

Ancillary Services

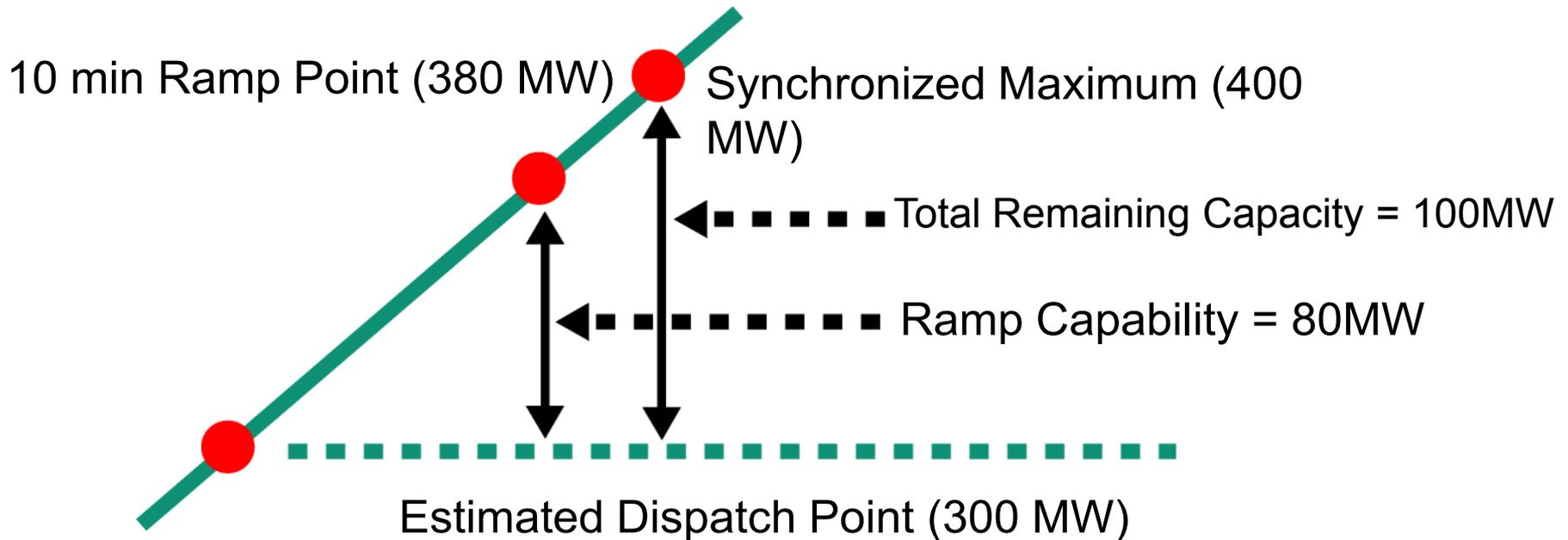
Synchronous Reserve Review

Excerpts from Gen 301 Training for CDS

Tier 1 and Tier 2 Resources

Tier 1 – Economic	Marginal, partially loaded units - online, following economic dispatch and able to increase output in response to a Spinning event; Demand Response that drops load in response to request
Tier 2 – Non-economic	Condensers (CTs and hydro), steam reduced to provide spinning, CTs on at min – operating at a point that deviates from economic dispatch, Demand Response that can drop load

Tier 1 Capability Calculation - Example



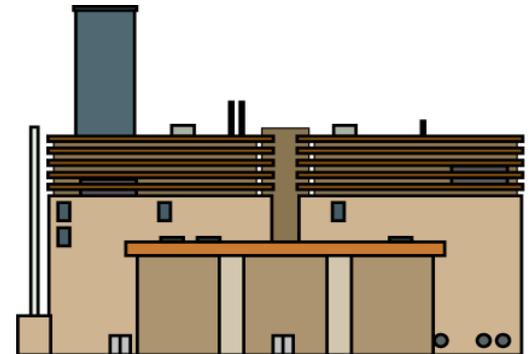
Synchronized Ramp Rate = 8 MW/min, therefore max
T1 capability = 8 MW/min * 10min = 80 MW

