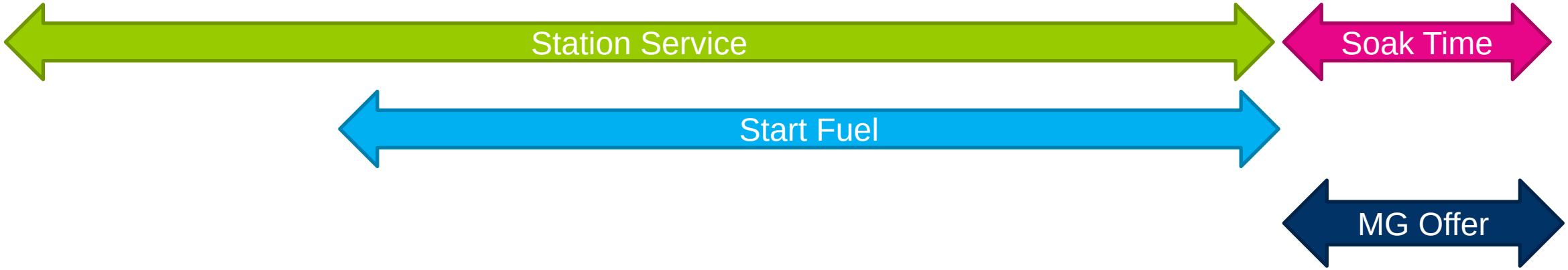
+ Start Maintenance Adder ($/Start) + Start Incremental Labor Cost ($/Start)

M15 Section 2.4 Start-up Cost

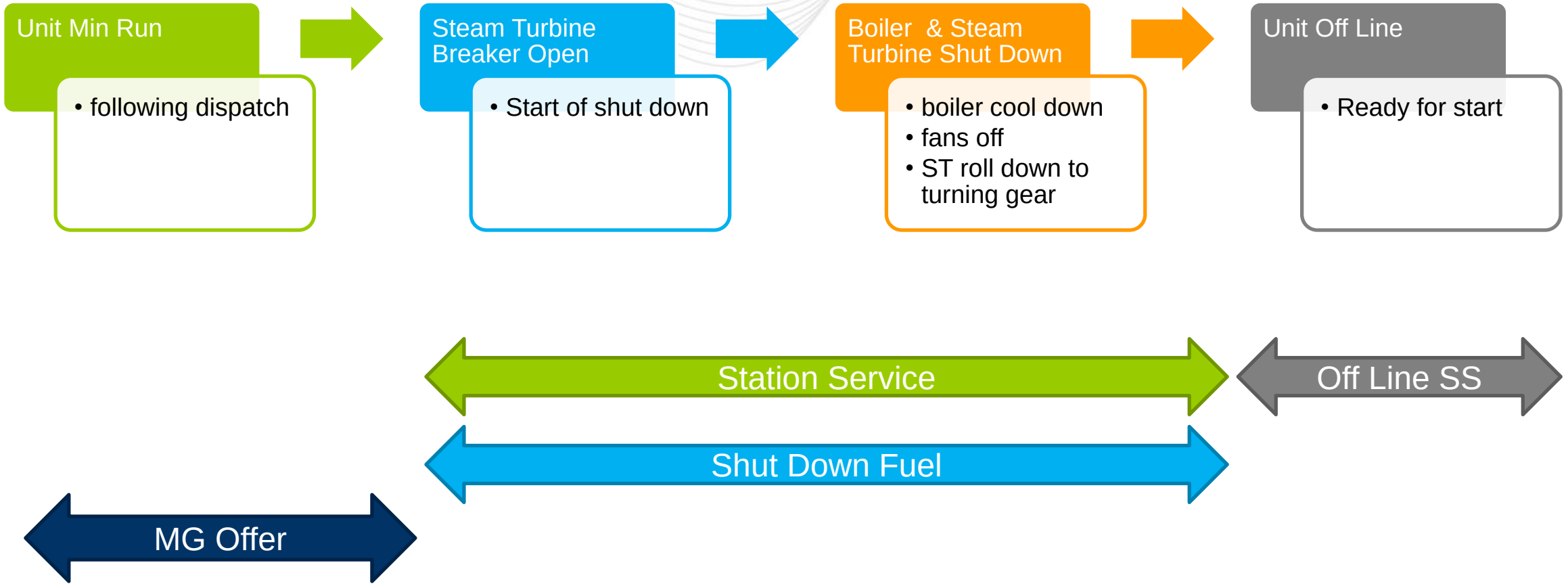
- Station Service Rate – A $/MWh value based on the 12-month rolling average off-peak energy prices updated quarterly by the Office of the Interconnection.
- Start Fuel - Fuel consumed from first fire of start process (initial reactor criticality for nuclear units) to breaker closing (including auxiliary boiler fuel) plus fuel expended from breaker opening of the previous shutdown to initialization of the (hot) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.
- Start Maintenance Adder – See Section 2.6
- Start Additional Labor Cost – Additional labor costs for startup required above normal station manning levels.

