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Understanding Appendix F

The “Heart” of the NERC GADS DRI

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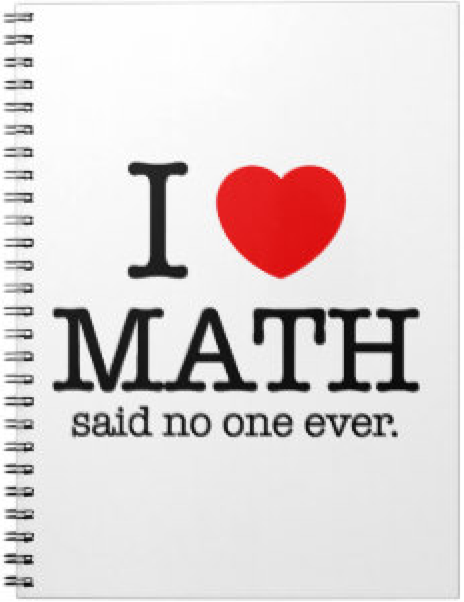
RELIABILITY | ACCOUNTABILITY

Agenda

- Overview of Appendix F
- Math Review
- Energy-Time diagram
- Event Hours
- Equivalent Hours
- Factors and Rates
- Calculation Types
- N/D Method
- Calculating EFORd
- Worked Examples
- Q &A



Disclaimer: This presentation covers the material in Appendix F from a more mathematically precise point of view. Appendix F is the governing document should any differences be noted.

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Overview of Appendix F

Appendix F, 42 total pages, pages 436-477 of the 2016 NERC GADS DRI PDF, in 9 sections:

- Summary, pages 436-441
- Notes, pages 442
- Unweighted, Single Unit Statistics w/OMC, pages 443-449, calculations 1-32d
- Unweighted, Grouped Unit Statistics w/OMC, pages 449-456, calculations 33-64d
- Weighted, Grouped Unit Statistics w/OMC, pages 457-463, calculations 65-94d
- Unweighted, Single/Grouped Unit Statistics w/o OMC, pages 463-465, calculations 95-118
- Weighted, Grouped Unit Statistics w/o OMC, pages 466-468, calculations 119-141
- Note #1 on EFORd pooling, pages 469-474
- Note #2 on EFORd pooling, pages 475-477

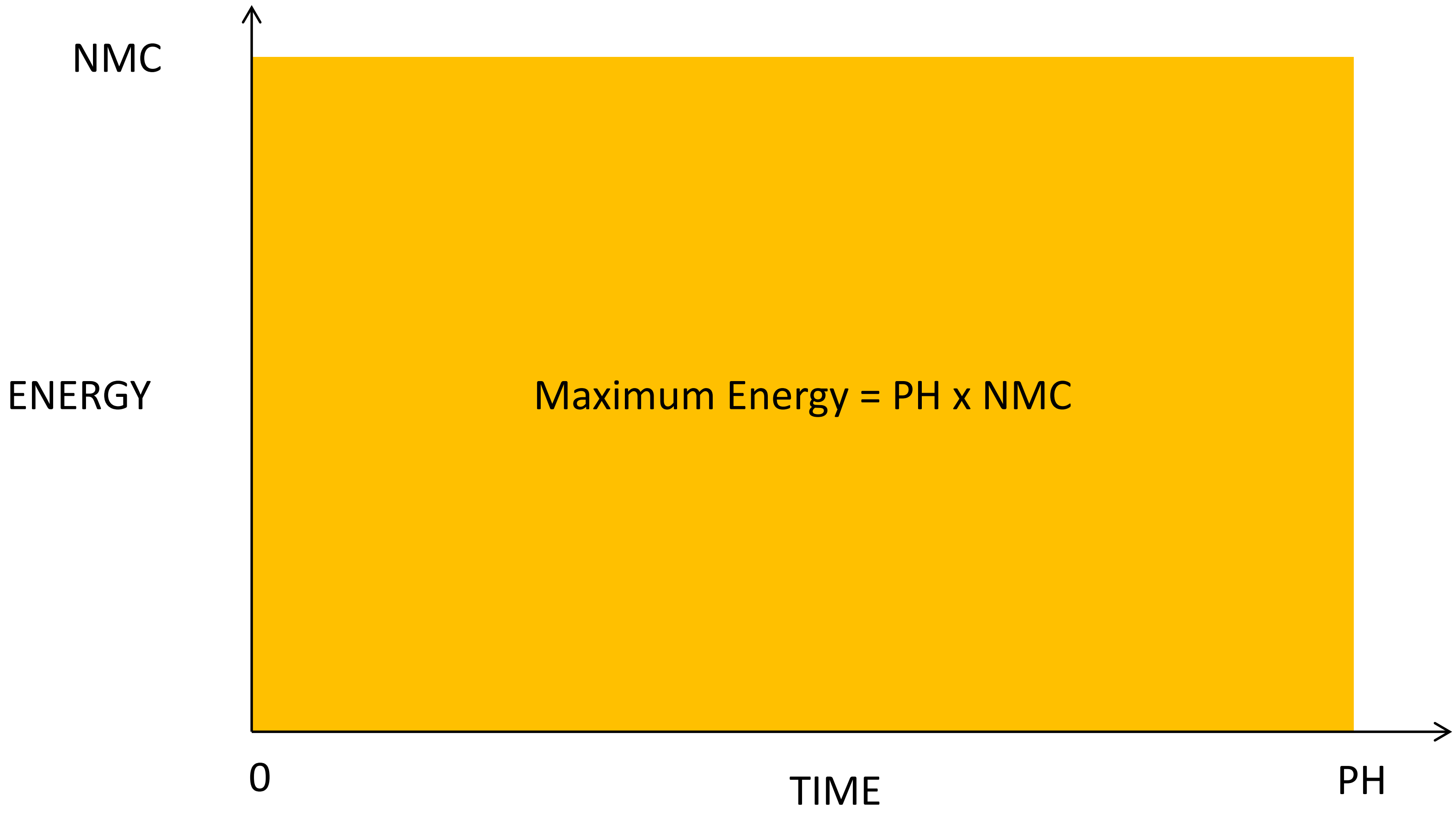
Math Review

1 + 1 = 2	Addition
1 – 1 = 0	Subtraction
1 x 1 = 1	Multiplication
1 / 1 = 1	Division
$\sum_{n=1}^{m} a_n = a_1 + a_2 + \ldots + a_m$	Summation

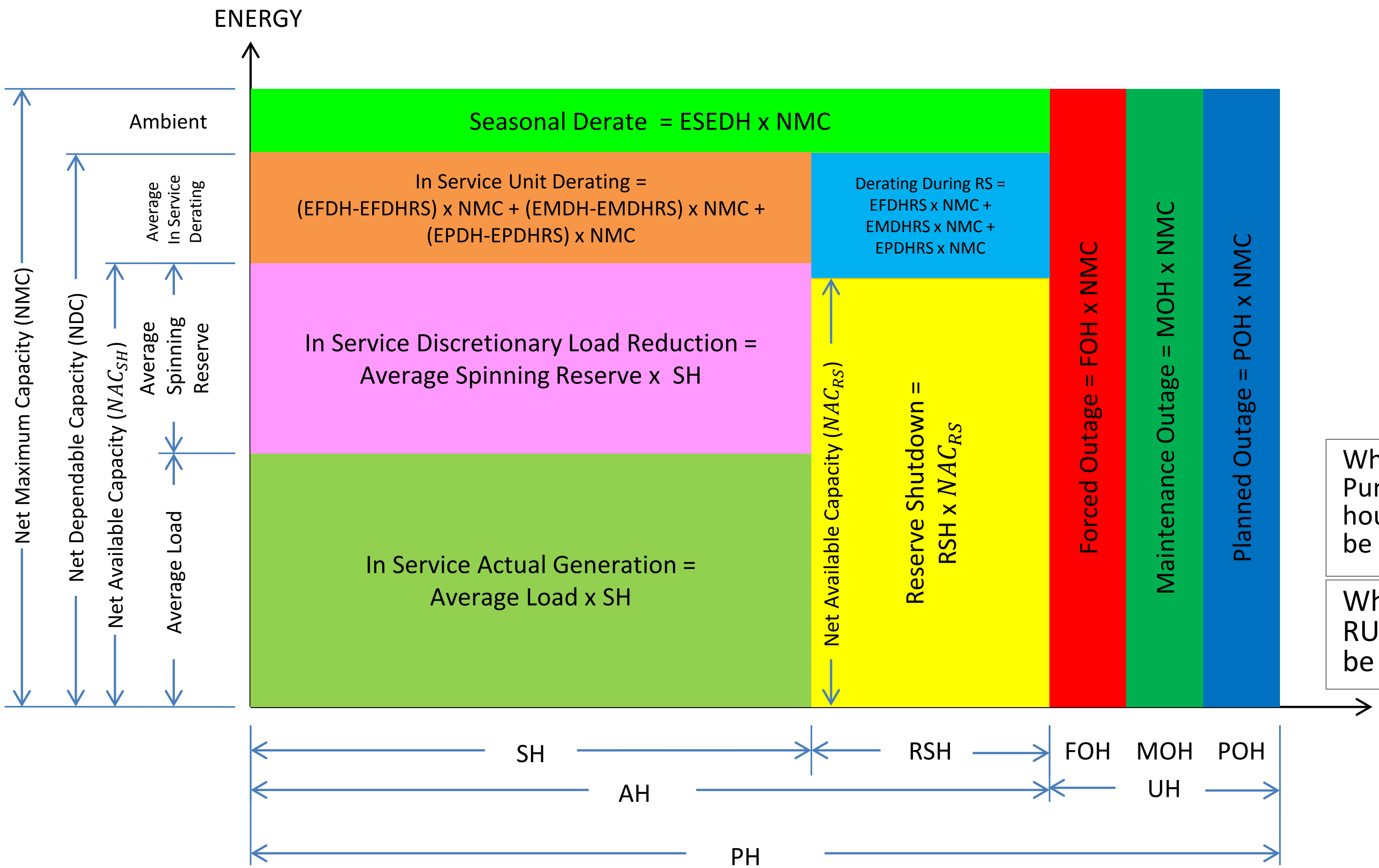
Math anxiety anyone?

Unfortunately, doing math for some people is like getting a root canal without any pain killers for the rest of us. So before we learn how to do NERC math, lets watch How Not To Do Math.