Ramp Rate is more limiting, so T1 capability = 80 MW

Initially, no Tier 1 estimate for Demand Response

Synchronized Reserve Providers

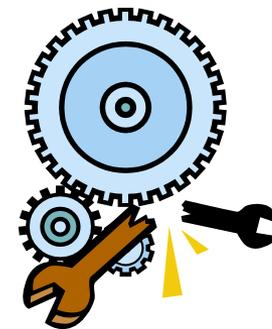
- **Who can provide Synchronized Reserves?**
 - Synchronized generators (steam, hydro, combustion turbine)
 - Either online or condensing
 - Demand Response
 - Limited to 25% of the Synchronized Reserve Requirement for each Reserve Zone
 - Not permitted in Dominion



Demand Response as Synchronized Reserve

- Demand Response must meet the following criteria to participate in the Synchronized Reserve Market:
 - Ability to receive and acknowledge All-call messages
 - Controls to automatically drop load
 - At most, one level of operator intervention in order to drop load
 - Telemetry that is capable of providing metering information at no less than a one minute scan rate around a call for Synchronized Reserve
 - Data must be submitted within 24 hours of Synchronized Reserve Event
 - Demand resources may be aggregated and offered into Synchronized Reserve Market as one combined resource

- Resources may self-schedule for Tier 2 Synchronized Reserve until 60 minutes before each hour with the following exceptions:
 - If a resource was scheduled prior to the 1 hour point, but becomes unavailable before or during the operating hour, another resource may be self-scheduled in its place
 - If a resource was unavailable for energy and therefore not evaluated as part of the Synchronized Reserve market, but becomes available during or before the hour, the resource may be self scheduled for Synchronized Reserve at that time



Prior to Operating Day

- By 1800 the day prior to the operating day the following information must be submitted:
 - Synchronized Reserve offer price
 - Energy use in MW (condensers only)
- Synchronized Reserve Offer MW may be entered with offer price, to set default for entire day
- All data submission pages will be available prior to the operating day (each page will be discussed in detail later)



Prior to Operating Hour - Offers

Tier 1 Information*

Synchronized Reserve Maximum

**

Synchronized Reserve Ramp Rate

**

>= Economic Ramp Rate

>= Economic Max

* Not applicable to Demand Response

Tier 2 Offer

Synchronized Quantity (MW)

**

Synchronized Offer (\$/MW)

Capped at O&M plus \$7.50 for generators

Capped at \$7.50 for Demand Response

Due by 1800 day prior

Due by 1800 day prior

Energy Use (MW)*

Synchronized Status

(called condensing status in eMKT)

**

Available, Unavailable
Self scheduled

** May be updated until 60 minutes prior to operating hour

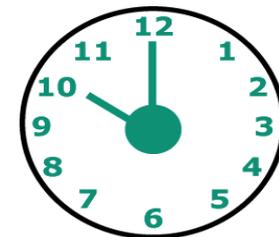
* Not applicable to Demand Response

Input: Synchronized Reserve Offer

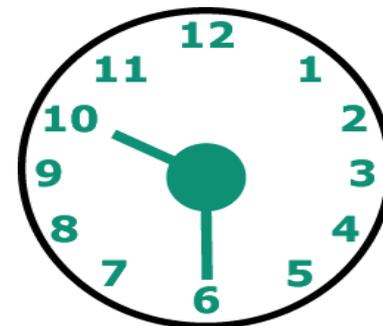
- Synchronized Reserve Cost Data
 - Heat Rate at ‘Economic Max MW’ in [Btu/kWh]
 - Heat Rate at ‘Economic Max – Synchronized MW’ in [Btu/kWh]
 - VOM – Variable Operating and Maintenance in [\$/MBtu]
 - For condensing units, only VOM required
 - Used in Synchronized market only to validate true cost
 - See PJM Manual M-15 Cost Development Guidelines for details
 - Offer will be rejected by eMKT if greater than cost plus \$7.50