Steam Unit Start-Up





Steam Unit Shut Down



Steam Unit Start-up Example

- Fuel Cost – Primary $4.00/MMBtu / Aux Boiler & Ignitor Fuel $14.00/MMBtu
- Performance Factor – 1.02
- Auxiliary Boiler Fuel – 2,000 MMBtu
- Boiler Ignitor Fuel – 4,000 MMBtu
- Boiler Primary Fuel to ST breaker closure – 8,000 MMBtu
- Boiler Shutdown Fuel – 100 MMBtu
- Station Service MWh to ST breaker closure – 90 MWh
- Station Service MWH during shutdown – 10 MWh
- Station Service Rate – $17.26 (1st Quarter of 2021)
- Maintenance Adder - $0.25/MMBtu
- Start additional labor cost - $0 per Start

Steam Unit Start-up Example

Start-up Cost ($/Start)

= Start Fuel Consumed (MMBtu/Start) * TFRC ($/MMBtu) * Performance Factor + (Station Service (MWh) * Station Service Rate ($/MWh)) + Start Maintenance Adder ($/Start) + Start Incremental Labor Cost ($/Start)

= [(2,000 + 4,000 (MMBtu)) * (14.00 + 0.24 ($/MMBtu)) + (8,000 + 100 (MMBtu)) * (4.00 + 0.24 ($/MMBtu))] * 1.02 + [(90 + 10 (MWh)) * $17.26/MWh] + $0/ Start*

+ $0 /Start

= $132,168 /Start

* Maintenance Adder was included in TFRC with units of $/MMBtu

M15 Section 5.4 Combined Cycle Start-up Cost

Start-up Cost ($/Start) =

Start Fuel Consumed (MMBtu/Start) * TFRC ($/MMBtu) * Performance Factor

+ (Station Service (MWh) * Station Service Rate ($/MWh))

+ Start Maintenance Adder ($/Start) + Start Incremental Labor Cost ($/Start)

+ (Station Service after Breaker Open (MWh) * Station Service Rate ($/MWh))

- (Net Generation from CT Synch to ST Synch (MWh) * Cost ($/MWh))

- (Net Generation Shutdown (MWh) * Cost ($/MWh))

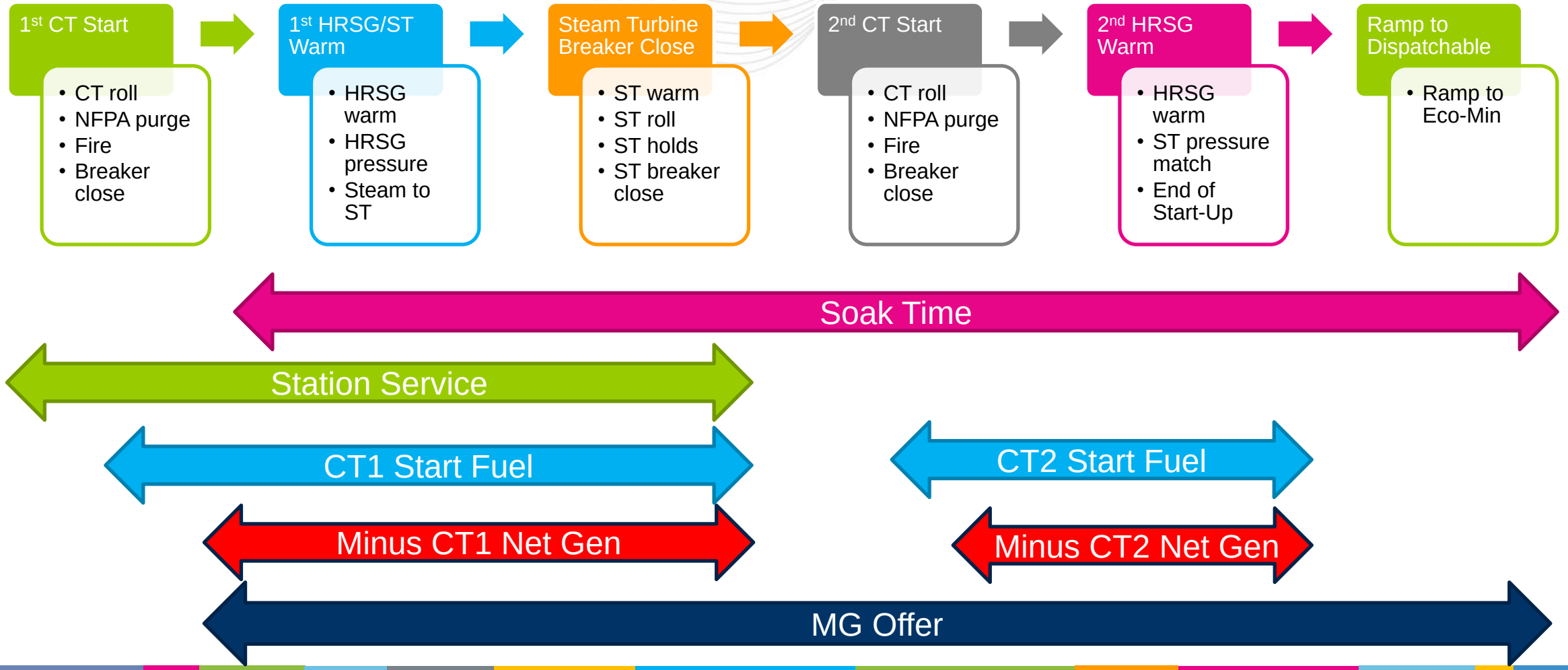
M15 Section 5.4 Combined Cycle Start Fuel Consumed