The Energy-Time Diagram



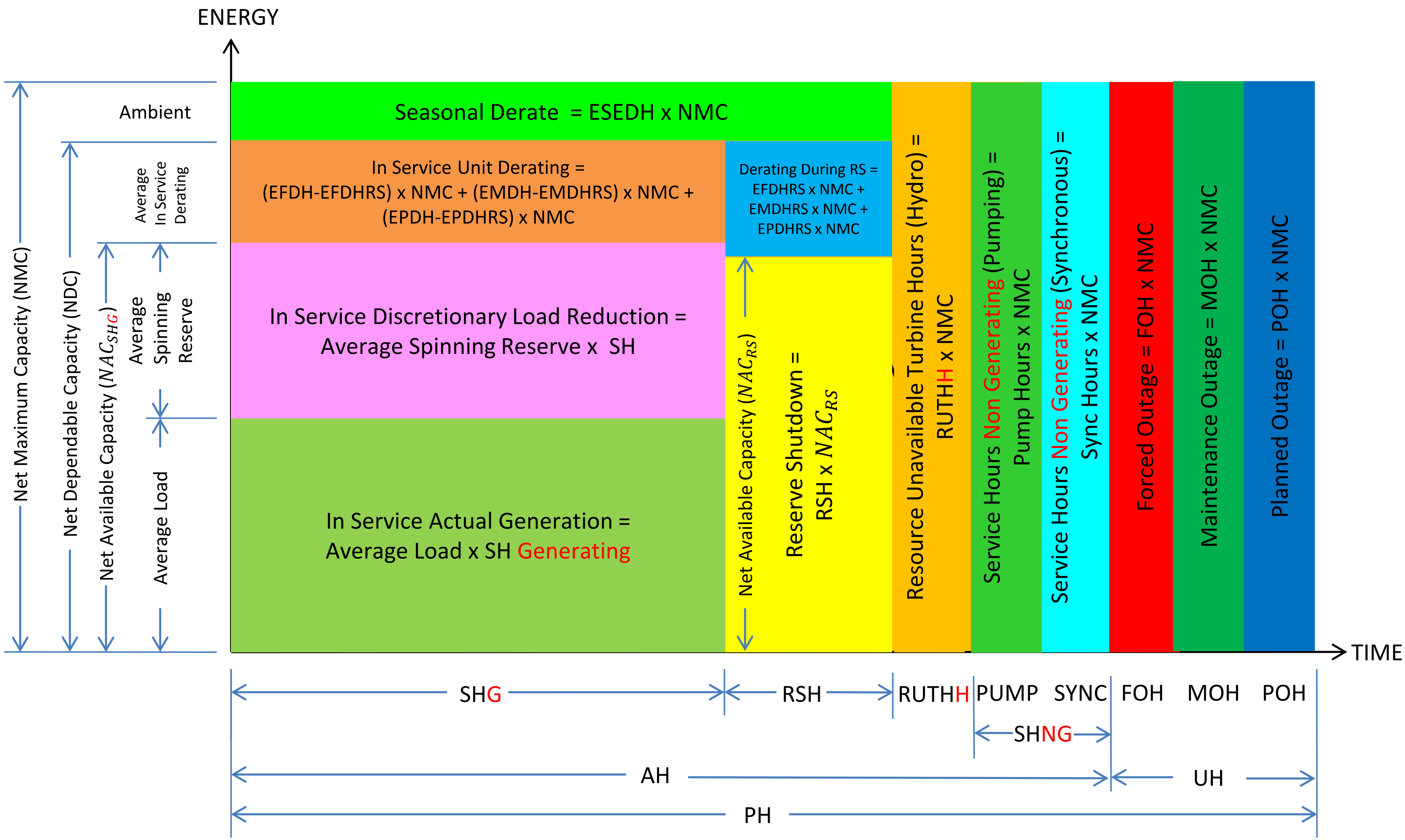
The Energy-Time Diagram For Conventional Units



Where would Pump and Sync hours (SHNG) be located?

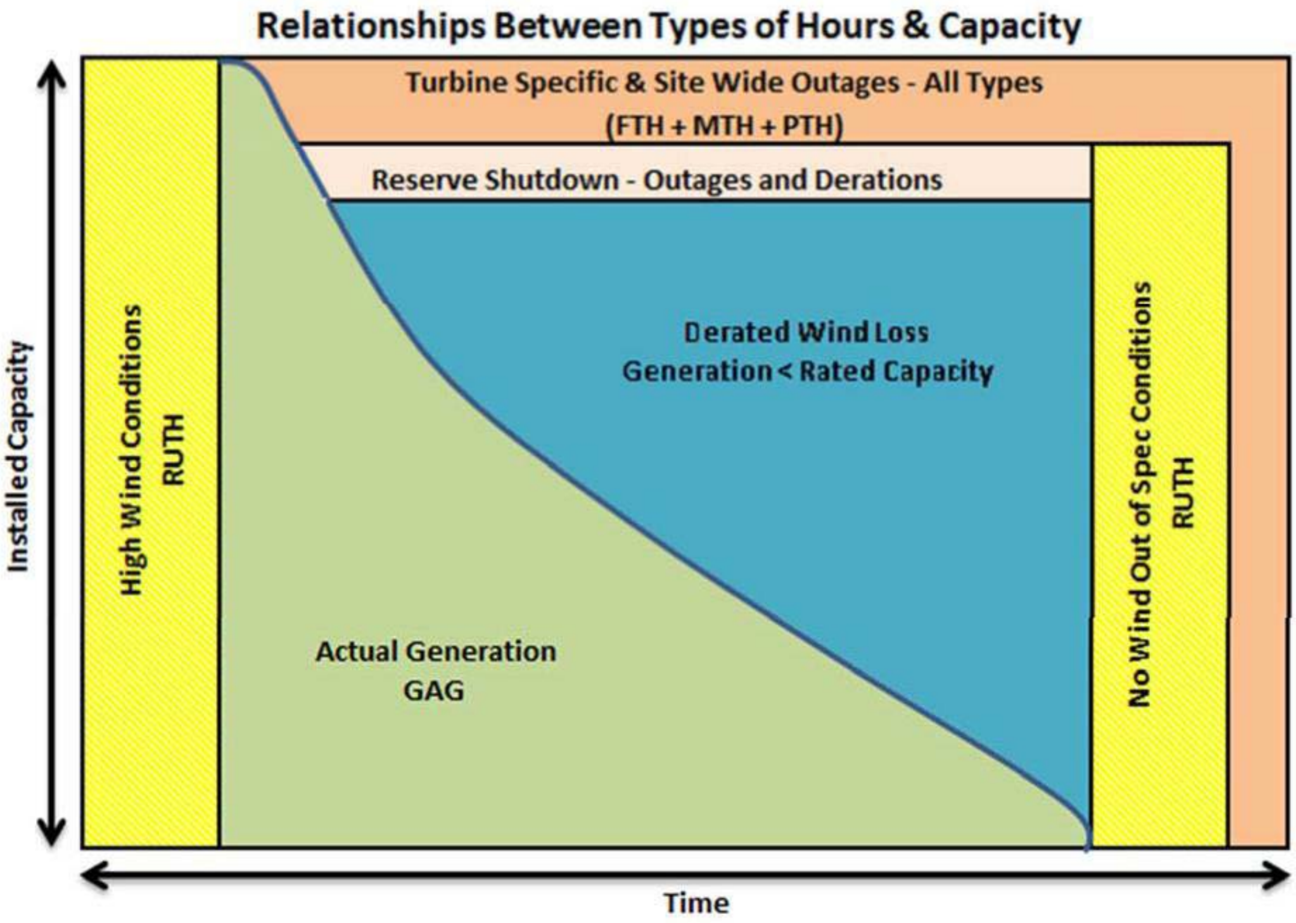
Where would RUTH hours be located?

The Energy-Time Diagram For Hydro Units



The Energy-Time Diagram For Wind Units

Wind DRI, page 45:



Constants

GADS uses some math constants as defined below.

Gross Maximum Capacity (GMC) = maximum capacity a unit can sustain when not restricted in any way; it is considered a **constant value** unless the unit is modified.

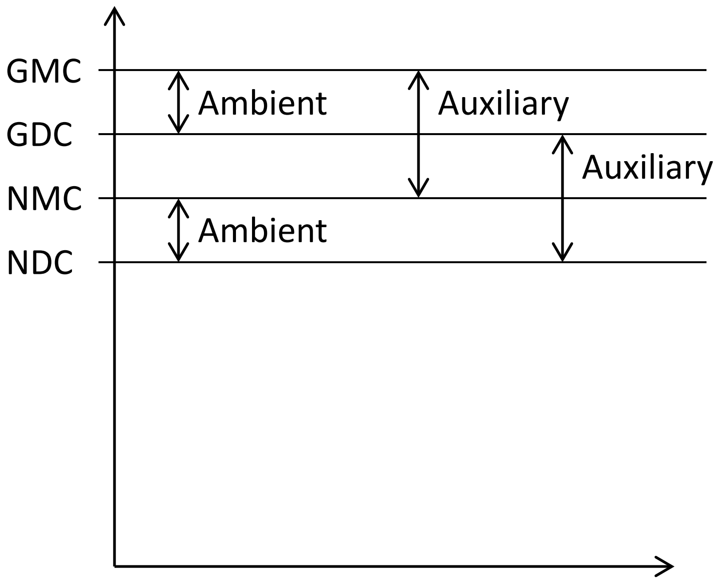
Gross Dependable Capacity (GDC) = GMC - ambient limitations; it can vary depending on the ambient limitations.

Net Maximum Capacity (NMC) = GMC - units auxiliary load; it is considered a **constant value** unless the unit is modified

Net Dependable Capacity (NDC) = GDC - units auxiliary load; it varies with GDC.

Note: Since GMC, GDC, NMC, and NDC are reported at the monthly level use the units average monthly auxiliary load.

Constants



- Definitions:
  - GMC = GMC
  - GDC = GMC - Ambient
  - NMC = GMC - Auxiliary
  - NDC = GDC - Auxiliary

- Derivation:
  - Prove: NMC - NDC = Ambient as per the Energy-Time diagram.
    - NMC – NDC = Ambient
    - (GMC - Auxiliary) - (GDC - Auxiliary) = Ambient
    - GMC - Auxiliary - GDC + Auxiliary = Ambient
    - GMC - GDC = Ambient
    - (NMC + Auxiliary) - (NDC + Auxiliary) = Ambient
    - NMC + Auxiliary - NDC - Auxiliary = Ambient
    - NMC - NDC = Ambient Q.E.D.

Mathematical Definitions

- The mathematical definition of an outage in NERC GADS is shown below:
  - NAC = 0
  - Net Available Capacity = 0

- The mathematical definition of a derate in NERC GADS is shown below:
  - 0 < NAC < NMC
  - Can you derate a unit to zero?
  - No because the definition would have to be 0 <= NAC < NMC.
  - If NAC = 0 you are on outage by definition!

Event Hours

Event hours are calculated by summing up the durations of the applicable events over the time period in question, typically one month.

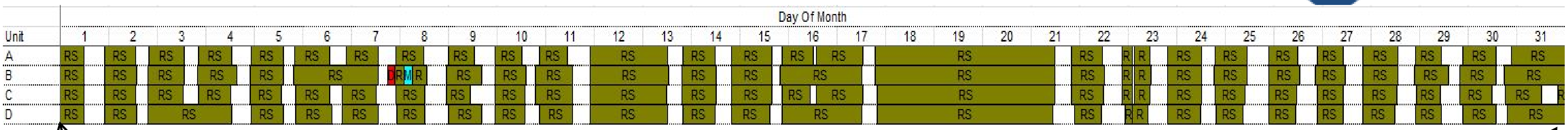
For instance, the Reserve Shutdown Hours (RSH) in August, 2008 are calculated by summing the durations of the Reserve Shutdown events (RS) that touch upon August, 2008.

The start and/or end dates of any RS events that begin or end before or after August are truncated so that only the portions touching August are included.

Example: where RS_n = the duration of the nth RS event and m is the total number of RS events to be summed, expanded out:

$$\textbf{RSH} = \sum_{n=1}^{m} RS_n = RS_1 + RS_2 + \ldots + RS_m$$

Event Hours



Start Dates truncated

Q: How many reserve shutdown events does each unit have?

A: A = 28, B = 27, C = 29, D = 26, Total = 110!