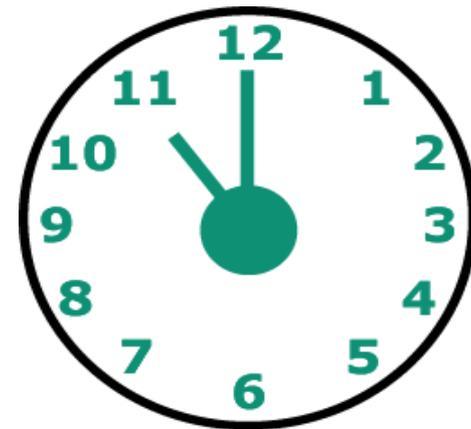
- Two hours prior to operating hour:
 - Tier 1 estimation will be run, based on current Synchronized Reserve maximums and Synchronized ramp rates for each unit
 - Estimated unit dispatch levels will be calculated taking into account transmission constraints and scheduled transactions
 - Tier 1 estimates derived from more limiting of: capability between dispatch point and Synchronized maximum; or Synchronized ramp rate times 10 minutes



- 90 minutes prior to operating hour:
 - Tier 1 estimation results will be posted as soon as complete, but not later than 90 minutes before the operating hour
 - If Tier 1 estimations cannot be posted by 90 minutes prior, the previous hour's estimates will be used
 - Tier 1 estimations posted publicly by reserve zone/sub-zone and privately by units

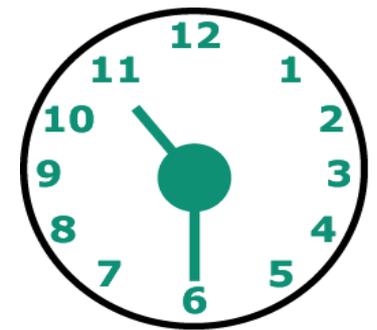


- 60 minutes prior to operating hour:
 - Units' self-scheduled Tier 2 quantities due
 - Units' Tier 2 offer quantities due
 - Market clearing will begin - joint optimization of regulation and Synchronized reserves
 - Tier 1 estimate begins



- 30 min prior to operating hour
 - PJM re-estimates amount of Tier 1 Synchronized Reserve available on each resource
 - Market clearing prices and Tier 2 assignments posted
 - Assignments posted on eMKT MUI
 - • This is the vehicle for Tier 2 Synchronized Assignment notification
 - Changes to posted assignments and condenser changes will be communicated verbally
 - Tier 2 assignments passed to Unit Dispatch System
 - Tier 1 estimates posted for next operating hour

If the available Tier 1 is sufficient to meet the synchronized reserve requirement, self-scheduled Tier 2 offers will not clear, no Tier 2 will be assigned, and the Tier 2 clearing price will be zero.

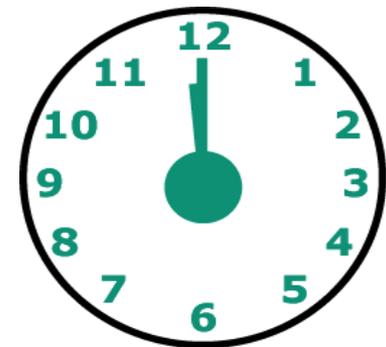


Synchronized Market Operation

- Synchronized Reserve Assignments
 - Individual unit dispatch signals from SCED will respect Tier 2 assignments
- Synchronized Reserve Events
 - Synchronized events will be called via the All-Call system
 - Timestamp on All-Call message is official event start time



- **During operating hour:**
 - Operators will be able to commit or de-commit additional resources as necessary to meet Synchronized Reserve Requirement during the operating hour.
 - Additional units will be committed if real time conditions vary from Tier 1 estimate.
 - Units will be chosen according to merit order price ranking



- Synchronized market clearing is a joint optimization between regulation and Synchronized reserves
- The goal of the optimization is to minimize the total cost of producing energy, regulation, and Synchronized reserve
- Resources cannot be committed for both Tier 2 Synchronized and regulation during the same hour
 - If Demand Side Response clears less than its' economic max for energy it can participate in the difference in the synchronized reserve market



Tier 2 Commitment

- Tier 2 selection based on merit order stacking of available resources
 - Merit order price includes Synchronized offer plus estimated opportunity cost plus energy usage, if any, plus startup costs
 - Start-up costs spread over expected duration of commitment
- Highest merit order price cleared determines SRMCP
 - SRMCP = Synchronized Reserve Market Clearing Price
 - Each area and reserve zone will have its own SRMCP