- **Start Fuel Consumed Cost** is the cost of start fuel (basic fuel cost plus fuel handling and other fuel-related costs) from first CT fire to breaker closing for the steam turbine generator, as measured during a normal start sequence, and the cost of shutdown fuel from last breaker opening to fuel valve closure. Additionally, this includes the cost of start fuel from CT first fire to the point where heat recovery steam generator (HRSG) steam pressure matches steam turbine inlet pressure, for any CT unit/HRSG combinations started after synchronization of the steam turbine generator.

M15 Section 5.4 CC Start-up Station Service/Net Generation

- **Station Service** is included from initiation of start sequence of initial CT to breaker closing of the steam turbine generator (total station use minus normal base station use) priced at the Station Service Rate
- Add to this (+) station service after breaker opening of the last component when finished operating as a CC unit, priced at the Station Service rate. (Station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use. This station service is not to include maintenance use or non-normal uses.)
- Minus (-) the integration of net generation from CT synchronization to steam turbine generator synchronization or to HRSG steam output at line pressure, priced at the actual cost of the unit.
- Minus (-) the integration of net generation during the shutdown period, priced at the actual cost of the unit.

2x1 Combined Cycle Unit Start-Up



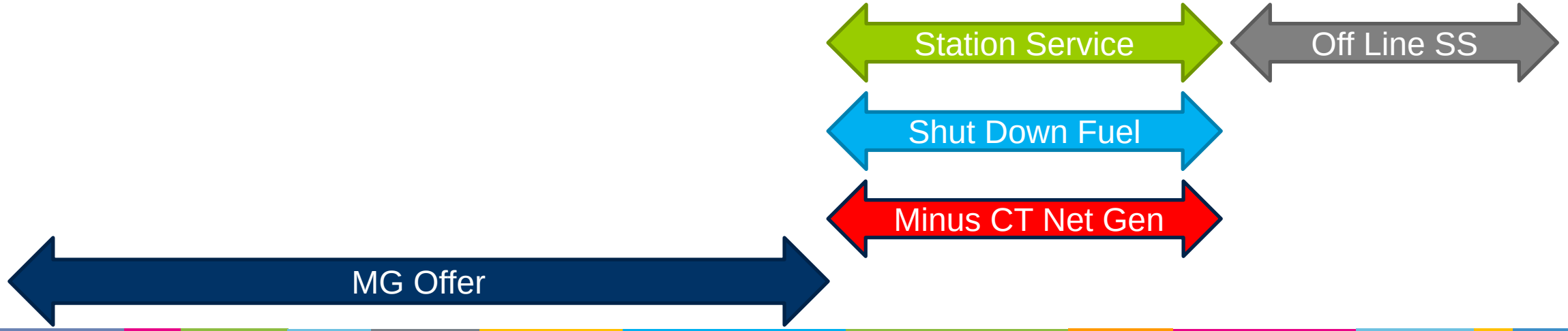
2x1 Combined Cycle Unit Shut Down

Unit Min Run
- following dispatch

Steam Turbine Breaker Open
- Start of shut down

CT1 and CT2 Breaker Open
- HRSG cool down
- ST roll down to turning gear

Unit Off Line
- Ready for start



2x1 Combined Cycle Cold Start-up Example

- Fuel Cost – CTs & aux boiler $4.00/MMBtu
- Performance Factor – 1.02
- Auxiliary boiler fuel – 500 MMBtu
- CT1 fuel to ST breaker closure (180 min) – 2,500 MMBtu
- CT2 fuel to HRSG pressure match (30 Min) – 500 MMBtu
- CT1 & CT2 average soaking output = 25 MWh
- CT1 & CT2 shutdown fuel – 0 MMBtu
- Station Service MWh to ST breaker closure – 15 MWh
- Station Service MWH during shutdown – 3 MWh
- Station Service Rate – $17.26 (1st Quarter of 2021)
- Maintenance Adder - $5,000 /Start
- Start additional labor cost - $0 per Start

Calculation of CT Net Generation Offset

The IMM recommends calculating a fuel offset using the unit's heat input coefficients to determine the "*integration of net generation from CT synchronization to steam turbine generator synchronization or to HRSG steam output at line pressure, priced at the actual cost of the unit*" for combined cycle start-up cost calculations