End Dates truncated

Unit A RSH = $\sum_{n=1}^{m=28} RS_n = RS_1 + RS_2 + \ldots + RS_{28}$

Unit B RSH = $\sum_{n=1}^{m=27} RS_n = RS_1 + RS_2 + \ldots + RS_{27}$

Unit C RSH = $\sum_{n=1}^{m=29} RS_n = RS_1 + RS_2 + \ldots + RS_{29}$

Unit D RSH = $\sum_{n=1}^{m=26} RS_n = RS_1 + RS_2 + \ldots + RS_{26}$

The difference between class room data and real world data is *volume*.

Event Hours

More examples: where $U1_n$= the duration of the nth U1 event and m is the total number of U1 events to be summed, et cetera (not expanded):

FOH = $\sum_{n=1}^{m} U1_p + \sum_{p=1}^{o} U2_p + \sum_{r=1}^{q} U3_r + \sum_{t=1}^{s} SF_t$

MOH = $\sum_{n=1}^{m} MO_n + \sum_{p=1}^{o} ME_p$

POH = $\sum_{n=1}^{m} PO_n + \sum_{p=1}^{o} PE_p$

RSH = $\sum_{n=1}^{m} RS_n$

PH = Days In Month x 24 -/+ 1 hour for DST in March and November respectively. PH may also be less than this when a unit goes commercial for the first time or is mothballed, inactivated, or retired.

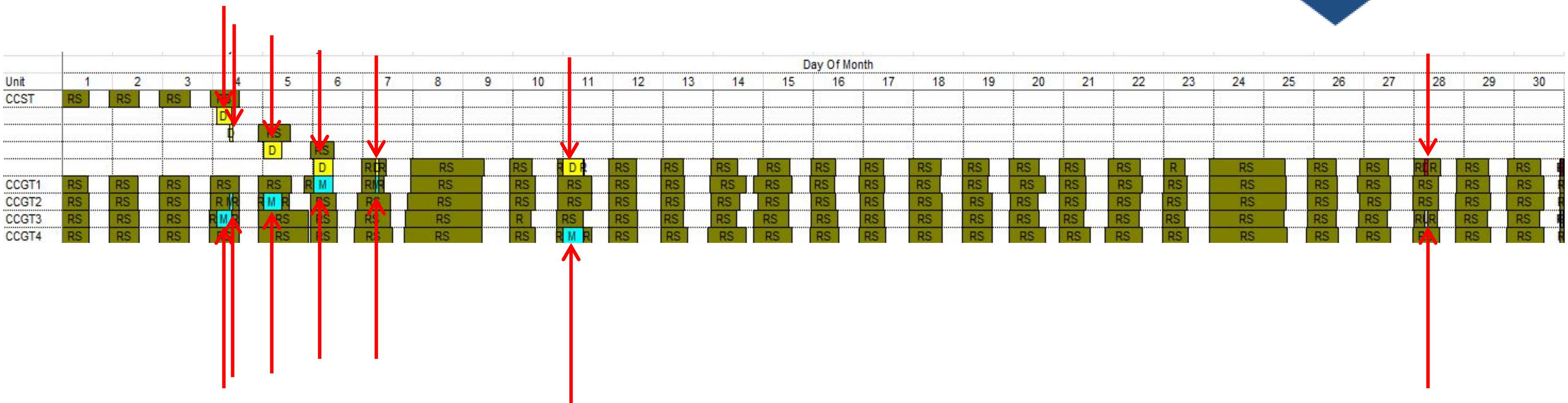
SH = PH – FOH – MOH – POH – RSH – Pump – Sync

There are no NERC event types for Pump and Sync hours and they typically have to be manually tracked.

There is no NERC event type for service hours (SH) either. They are calculated from the other event hours using the equation shown above. If any of your event hour sums are wrong your service hours will be too - errors propagate!

Old math saying: All the errors are in the data and calculations you didn't check!

Event Hours



How many outage events does each CCGT have?

Why is there a derate on the CCST for every outage on a CCGT?

This is a 4 x 4 x 1 combined cycle unit and the derates are concurrent events.

Event Hours

More examples: where $U1_n$= the duration of the nth U1 event and m is the total number of U1 events to be summed, et cetera (not expanded):

$$\text{FOH} = \sum_{n=1}^{m} U1_p + \sum_{p=1}^{o} U2_p + \sum_{r=1}^{q} U3_r + \sum_{t=1}^{s} SF_t$$

Now lets have a little fun . . . .

Dig into your pocket or purse and pull out some change.

Q: If quarters are U1 events, nickels U2 events, pennies U3 events, and dimes are SF events, what are your values for m, o, q, and s? (Everyone will be different.)

A: m = # quarters (U1 events)

o = # nickels (U2 events)

q = # pennies (U3 events)

s = # dimes (SF events)

Bonus Q: If the face value of each coin is it's duration, what is FOH?

Bonus A: FOH = m x 25 + o x 5 + q x 1 + s x 10

If m = 3, o = 2, q = 3, and s = 2 then, FOH = 3 x 25 + 2 x 5 + 3 x 1 + 2 x 10 = 108 hours.

NERC math is as easy as counting your pocket change!

Equivalent Hours

Equivalent hours are derate events expressed as full outage hours.

Equivalent hours are calculated by multiplying the derate duration by the MW reduction and dividing by NMC.

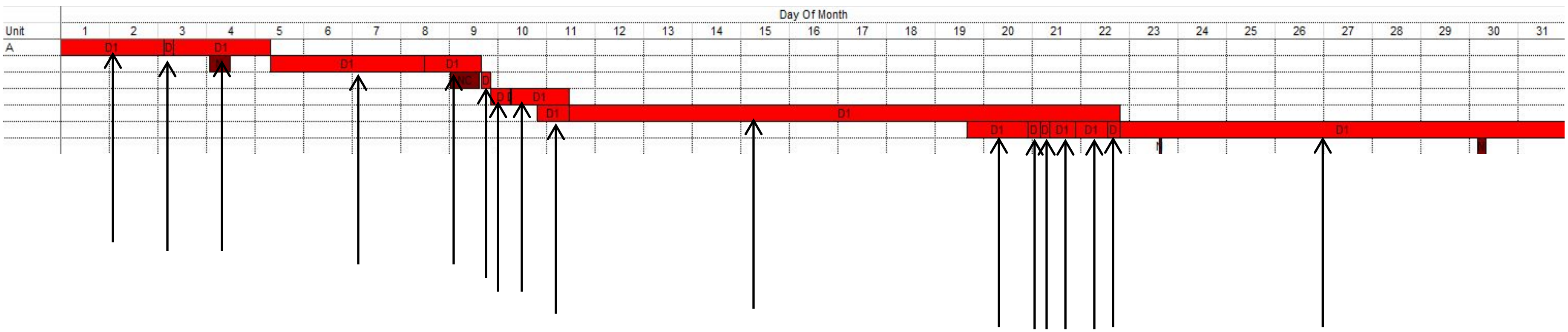
For instance, the Equivalent Forced Derated Hours (EFDH) in April, 2016 are calculated by summing the durations of the derate event types D1, D2, and D3 that touch upon April, 2016, which are not shadowed by outages.

The start and/or end dates of any D1, D2, or D3 derate events that begin or end before or after April are truncated so that only the portions touching April are included.

Example: where $D1_n$= the duration of the nth D1 event, and m is the total number of D1 events to be summed, et cetera:

EFDH = $\sum_{n=1}^{m} \frac{(D1_n \; x \; Reduction_n)}{NMC} + \sum_{p=1}^{o} \frac{(D2_p \; x \; Reduction_p)}{NMC} + \sum_{r=1}^{q} \frac{(D3_r \; x \; Reduction_r)}{NMC}$

Equivalent Hours



This is a big coal unit that ran all month with some minor problems.

17 D1 derates on this unit in one month!

On the 10-11 and 19-22 what was occurring?

Overlapping derates which are additive.

What else might be occurring?

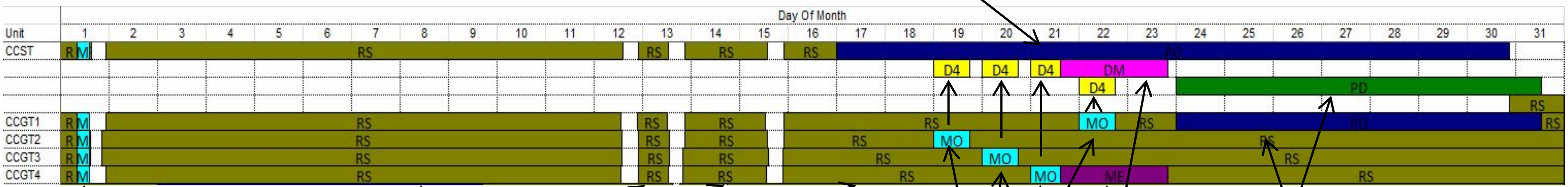
Variable derates – same problem with a varying unit reduction.

Equivalent Hours

- More examples: where $D1_n$= the duration of the nth D1 event, and m is the total number of D1 events to be summed, including during RS events, et cetera -
- **EFDH** = $\sum_{n=1}^{m}\frac{(D1_n\ x\ Reduction_n)}{NMC} + \sum_{p=1}^{o}\frac{(D2_p\ x\ Reduction_p)}{NMC} + \sum_{r=1}^{q}\frac{(D3_r\ x\ Reduction_r)}{NMC}$
- **EMDH** = $\sum_{n=1}^{m}\frac{(D4_n\ x\ Reduction_n)}{NMC} + \sum_{p=1}^{o}\frac{(DM_p\ x\ Reduction_p)}{NMC}$
- **EPDH** = $\sum_{n=1}^{m}\frac{(PD_n\ x\ Reduction_n)}{NMC} + \sum_{p=1}^{o}\frac{(DP_p\ x\ Reduction_p)}{NMC}$
- **EUDH** = $\sum_{n=1}^{m}\frac{(D1_n\ x\ Reduction_n)}{NMC} + \sum_{p=1}^{o}\frac{(D2_p\ x\ Reduction_p)}{NMC} + \sum_{r=1}^{q}\frac{(D3_r\ x\ Reduction_r)}{NMC} + \sum_{n=1}^{m}\frac{(D4_n\ x\ Reduction_n)}{NMC} + \sum_{p=1}^{o}\frac{(DM_p\ x\ Reduction_p)}{NMC}$
- Hint: EUDH = EFDH + EMDH, so don't calculate it separately!
- EFDHRS = EFDH only during RS events
- **EMDHRS** = $\sum_{n=1}^{m}[\frac{(D4_n\ x\ Reduction_n)}{NMC}]$ only during RS events. Why are DM events not included?
- **EPDHRS** =$\sum_{n=1}^{m}[\frac{(PD_n\ x\ Reduction_n)}{NMC}]$ only during RS events. Why are DP events not included?

Equivalent Hours

PO on the CCST which doesn't affect the CCGT.



5 MO at once!

Lots of RS events.

4 MO with concurrent D4 events.

ME with a concurrent DM

PO with a concurrent PD

Busy month!!!