- Synchronized Reserve Market Clearing Prices (SRMCPs):
 - Separate market will be cleared for RFC Synchronized Reserve Zone and Southern Synchronized Reserve Zone
 - Separate price will be posted for the Mid Atlantic Synchronized Reserve Sub-Zone
 - Price will equal the RFC Synchronized Reserve Zone unless transfer limited conditions exist.
 - Clearing prices determined from bid plus opportunity cost of Tier 2 resources committed to meet reserve requirement
 - SRMCP will be zero if no Tier 2 is committed



Calculate Merit Order Price

Unit Merit Order Price = Synchronized Offer + Opportunity Cost + Startup Cost + Energy Use Cost

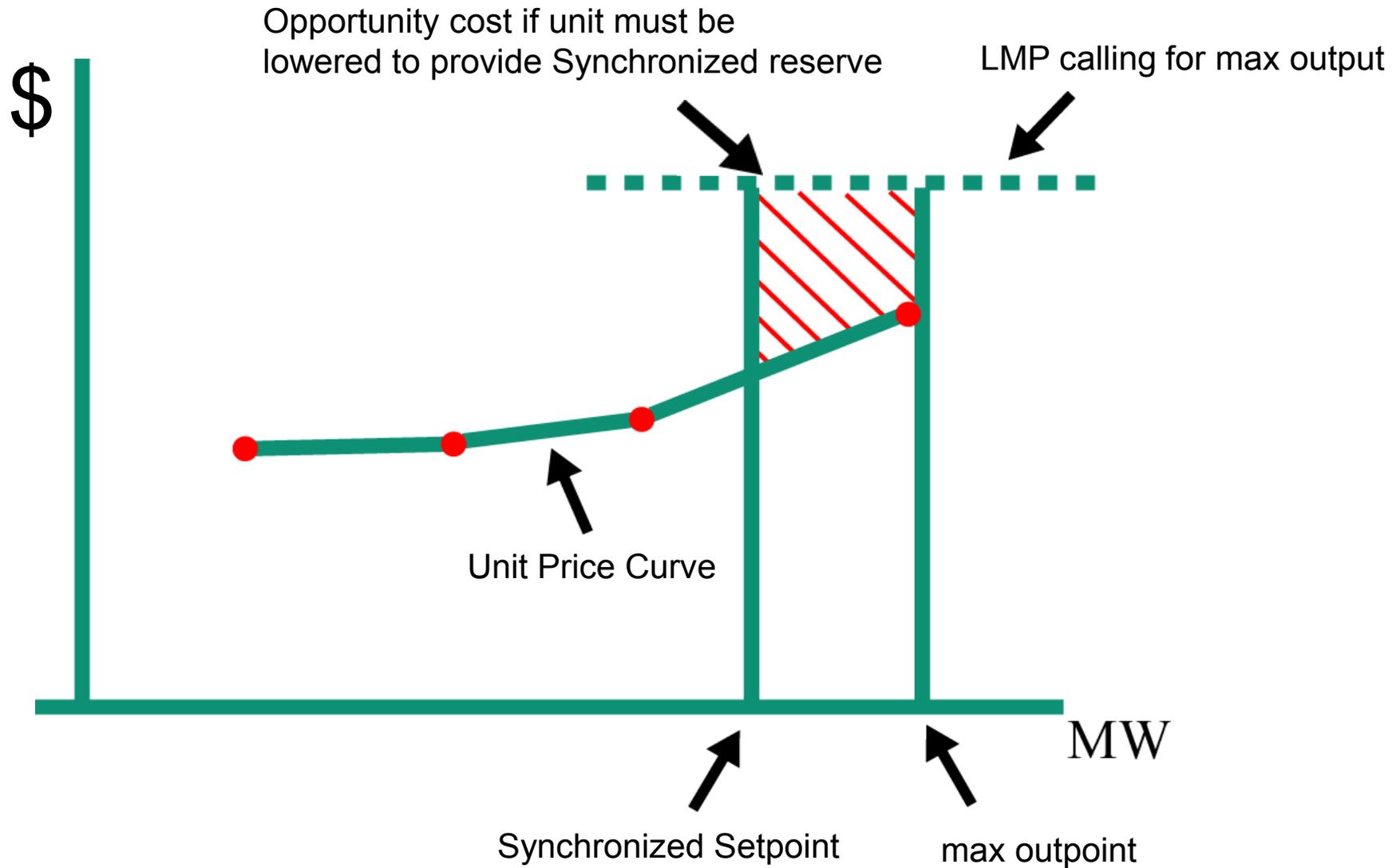
Opportunity Cost (Non-Condensing units)=
 $|LMP - ED| * GENOFF$