Inputs for the Calculation

- Heat Input from CT1 fire to ST breaker close and CT2 fire to HRSG pressure match
  = 2500 MMBtu + 500 MMBtu = 3000 MMBtu

- Average CT1 & CT2 generation to ST breaker close and HRSG pressure match
  = [(25 MWh * 180 min) + (25 MWh * 30 min)] / 2 = 43.75 MWh

- Average Time for CT1 to ST breaker close and CT2 to HRSG pressure match
  = (180 min + 30 min) / 2 =105 min

Calculation of CT Net Generation Offset

Heat Input Polynomial Coefficients					
Perf.Factor	a	b	c		
1.02000	0.007800000	4.516400	312.36		
Plant Supplied Data		as a function of HRSG temperature			Comments
Step	Start-up Offer Heat Input Assumptions:	hot	intermediate	cold	
(A)	Heat Input from First Fire to ST breaker close (MBtu)	1,000.00	2,000.00	3,000.00	Assume CT First Fire to breaker close is 50 MBtu/CT.
(B)	ST brk close to CT shutdown heat input (MBtu)	0	0	0	No shutdown fuel burn
(C)	Station Service from initiation to ST brk.close(MWh)	5.0	10.0	15.0	
(D)	Generation from CT brk.close to ST brk.close (MWh)	18.75	31.25	43.75	average for each of the 2 CTs
(E)	CT breaker close to STG breaker close (minutes)	45.00	75.00	105.00	average for each of the 2 CTs
(F) = ((A)-100)/(E)	Average Heat Input level (MBtu/minute) soaking ST	20.00	25.33	27.62	note 100 MMBtu (50/CT) subtracted for ignition to brk.close burn
(G) = (D)/(E)	Average Output level (MWh/minute) while soaking ST	0.42	0.42	0.42	
(H) = 60 x (G) x 2 CTs	Average CT generator output level (MW)	50.00	50.00	50.00	doubled because there are two CTs
(I) = Poly. at (H) x (E)/60	Heat Input "GenOffset" (MBtu) applying polynomial	426.63	711.04	995.46	GenOffset
Net of Offset = (A)+(B)-(I)	Net Heat Input after "GenOffset" is netted out(MBtu)	**573**	**1,289**	**2,005**	

- Use 995.46 MMBtu for CT1 & CT2 Net Generation Offset for the Cold Start-up Cost Calculation

2x1 Combined Cycle Cold Start-up Cost

Start-up Cost ($/Start) =
[Aux Boiler Fuel + Start Fuel Consumed – CT1 & CT2 Net Generation Offset Fuel (MMBtu/Start)]
* TFRC ($/MMBtu) * Performance Factor + (Station Service (MWh) * Station Service Rate ($/MWh))
+ Start Maintenance Adder ($/Start) + Start Incremental Labor Cost ($/Start)
+ (Station Service after Breaker Open (MWh) * Station Service Rate ($/MWh))

Start-up Cost ($/Start) =
[500 + 3000 – 995.46 (MMBtu/Start) * $4.00 /MMBtu * 1.02 + (15 MWh * $17.26 / MWh)
+ $5000 /Start + $0 + (3 MWh * $17.26/MWh)

= $15,529.2 per start

Contact

CDS Chair :
Nicole Scott ,
Nicole.Scott@pjm.com

CDS Secretary:
Heather Reiter,
Heather.Reiter@pjm.com

Presenter/SME:
Thomas Hauske,
Thomas.Hauske@pjm.com

Member Hotline

(610) 666 – 8980

(866) 400 – 8980

custsvc@pjm.com