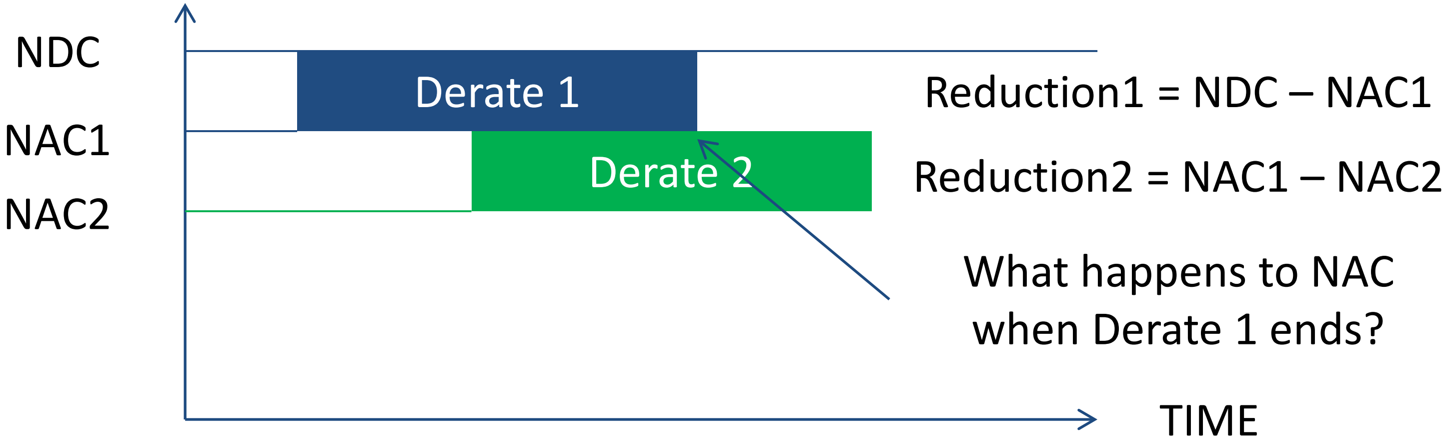
Equivalent Hours

Duration = (End Date – Start Date) x 24 -/+ 1 if it crosses the DST hour (2AM) in March or November respectively.

Derates are additive unless specified as dominant (where one derate shadows another like an outage).

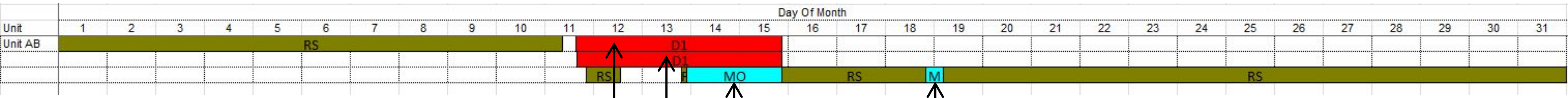
Size of Reduction is determined by subtracting the Net Available Capacity (NAC) from the Net Dependable Capacity (NDC).

In cases of multiple derates, the Size of Reduction of each derating will be determined by the difference in the Net Available Capacity of the unit prior to the derating and the reported Net Available Capacity as a result of the derating.



Equivalent Hours

- Here is a situation where we have a pair of dominant derates.




```
      Event Type: D1 Unplanned Derating-immediate
 Event Reduction: 20
  Event Capacity: 727
      Cause Code: 4262 Intercept valves
Event Description: 34,F340,Load derate to 750 MWG due the right lower intercept valve stuc
                   k in closed postion.
```

```
      Event Type: D1 Unplanned Derating-immediate
 Event Reduction: 354
  Event Capacity: 373
      Cause Code: 3460 Other Feedwater Booster Pump Problems
Event Description: 54,F540,Load derate to 380 MWG due to inboard seal failure on 1B boiler
                    feed boster pump.
```

```
      Event Type: MO Maintenance Outage-deferrable beyond next weekend but before next PO
 Event Reduction: 747
  Event Capacity: 0
      Cause Code: 3460 Other Feedwater Booster Pump Problems
Event Description: 54,F540,Maintenance outage to repair 1B boiler feed booster pump inboar
                   d seal.
```

```
      Event Type: MO Maintenance Outage-deferrable beyond next weekend but before next PO
 Event Reduction: 747
  Event Capacity: 0
      Cause Code: 4262 Intercept valves
Event Description: 34,F340,Maintenance outage to clean servo and stroke right lower interc
                   ept valve.
```

Notice the quality of the data: 1) the Cause Code and Event Descriptions are complimentary, 2) the Cause Codes are the same for matching events, 3) there are Amplification and Failure Codes on all of the events, and 4) the exact equipment having the problem(s) is identified.

Equivalent Hours

ESEDH = Equivalent Seasonal Derated Hours

ESEDH = $\frac{(NMC - NDC)}{NMC}$ **x AH**

ESEDH = $\frac{(NMC - NDC)}{NMC}$ **x (RSH + SH)**

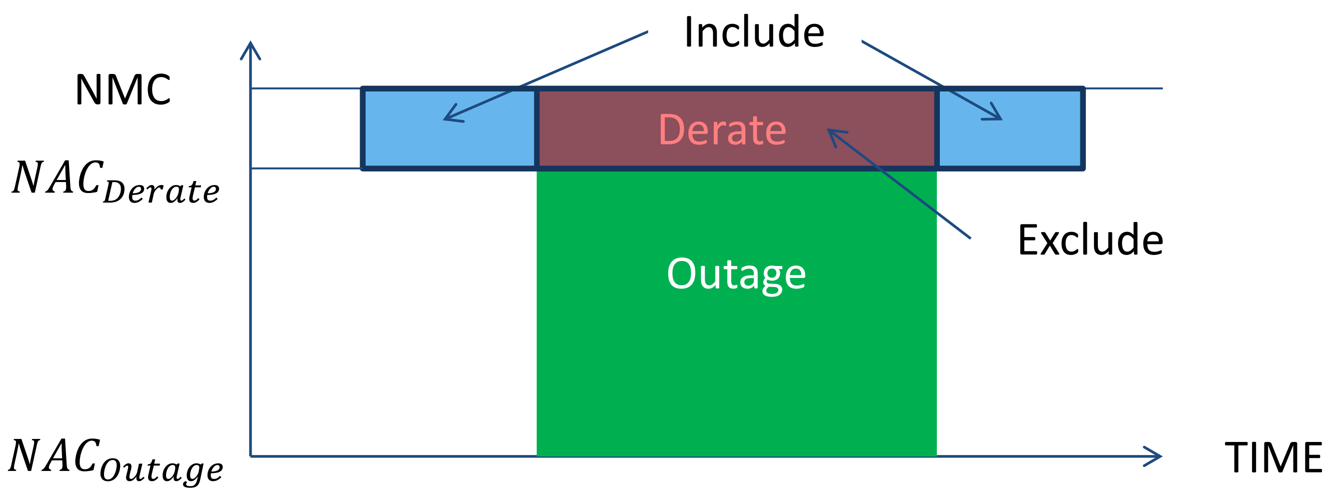
ESEDH = $\frac{(NMC - NDC)}{NMC}$ **x (PH − FOH − MOH − POH)**

AH = RSH + SH = PH – FOH – MOH - POH

Note: only the WEAF and WSEDF calculations use ESEDH.

Equivalent Hours

Shadowing occurs when an outage overlaps a derate. The unit is already at NAC = 0 due to the outage so the overlapped portion of the derate is "cut out" for calculation purposes, otherwise NAC < 0 but NAC >= 0 must always be true.



Factors and Rates

In this section we will examine energy weighted factors and rates.

In general:

Factors are based on period hours (PH), except for GOF and NOF.

- They tell you how well you did during the period.
- They are additive: WAF + WFOF + WMOF + WPOF = 100%.
- They end with an “F”: EAF

Rates are based on service hours (SH), except for GHR and NHR.

- They tell you how well you did when the unit ran.
- They are not additive!
- They end with an “R”: EUOR

Factors And Rates

NERC 62: SR = Starting Reliability

$$SR = \frac{\sum_{n=1}^{m} ACTSU_n}{\sum_{n=1}^{m} ATTSU_n} \times 100$$

SR = probability of successful startup.

ATTSU = count of attempted starts.

ACTSU = count of actual starts.

ATTSU – ACTSU = count of SF events.

ATTSU >= ACTSU is always true.

SR is a really hard goal to make compared to other factors and rates!

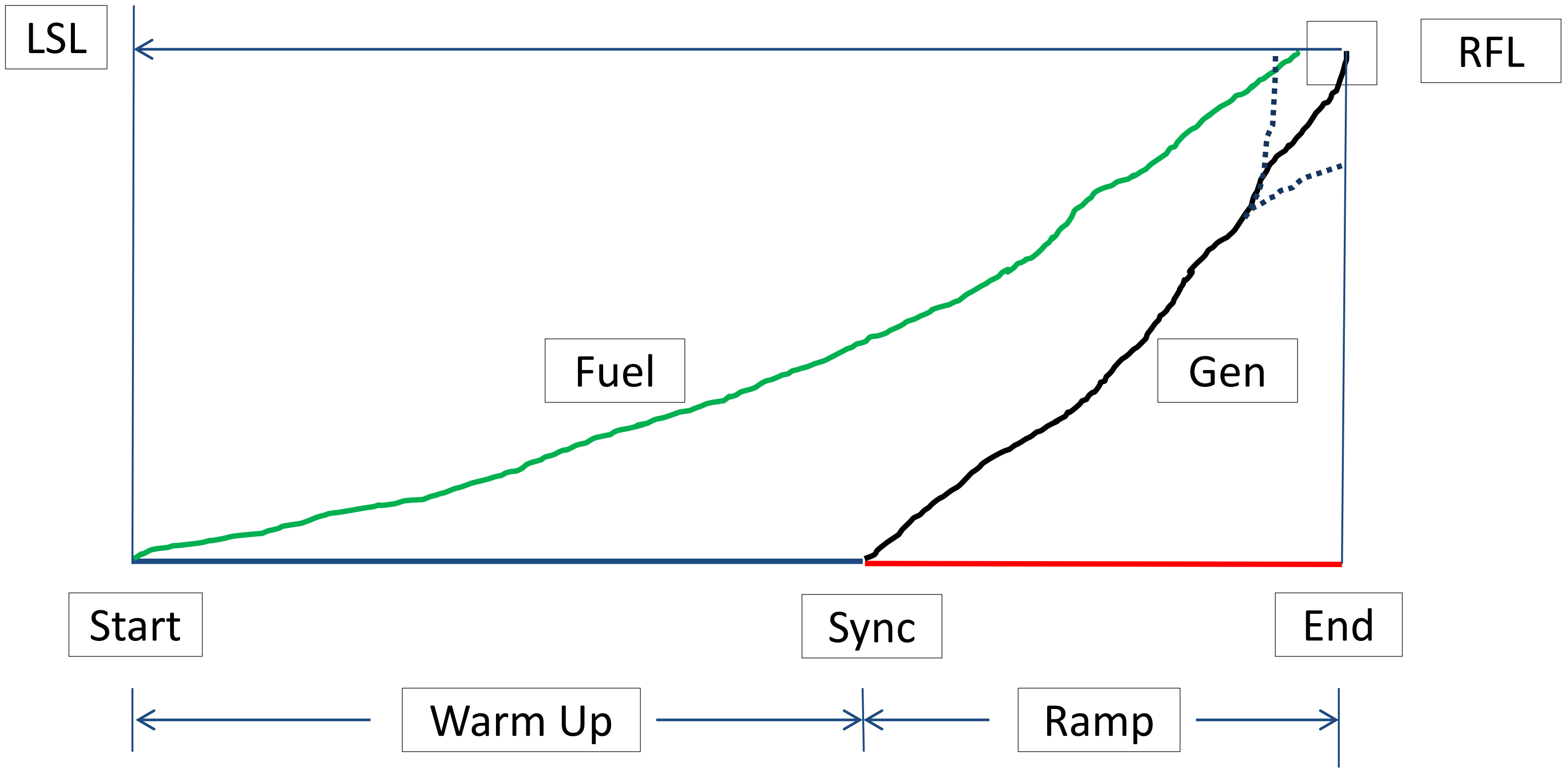
IEEE Std 762 9.22

$$SR = \frac{\sum_{i=1}^{n} (\text{Number of actual unit starts})_i}{\sum_{i=1}^{n} (\text{Number of attempted starts})_i} \times 100$$

Factors And Rates

SF Failures and how they affect SR:

1) Don't sync. 2) Don't make RFL. 3) Take too long.