LMP	forecast LMP at generator bus
ED	price at setpoint unit maintains to provide full amount of Synchronized reserve
GENOFF	MW deviation between economic dispatch & Synchronized setpoint

Calculate Merit Order Price

$$\text{Opportunity Cost (Condensing units)} = \text{Max}(0, \text{LMP} - \text{energy offer}) * \text{MW} \\ \text{capability} / \text{Synchronized} \\ \text{capability}$$

Lost Opportunity Cost Calculation



Spin Market Clearing Example

- Unit conditions as shown
- All CTs can operate as condensers
- No unit limited by Synchronized ramp rate

- Total Synchronized Req. = 205 MW
- Tier 1 Estimate = 30 MW

Unit	Type	Synch Max	Est Disp Point	Tier 1 Estimate
A	Steam	200	190	10
B	Steam	250	250	0
C	Steam	150	150	0
D	Steam	200	195	5
E	CT	50	0	0
F	CT	20	20	0
G	Steam	300	285	15
H	CT	40	0	0

Spin Market Clearing Example

- Tier 2 Offer submission:
(No later than 60 min before operating hour)
- Tier 2 Self Scheduled = 45 MW
- Tier 2 Requirement = 130 MW

Unit	Tier 1 Estimate	Tier 2 Self Sched	Tier 2 Offer MW
A	10	0	20
B	0	15	15
C	0	0	15
D	5	10	35
E	0	0	50
F	0	20	20
G	15	0	50
H	0	0	40

Spin Market Clearing Example

Results:

Unit	Tier 1 Estimate	Tier 2 Self Sched	Tier 2 Offer MW	Tier 2 Offer \$	Tier 2 Rank Price	Tier 2 Cleared
B	0	15	15	\$10	\$16	0
D	5	10	35	\$15	\$17	20
C	0	0	15	\$12	\$18	15
E	0	0	50	\$18	\$19	50
G	15	0	50	\$20	\$26	35
A	10	0	20	\$25	\$30	10
H	0	0	40	\$28	\$38	0
F	0	20	20	\$35	\$45	0

SRMCP
Synchronized
Market
Clearing
Price
(\$30)

Tier 2 Cleared = 130 MW

Offer + Opportunity Cost



Spin Market Clearing Example

Results:

Receive
SRMCP of
\$30/MW
assigned

Tier 1 Estimate = 30 MW

Tier 2 Self - Scheduled = 45 MW

Tier 2 Assigned = 130 MW

Total Requirement = 205 MW



Settlement Overview

Tier 1 Credits

- Resources responding to loading of Synchronized Reserve paid \$50 premium above event LMP for MW delivered

Tier 1 Charges

- Based on percentage share of total credits above what participants own resources supplied
- Charges and Credits only apply if Synchronized Reserve is actually dispatched and loaded