Factors And Rates

NERC 65: WFOF = Weighted Forced Outage Factor

$$\mathbf{WFOF} = \frac{\sum_{n=1}^{m}(FOH_n \; x \; NMC_n)}{\sum_{n=1}^{m}(PH_n \; x \; NMC_n)} \; \mathbf{x\ 100}$$

WFOF = percent of time on forced outage.

Forced outage event types: U1, U2, U3, SF.

WAF + WFOF + WMOF + WPOF = 100%

IEEE Std 762 10.3

$$WFOF = \left(\frac{\sum_{i=1}^{n}(FOH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 66: WMOF = Weighted Maintenance Outage Factor

$$\textbf{WMOF} = \frac{\sum_{n=1}^{m}(MOH_n \; x \; NMC_n)}{\sum_{n=1}^{m}(PH_n \; x \; NMC_n)} \; \textbf{x 100}$$

WMOF = percent of time on maintenance outage.

Maintenance outage event types: MO, ME.

WAF + WFOF + WMOF + WPOF = 100%

IEEE Std 762 10.4

$$WMOF = \left(\frac{\sum_{i=1}^{n}(MOH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 67: WPOF = Weighted Planned Outage Factor

$$\textbf{WPOF} = \frac{\sum_{n=1}^{m}(POH_n \ x \ NMC_n)}{\sum_{n=1}^{m}(PH_n \ x \ NMC_n)} \ \textbf{x 100}$$

WPOF = percent of time on planned outage.

Planned outage event types: PO, PE.

WAF + WFOF + WMOF + WPOF = 100%

IEEE Std 762 10.1

$$WPOF = \left(\frac{\sum_{i=1}^{n}(POH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 68: WUOF = Weighted Unplanned Outage Factor

$$\textbf{WUOF} = \frac{\sum_{n=1}^{m}[(FOH_n + MOH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WUOF = percent of time on unplanned outage.

Unplanned outage event types: U1, U2, U3, SF, MO, ME.

Remember: forced and maintenance outages are unplanned events.

IEEE Std 762 10.2

$$WUOF = \left(\frac{\sum_{i=1}^{n}[(FOH_i + MOH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

NERC 69: WSOF = Weighted Scheduled Outage Factor

$$\textbf{WSOF} = \frac{\sum_{n=1}^{m}[(MOH_n + POH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WSOF = percent of time on scheduled outage.

Scheduled outage event types: MO, ME, PO, PE.

Remember: planned and maintenance outages are scheduled events.

IEEE Std 762 not defined.

Factors And Rates

NERC 70: WUF = Weighted Unavailability Factor

$$\textbf{WUF} = \frac{\sum_{n=1}^{m}[(FOH_n + MOH_n + POH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WUF = percent of time unavailable due to outages.

Unavailable event types: U1, U2, U3, SF, MO, ME, PO, PE.

Remember: a unit is unavailable during forced, planned and maintenance outages.

WAF + WUF = 100%

IEEE Std 762 10.5

$$WUF = \left(\frac{\sum_{i=1}^{n}[(POH_i + MOH_i + FOH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 71: WAF = Weighted Availability Factor

$$\mathbf{WAF} = \frac{\sum_{n=1}^{m}[(PH_n - FOH_n - MOH_n - POH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \mathbf{x\ 100}$$

WAF = percent of time available without outages.

PH – FOH – MOH – POH = RSH + SH = AH

Available event types: RS!

FOH, MOH, and POH affect WAF *indirectly*.

WAF + WFOF + WMOF + WPOF = 100%

WAF + WUF = 100%

IEEE Std 762 10.6

$$WAF = \left(\frac{\sum_{i=1}^{n}(AH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 72: WSF = Weighted Service Factor

$$\mathbf{WSF} = \frac{\sum_{n=1}^{m}(SH_n \; x \; NMC_n)}{\sum_{n=1}^{m}(PH_n \; x \; NMC_n)} \; \mathbf{x\ 100}$$

WSF = percent of time online.

SH <= PH is always true.

IEEE Std 762 10.7

$$WSF = \left(\frac{\sum_{i=1}^{n}(SH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 73: WSEDF = Weighted Seasonal Derated Factor

$$\textbf{WSEDF} = \frac{\sum_{n=1}^{m}(ESEDH_n \ x \ NMC_n)}{\sum_{n=1}^{m}(PH_n \ x \ NMC_n)} \ \textbf{x 100}$$

Where ESEDH = $\frac{(NMC - NDC)}{NMC}$ x AH

WSEDF = percent of time seasonally derated.

WEAF + WEUF + WSEDF = 100%

IEEE Std 762 10.8

$$WSDF = \left(\frac{\sum_{i=1}^{n}(ESDH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 74: WUDF = Weighted Unit Derating Factor

$$\textbf{WUDF} = \frac{\sum_{n=1}^{m}[(EFDH_n + EMDH_n + EPDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WUDF = percent of time derated.

Derating event types: D1, D2, D3, D4, DM, PD, DP.

Derate events are also known as “partial outages”.

A Non-Curtailing (NC) event is just a derate waiting to happen.

IEEE Std 762 10.9

$$WUDF = \left(\frac{\sum_{i=1}^{n}(EUNDH_i \times NMC_i)}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 75: WEUF = Weighted Equivalent Unavailability Factor

$$\textbf{WEUF} = \frac{\sum_{n=1}^{m}[(FOH_n + MOH_n + POH_n + EFDH_n + EMDH_n + EPDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WEUF = percent of time unavailable due to outages and derates.

Event types involved: U1, U2, U3, SF, MO, ME, PO, PE , D1, D2, D3, D4, DM, PD, DP

"Equivalent" just means that derates are included.

IEEE Std 762 10.10

$$WEUF = \left(\frac{\sum_{i=1}^{n}[(POH_i + MOH_i + FOH_i + EUNDH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 76: WEAF = Weighted Equivalent Availability Factor

WEAF =

$$\frac{\sum_{n=1}^{m}[(PH_n - FOH_n - MOH_n - POH_n - EFDH_n - EMDH_n - EPDH_n - ESEDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \mathbf{x\ 100}$$

WEAF = percent of time available without outages, derates or seasonal derates.

PH – FOH – MOH – POH = RSH + SH = AH

Event types involved: U1, U2, U3, SF, MO, ME, PO, PE , D1, D2, D3, D4, DM, PD, DP

WEAF and WSEDF are the only factors or rates to use ESEDH. When ESEDH > 0 it makes WEAF smaller because it is subtracted in the numerator.

IEEE Std 762 10.11

$$WEAF = \left(\frac{\sum_{i=1}^{n}[(AH_i \times NMC_i) - (EUNDH_i + ESDH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 77: GCF = Gross Capacity Factor

$$\textbf{GCF} = \frac{\sum_{n=1}^{m} GAG_n}{\sum_{n=1}^{m}(PH_n \; x \; GMC_n)} \textbf{ x 100}$$

GCF = percent of maximum gross energy produced during the period.

Note that GCF is inherently energy weighted; energy weighting is built in.

GAG = Gross Available Generation.

Gross = Net + Aux

IEEE Std 762 10.12

$$GCF = \left(\frac{\sum_{i=1}^{n} (\text{GAAG})_i}{\sum_{i=1}^{n} (GMC_i \times PH_i)} \right) \times 100$$

Factors And Rates

NERC 78: NCF = Net Capacity Factor

NCF = $\frac{\sum_{n=1}^{m} NAG_n}{\sum_{n=1}^{m}(PH_n \; x \; NMC_n)}$ **x 100**

NCF = percent of maximum net energy produced for the period.

Note that NCF is inherently energy weighted; energy weighting is built in.

NAG = Net Available Generation

Net = Gross – Aux

IEEE Std 762 10.13

$$NCF = \left(\frac{\sum_{i=1}^{n} (\mathrm{NAAG})_i}{\sum_{i=1}^{n} (PH_i \times NMC_i)} \right) \times 100$$

NERC 79: GOF = Gross Output Factor

$$\textbf{GOF} = \frac{\sum_{n=1}^{m} GAG_n}{\sum_{n=1}^{m}(SH_n \ x \ GMC_n)} \textbf{ x 100}$$

GOF = percent of maximum gross energy produced while online.

Because SH <= PH, GOF >= GCF.

Note that GOF is inherently energy weighted; energy weighting is built in.

GAG = Gross Available Generation.

Gross = Net + Aux

IEEE Std 762 10.14

$$GOF = \left(\frac{\sum_{i=1}^{n} (\mathrm{GAAG})_i}{\sum_{i=1}^{n} (GMC_i \times SH_i)} \right) \times 100$$

Factors And Rates

NERC 80: NOF = Net Output Factor

$$\textbf{NOF} = \frac{\sum_{n=1}^{m} NAG_n}{\sum_{n=1}^{m}(SH_n \; x \; NMC_n)} \; \textbf{x 100}$$

NOF = percent of maximum net energy produced while online.

NOF = how hard did you run when you ran?

Because SH <= PH, NOF >= NCF.

Note that NOF is inherently energy weighted; energy weighting is built in.

NAG = Net Available Generation

Net = Gross – Aux

IEEE Std 762 10.15

$$NOF = \left(\frac{\sum_{i=1}^{n} (NAAG)_i}{\sum_{i=1}^{n} (NMC_i \times SH_i)} \right) \times 100$$

Factors And Rates

NERC 81: WEMOF = Weighted Equivalent Maintenance Outage Factor

$$\textbf{WEMOF} = \frac{\sum_{n=1}^{m}[(MOH_n + EMDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WEMOF = percent of time on maintenance outage or derate.

Maintenance outage event types: MO, ME, D4, DM.

IEEE Std 762 10.21

$$WENOF = \left(\frac{\sum_{i=100}^{n}[(MOH_i + EMDH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 82: WEPOF = Weighted Equivalent Planned Outage Factor

$$\textbf{WEPOF} = \frac{\sum_{n=1}^{m}[(POH_n + EPDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WEPOF = percent of time on planned outage or derate.

Planned outage event types: PO, PE, PD, DP.

IEEE Std 762 10.18

$$WEPOF = \left(\frac{\sum_{i=1}^{n}[(POH_i + EPDH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

NERC 83: WEFOF = Weighted Equivalent Forced Outage Factor

$$\textbf{WEFOF} = \frac{\sum_{n=1}^{m}[(FOH_n + EFDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WEFOF = percent of time on forced outage or derate.

Forced outage event types: U1, U2, U3, SF, D1, D2, D3.

IEEE Std 762 10.20

$$WEFOF = \left(\frac{\sum_{i=1}^{n}[(FOH_i + EFDH_i)\times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 84: WESOF = Weighted Equivalent Scheduled Outage Factor

$$\textbf{WESOF} = \frac{\sum_{n=1}^{m}[(MOH_n + POH_n + EMDH_n + EPDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WESOF = percent of time on scheduled outage or derate.

Scheduled outage event types: MO, ME, PO, PE, D4, DM, PD, DP.

IEEE Std 762 not defined.

Factors And Rates

NERC 85: WEUOF = Weighted Equivalent Unplanned Outage Factor

$$\textbf{WEUOF} = \frac{\sum_{n=1}^{m}[(FOH_n + MOH_n + EFDH_n + EMDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\ \textbf{x 100}$$

WEUOF = percent of time on unplanned outage or derate.

Unplanned outage event types: U1, U2, U3, SF, MO, ME, D1, D2, D3, D4, DM.

IEEE Std 762 10.19

$$WEUOF = \left(\frac{\sum_{i=1}^{n}[(FOH_i + EFDH_i + MOH_i + EMDH_i) \times NMC_i]}{\sum_{i=1}^{n}(PH_i \times NMC_i)} \right) \times 100$$

Factors And Rates

NERC 86: WFOR = Weighted Forced Outage Rate

$$\textbf{WFOR} = \frac{\sum_{n=1}^{m}(FOH_n \ x \ NMC_n)}{\sum_{n=1}^{m}[(FOH_n + SH_n + Pump_n + Sync_n) \ x \ NMC_n)]} \ \textbf{x 100}$$

WFOR = probability of being on forced outage.

Forced outage event types: U1, U2, U3, SF.

IEEE Std 762 10.16.1

$$WFOR_T = \left(\frac{\sum_{i=1}^{n}(FOH_i \times NMC_i)}{\sum_{i=1}^{n}(FOH_i + SH_i + (\mathrm{SHNG})_i) \times NMC_i} \right) \times 100$$

Factors And Rates

NERC 88: WEFOR = Weighted Equivalent Forced Outage Rate

$$\textbf{WEFOR} = \frac{\sum_{n=1}^{m}[(FOH_n + EFDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}[(FOH_n + SH_n + Pump_n + Sync_n + EFDHRS_n)\ x\ NMC_n)]}\ \mathbf{x\ 100}$$

WEFOR = probability of being on forced outage or derate.

Forced outage event types: U1, U2, U3, SF, D1, D2, D3.

IEEE Std 762 10.17.1

$$WEFOR_T = \left(\frac{\sum_{i=1}^{n}[FOH_i + EFDH_i) \times NMC_i]}{\sum_{i=1}^{n}[(FOH_i + SH_i + (\mathrm{SHNG})_i + ERSFDH) \times NMC_i]} \right) \times 100$$

Factors And Rates

NERC 90: WEPOR = Weighted Equivalent Planned Outage Rate

$$\textbf{WEPOR} = \frac{\sum_{n=1}^{m}[(POH_n + EPDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}[(POH_n + SH_n + Pump_n + Sync_n + EPDHRS_n)\ x\ NMC_n)]}\ \textbf{x 100}$$

WEPOR = probability of being on planned outage or derate.

Planned outage event types: PO, PE, PD, DP.

IEEE Std 762 not defined.

Factors And Rates

NERC 91: WEMOR = Weighted Equivalent Maintenance Outage Rate

WEMOR = $$\frac{\sum_{n=1}^{m}[(MOH_n + EMDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}[(MOH_n + SH_n + Pump_n + Sync_n + EMDHRS_n)\ x\ NMC_n)]}$$ **x 100**

WEMOR = probability of being on maintenance outage or derate.

Maintenance outage event types: MO, ME, D4, DM.

IEEE Std 762 not defined.

Factors And Rates

NERC 92: WEUOR = Weighted Equivalent Unplanned Outage Rate

WEUOR = $$\frac{\sum_{n=1}^{m}[(FOH_n + MOH_n + EFDH_n + EMDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}[(FOH_n + MOH_n + SH_n + Pump_n + Sync_n + EFDHRS_n + EMDHRS_n)\ x\ NMC_n)]}$$ **x 100**

WEUOR = probability of being on maintenance outage or derate.

Unplanned outage event types: U1, U2, U3, SF, MO, ME, D1, D2, D3, D4, DM.

IEEE Std 762 not defined.

Factors and Rates

In summary, here are the Factors and Rates defined by NERC grouped by category:

- Forced – WFOF, WEFOF, WFOR, WEFOR
- Maintenance – WMOF, WEMOF, WEMOR
- Planned – WPOF, WEPOF, WEPOR
- Derated - WSDF, WUDF
- Unplanned – WUOF, WEUOF, WEUOR
- Available – WAF, WEAF
- Unavailable – WUF, WEUF
- Scheduled – WSOF, WESOF
- Other - SR, WSF, GCF, NCF, GOF, NOF

Factors and Rates

Can you define your own factors and rates?

Yes!

In this next section we will examine four calculations that are not defined by NERC or IEEE but are widely used in industry. Some just need GADS data while others require additional inputs. Non-NERC data is shown in red.

They are:

- Heat Rate and Unit Efficiency
- LMWH
- Production Efficiency
- Opportunity

Factors And Rates

Heat Rate = $\frac{Energy_{In}}{Energy_{Out}}$

$Energy_{In}$ = fuel burned, Btu

$Energy_{Out}$ = electricity produced, Kwh

NERC does not define heat rate. The definition above is the standard one used by mechanical engineers. The reason NERC does not define heat rate is because of the different ways in which fuel and generation are reported.

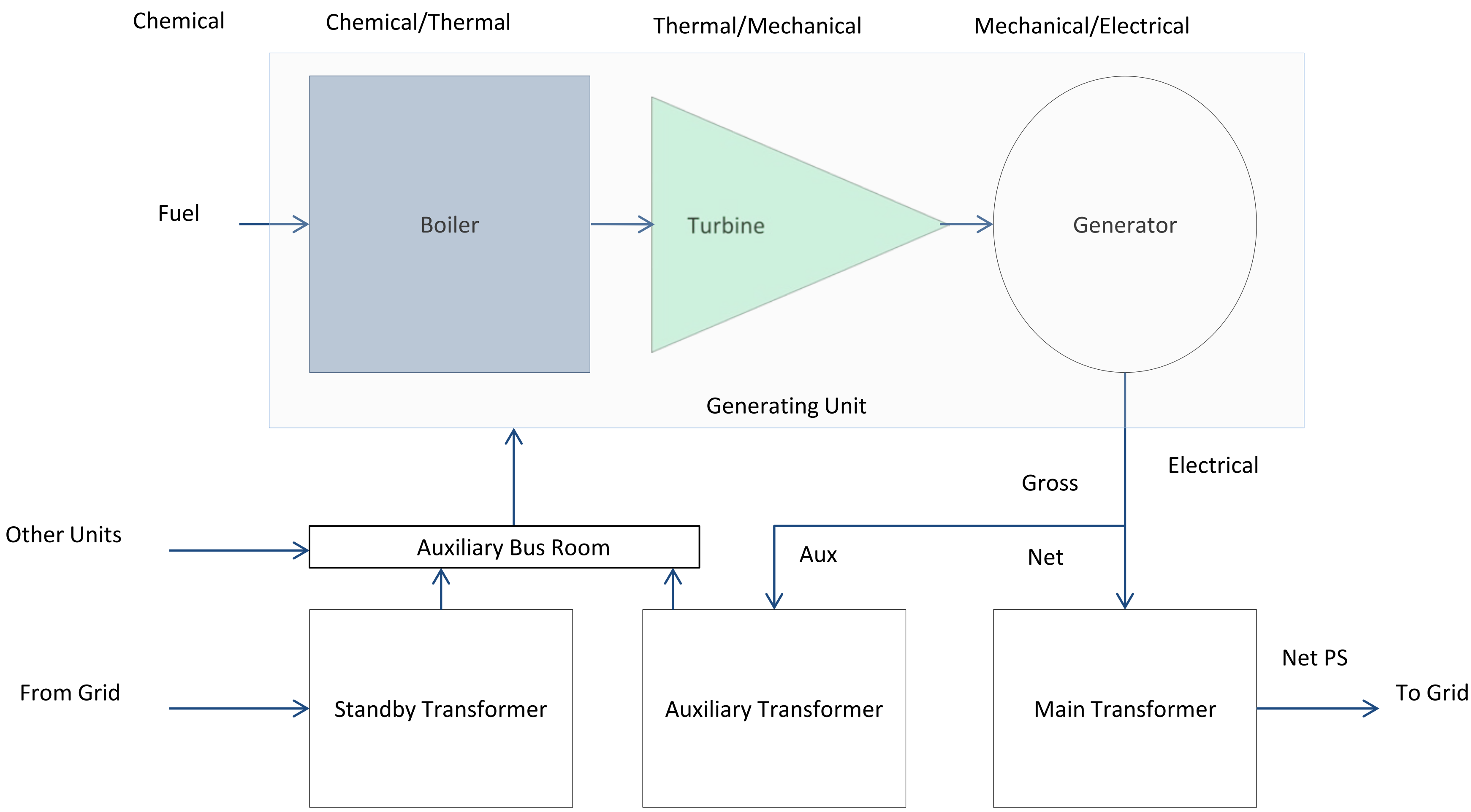
And if you know the heat rate on a unit you can also find its efficiency:

Unit Efficiency = $\left(\frac{3412}{Heat\ Rate}\right) \times 100$

(Note: 1 Kwh = 3412 Btu)

Only NERC data is needed to calculate heat rate and unit efficiency. This is a simple additional calculation you can make using the NERC data set.

Factors And Rates

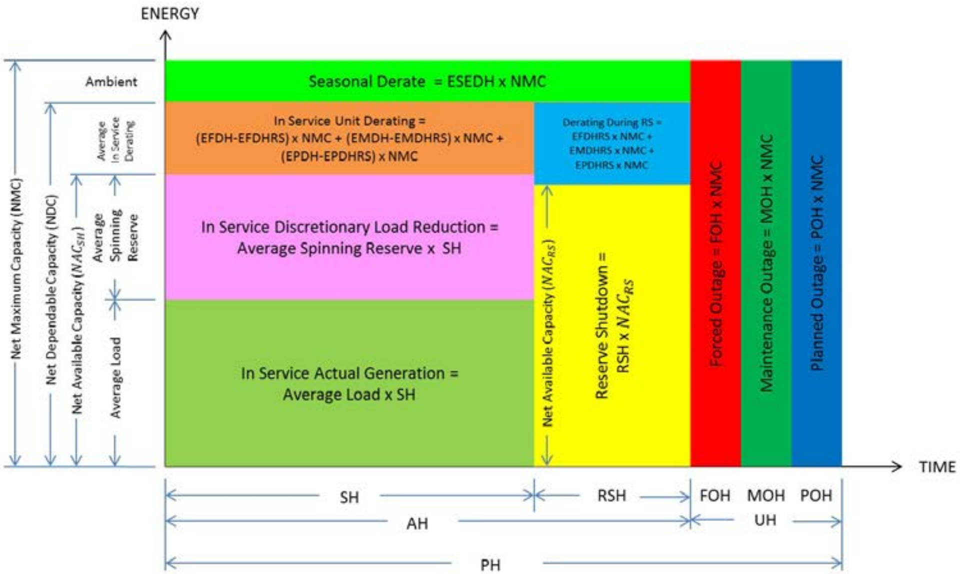


Lost MW Hours (LMWH)

- LMWH = (FOH + MOH + POH + EFDH + EMDH + EPDH) x NMC
- LMWH = the maximum energy lost from outages and derates.