Tier 2 Credits

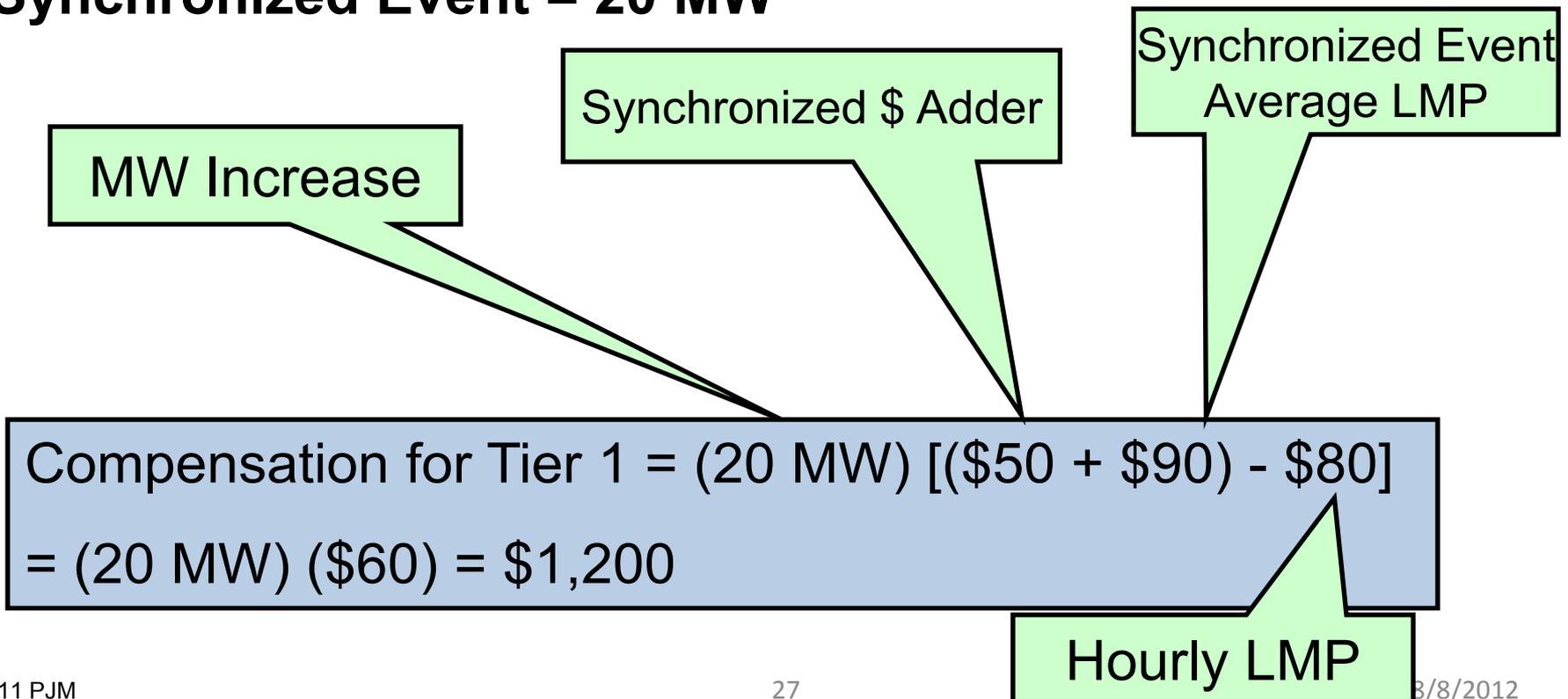
- Resources self-scheduled or PJM scheduled to provide Tier 2 Synchronized reserve are paid the SRMCP times MW assigned.
- Additional credits for costs not recovered by SRMCP

Tier 2 Charges

- SRMCP times self-scheduled or MW purchased from Market toward participant's obligation
- Participant's share of unrecovered above SRMCP
- Charges and Credits apply whenever Tier 2 Synchronized is assigned regardless whether it is ever actually asked to load

Tier 1 Compensation Example

- Hourly Integrated LMP = \$80
- Synchronized Reserve Event LMP = \$90
- Unit's Integrated MW Increase over the Synchronized Event = 20 MW



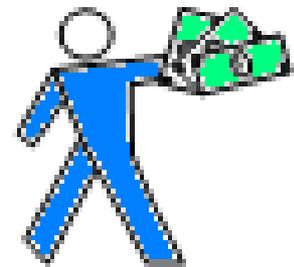
Tier 1 Compensation

- Premium will be paid for energy delivered by Tier 1 resources in response to a Synchronized request
 - Minus regulation capability
- For events that span multiple hours, an integrated response will be calculated for each hour