ME = Maximum Energy = PH x NMC
ISAG = In Service Actual Generation
= Average Load x SH
ISDLR = In Service Discretionary Load Reduction
= Average Spinning Reserve x SH
ISUD = In Service Unit Derating
= ((EFDH – EFDHRS) +
(EMDH – EMDHRS) +
(EPDH - EPDHRS)) x NMC
SD = Seasonal Derate
= ESEDH x NMC
DDR = Derating During RS
= (EFDHRS + EMDHRS + EPDHRS) x NMC
RS = Reserve Shutdown
= RS x NAC_{RS}
O = Outages
= (FOH + MOH + POH) x NMC

NAC_{RS} can be calculated using just NERC data so only the NERC data is needed to calculate LMWH. This is a more complex additional calculation you can make using the NERC data set.



Production Efficiency

- Electric generating units are typically dispatched using mathematical models, called Input/Output models, or I/O models for short, where I = Fuel energy in, MMBTU, and O = Electrical energy out, MWH.
- I/O models typically have the form I = A + B x O + C x O^2 + D x O^3 + …
- A, B, C, D, et cetera are the I/O model coefficients.
- A common problem in our industry is determining how well the actual unit behaves compared to the I/O model. Production Efficiency (PE) is often calculated to answer this question. PE is defined as:

$$\textbf{Production Efficiency} = \frac{\sum_{n=1}^{m}(Model\ Fuel_m\ x\ NMC_m)}{\sum_{n=1}^{m}(Actual\ Fuel_m\ x\ NMC_m)}$$

- I/O models only apply across the unit operating load range, typically LSL to HSL (Low and High Sustainable Limits), so corrections are often added to account for startup fuel, duct burners, offline auxiliary power, et cetera, depending on the values of the actual fuel and electrical energy out, to improve the accuracy of the calculation.

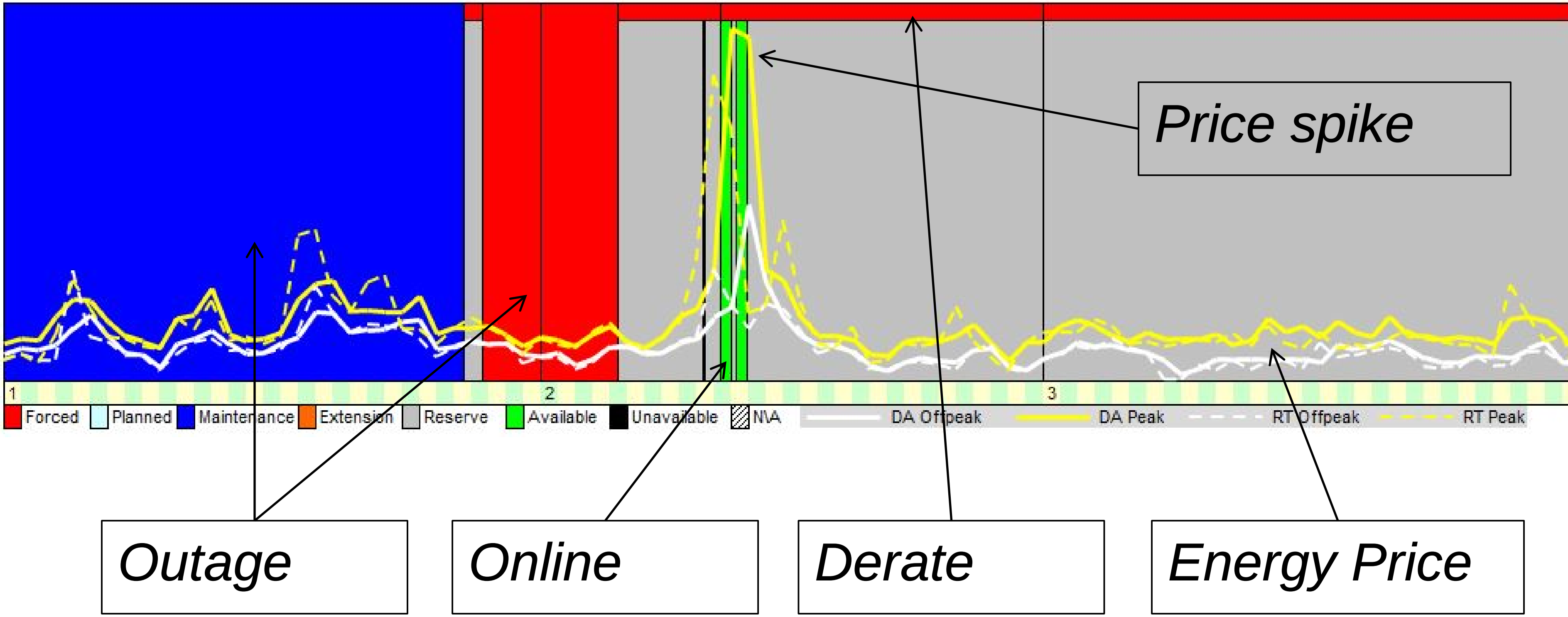
Opportunity

- Energy is sold in increments, typically the 15 minute intervals of the spot gas market. You can make money in one 15 minute interval and lose money in the next one due to the volatility of energy prices in the market.
- When a unit is on outage you often would like to know the opportunity (lost energy revenues) caused by the outage.
- **Opportunity = $\sum_{n=1}^{m}$(Profit Margin$_m$ x Loss$_m$ x Duration$_m$)**

  where:
  - m is the number of energy market intervals over which the outage event is analyzed
  - Profit Margin = Market Price - Production Cost
  - Production Cost = Fuel Cost x Net Heat Rate (a very simple model)
  - Loss = NMC – NAC   (for maximum Loss)
  - Duration = energy market interval, typically 15 minutes.
- Calculating Production Cost and Loss accurately can be very complex. The model shown is a good quick estimate based on a few simple inputs.

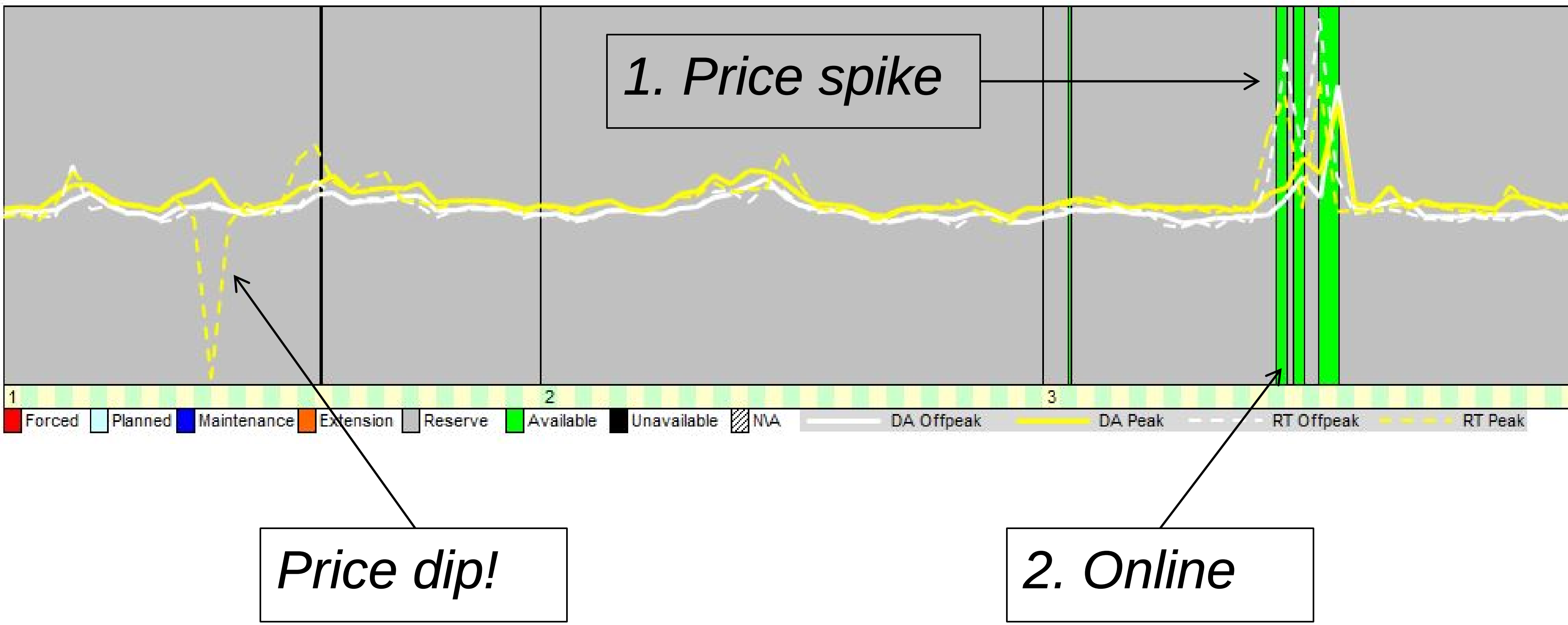
Data Visualization

- One of the most useful things you can do with the GADS data is to visualize it by plotting it out.