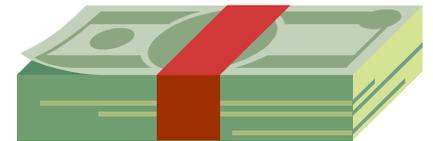
Tier 1 Compensation Limit

- Tier 1 credits awarded for response up to 110% of the unit's capability
 - Capability is determined from the Synchronized ramp rates and Synchronized maximum entered for each unit
- Credit may be awarded for more than 110% if other units under-respond, awarded on a pro-rata basis such that the aggregate Tier 1 credits do not exceed 110% of aggregate capability of all units



Tier 2 Compensation

- Self-scheduled Tier 2 credits equal the SRMCP (for the correct location) times the amount of Tier 2 Self-Scheduled
- PJM Assigned Tier 2 will be credited the higher of:
 - $(SRMCP) * (\text{Assigned Synchronized Capability})$
 - $(\text{Synchronized offer}) * (\text{Assigned Synchronized capability}) + (\text{Opportunity Cost in Real time}) + (\text{Energy use incurred in Real time} - \text{for units in condensing mode only}) + \text{Startup costs}$



Tier 2 Compensation

- Unit called on by PJM for the purpose of providing Synchronized is guaranteed recovery of all costs including:
 - Startup
 - No load
 - Minimum Energy costs
 - ☐ Recovered through Operating Reserve

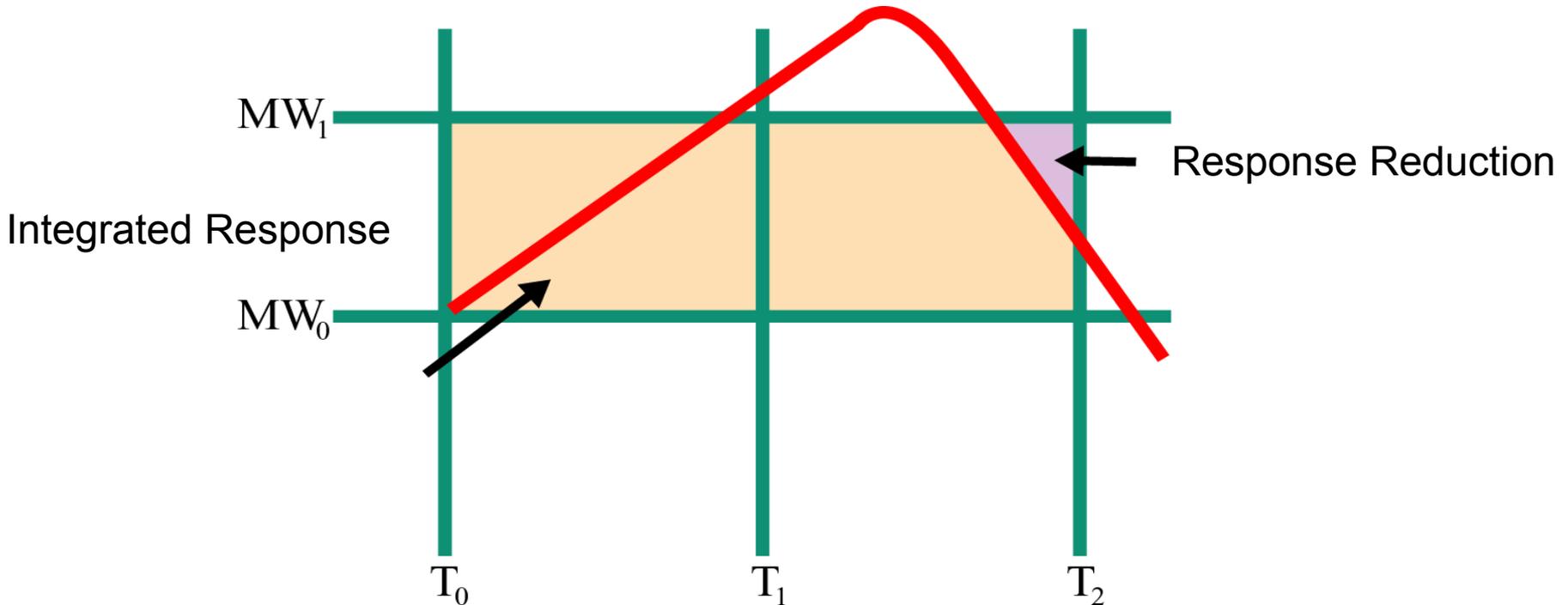


Response Calculation / Verification

- Unit responses are verified by the PJM Performance Compliance Dept following each event
- Actual responses compared to assignments at start of Synchronized event used to determine penalties



Response Calculation / Verification

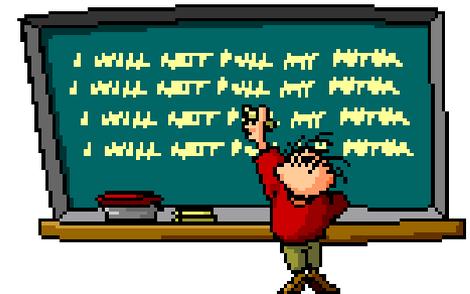


MW_0 is the lowest output at T_0 (start) +/- one minute

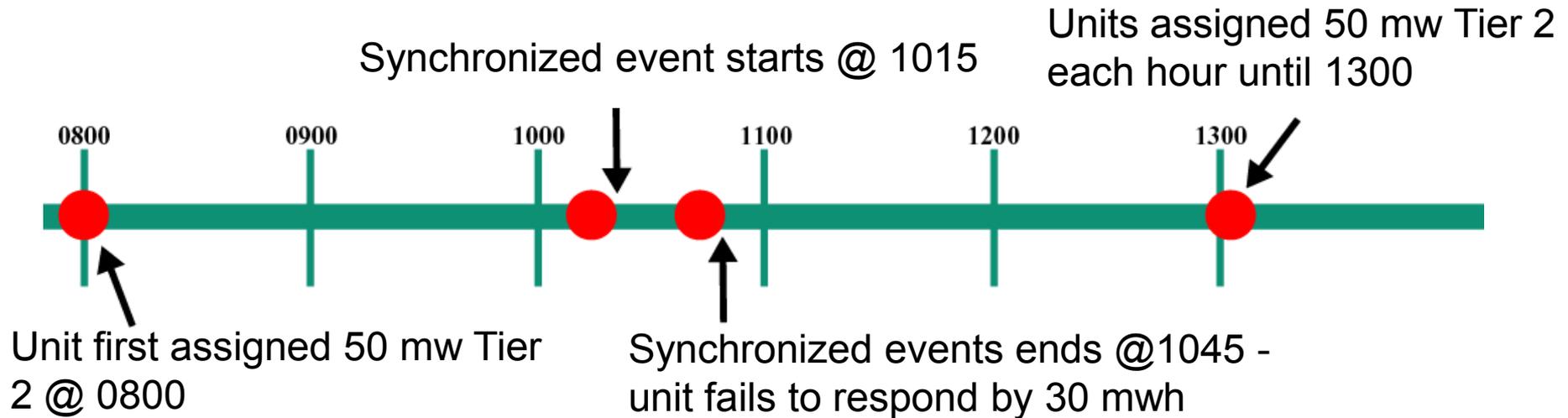
MW_1 is the highest output at T_1 (10 minutes, or event end, if sooner) +/- one minute

T_2 is the end of the event or 30 minutes past the start of the event

- No penalties exist for Tier 1 (payment made for actual response only)
- Tier 2 units that fail to respond to a Synchronized event when assigned or self-scheduled at the beginning of the event are penalized as follows:
 - Unit forfeits Tier 2 revenue for the amount of non-response over the contiguous hours the unit was assigned Tier 2 when the event occurred
 - Owner of the unit incurs an additional obligation in the amount of the shortfall for the next three same-peak days (Similar profile day)
 - Obligation penalty may be offset by over-response from other units assigned or self scheduled Tier 2



Penalties - Example



Penalties:

- 1) Unit will forfeit 30mw worth of Tier 2 credit from 0800 until 1300
- 2) Company will incur 30mw additional obligation for next three same peak days (Similar profile days)