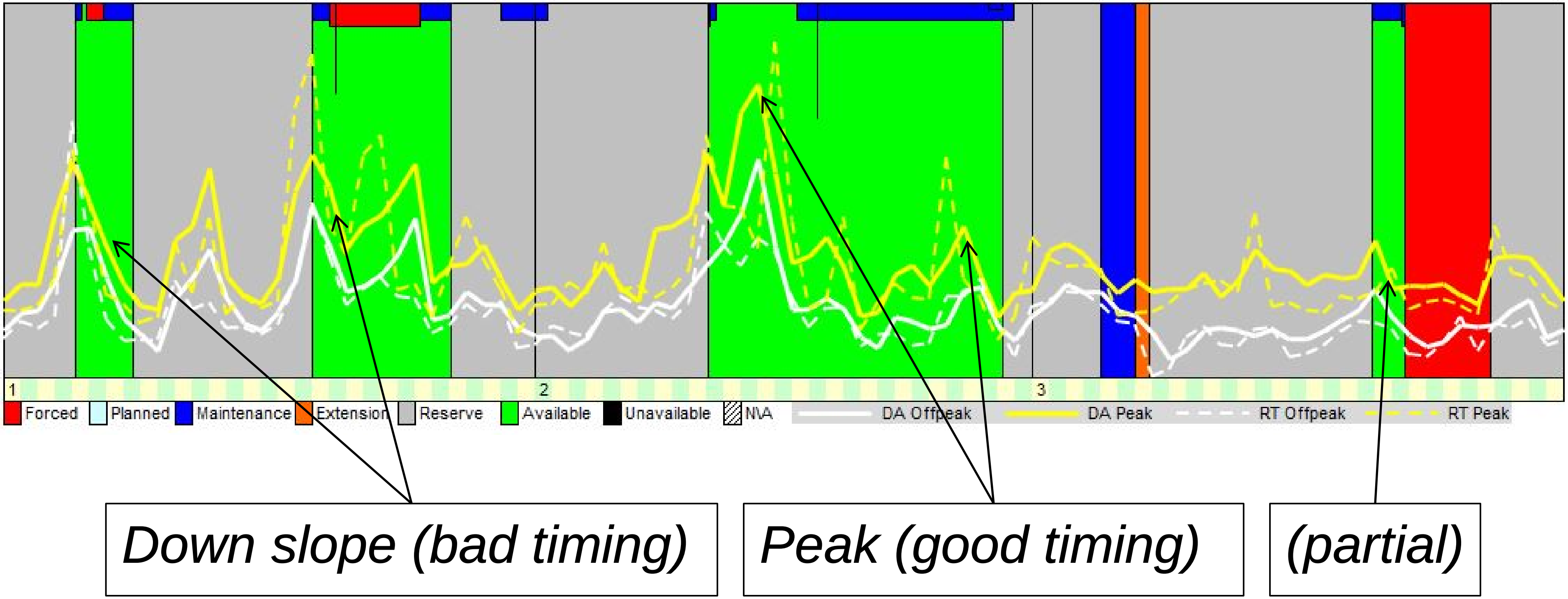


Data Visualization

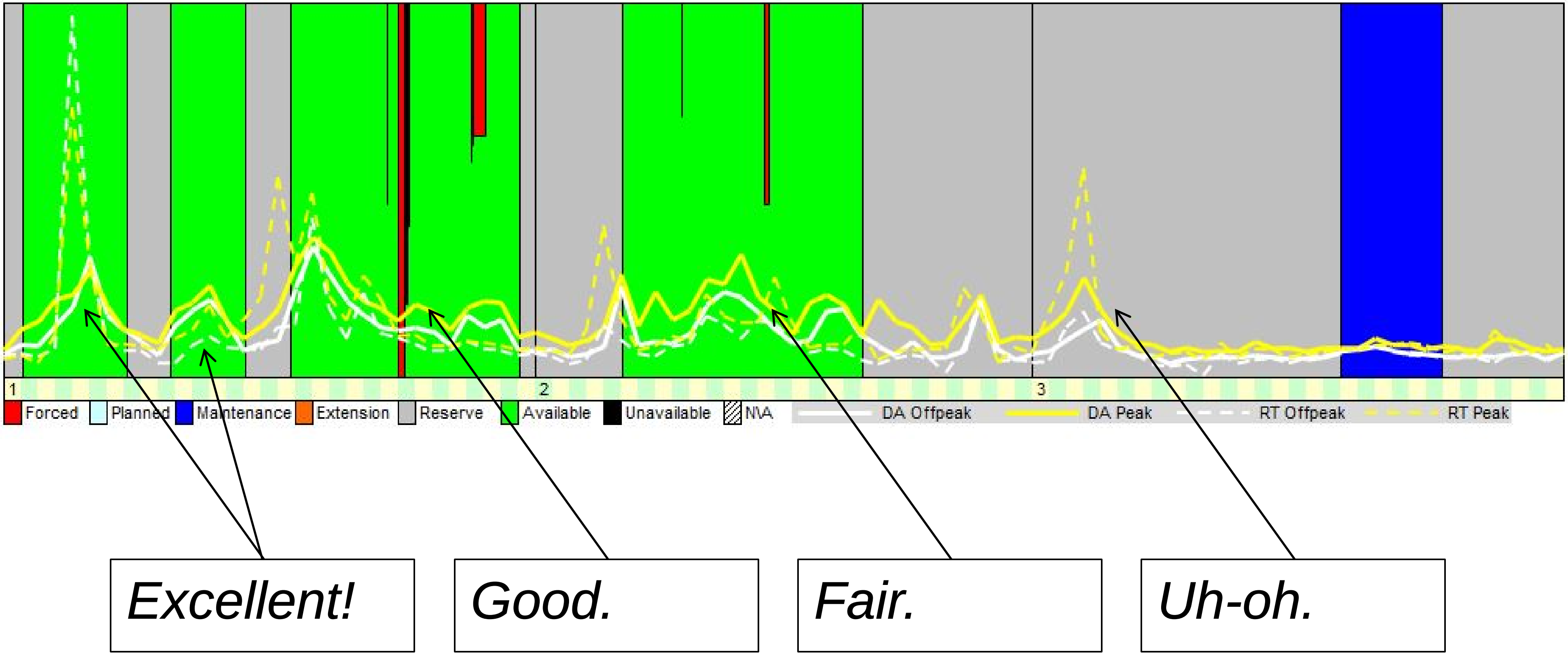
- Do you see a pattern? It has two parts to it.



- Now that you know the pattern, can you tell how well you are doing?



- What else might be going on?



NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Tips for Factors And Rates

- When doing any kind of analysis using GADS data it is important to consider the following:
- Calculate the pertinent factors and rates for all of your units, plants, regions, et cetera, in order to get the big picture.
- Compare similar or sister units within your own fleet.
- Benchmark your results against national averages.
- Examine the events underlying the factors and rates to determine their contributions. Cause codes and LMWH are good ways to do this.
- Bring in any other data sources you have and add them to the analysis as well such as unit characteristics and weather data.
- Add boundary conditions to your analysis and determine go/no go values.
- With enough data a problem or trend may often become apparent.
- When deciding your conclusions ask yourself how much is due to management decisions (like budget cuts or a no overtime policy) and how much is due to the state of the equipment (such as age and wear)?

Calculation Types

There are six (6) basic factor/rate calculation types. Below are all six types of EAF:

Unweighted (time based), single unit, w/OMC, equation #12:

$$\text{EAF} = \frac{AH - EPDH - EUDH - ESEDH}{PH} \text{ x } 100$$

Unweighted (time based), multiple units, w/OMC, equation #44:

$$\text{EAF} = \left(\frac{\sum_{n=1}^{m}(AH_n - EPDH_n - EUDH_n - ESEDH_n)}{\sum_{n=1}^{m} PH_n}\right) \text{ x } 100$$

Unweighted (time based), single unit, w/o OMC, equation #105:

$$\text{XEAF} = \frac{AH - EPDH - EUDH - ESEDH}{PH} \text{ x } 100$$

Unweighted (time based), multiple units, w/o OMC, equation same as #44 but not listed in DRI:

$$\text{XEAF} = \left(\frac{\sum_{n=1}^{m}(AH_n - EPDH_n - EUDH_n - ESEDH_n)}{\sum_{n=1}^{m} PH_n}\right) \text{ x } 100$$

Weighted (energy based), single or multiple units, w/OMC, equation #76:

$$\text{WEAF} = \left(\frac{\sum_{n=1}^{m}[(AH_n - EPDH_n - EUDH_n - ESEDH_n) \; x \; NMC_n]}{\sum_{n=1}^{m}(PH_n \; x \; NMC_n)}\right) \text{ x } 100$$

Weighted (energy based), single or multiple units, w/o OMC, equation #129:

$$\text{XWEAF} = \left(\frac{\sum_{n=1}^{m}[(AH_n - EPDH_n - EUDH_n - ESEDH_n) \; x \; NMC_n]}{\sum_{n=1}^{m}(PH_n \; x \; NMC_n)}\right) \text{ x } 100$$

- The types of all the other factors and rates are the same.
- In unweighted (time based) equations each unit has equal weight.
- In weighted (energy based) equations each unit is weighted by its NMC.

Calculation Types

Tip:

Since w/o OMC only affects AH

And AH = RSH + SH

And PH = FOH + MOH + POH + RSH + SH

Then AH = PH – FOH – MOH – POH

Therefore the equation below will calculate EAF, w/ or w/o OMC:

$$\textbf{WEAF} = \left(\frac{\sum_{n=1}^{m}[(PH_n - FOH_n - MOH_n - POH_n - EPDH_n - EUDH_n - ESEDH_n)\ x\ NMC_n]}{\sum_{n=1}^{m}(PH_n\ x\ NMC_n)}\right)\ \textbf{x 100}$$

- *The only differences between w/ and w/o OMC equations are the names of the equations (w/o OMC preceded by "X") and the values of the input terms.*
- *The only differences between unweighted and weighted equations are the names of the equations (weighted preceded by "W") and the inclusion of NMC in the numerator and denominator terms for weighted equations.*

Input term cross reference:

NERC Formula	Name	ACTSU	ATTSU	EFDH	EFDHRS	EMDH	EMDHRS	EPDH	EPDHRS	ESEDH	FOH	GAG	GMC	MOH	NAG	NMC	PH	POH	PUMPHRS	RSH	SH	SYNCHRS
62	SR	X	X																			
65	WFOF										X					X	X					
66	WMOF													X		X	X					
67	WPOF															X	X	X				
68	WUOF										X			X		X	X					
69	WSOF													X		X	X	X				
70	WUF										X			X		X	X	X				
71	WAF															X	X			X	X	
72	WSF															X	X				X	
73	WSEDF									X						X	X					
74	WUDF			X		X		X								X	X					
75	WEUF			X		X		X			X			X		X	X	X				
76	WEAF			X		X		X		X						X	X			X	X	
77	GCF											X	X				X					
78	NCF														X	X	X					
79	GOF											X	X								X	
80	NOF														X	X					X	
81	WEMOF					X								X		X	X					
82	WEPOF							X								X	X	X				
83	WEFOF			X							X					X	X					
84	WESOF					X		X						X		X	X	X				
85	WEUOF			X		X					X			X		X	X					
86	WFOR										X					X			X		X	X
88	WEFOR			X	X						X					X			X		X	X
90	WEPOR							X	X							X		X	X		X	X
91	WEMOR					X	X							X		X			X		X	X
92	WEUOR			X	X	X	X				X			X		X			X		X	X

N/D Method

Numerator/Denominator cross reference:

NERC Formula	Name	Description	Numerator Formula	Denominator Formula
62	SR	Starting Reliability	ACTSU	ATTSU
65	WFOF	Weighted Forced Outage Factor	FOH x NMC	PH x NMC
66	WMOF	Weighted Maintenance Outage Factor	MOH x NMC	PH x NMC
67	WPOF	Weighted Planned Outage Factor	POH x NMC	PH x NMC
68	WUOF	Weighted Unplanned Outage Factor	(FOH + MOH) x NMC	PH x NMC
69	WSOF	Weighted Scheduled Outage Factor	(POH + MOH) x NMC	PH x NMC
70	WUF	Weighted Unavailability Factor	(FOH + MOH + POH) x NMC	PH x NMC
71	WAF	Weighted Availability Factor	(PH - FOH - MOH - POH) x NMC	PH x NMC
72	WSF	Weighted Service Factor	SH x NMC	PH x NMC
73	WSEDF	Weighted Seasonal Derating Factor	ESEDH x NMC	PH x NMC
74	WUDF	Weighted Unit Derating Factor	(EFDH + EMDH + EPDH) x NMC	PH x NMC
75	WEUF	Weighted Equivalent Unavailability Factor	(FOH + MOH + POH + EFDH + EMDH + EPDH) x NMC	PH x NMC
76	WEAF	Weighted Equivalent Availability Factor	(PH - FOH - MOH - POH - EFDH - EMDH - EPDH - ESEDH) x NMC	PH x NMC
77	GCF	Gross Capacity Factor	GAG	PH x GMC
78	NCF	Net Capacity Factor	NAG	PH x NMC
79	GOF	Gross Output Factor	GAG	SH x GMC
80	NOF	Net Output Factor	NAG	SH x NMC
81	WEMOF	Weighted Equivalent Maintenance Outage Factor	(MOH + EMDH) x NMC	PH x NMC
82	WEPOF	Weighted Equivalent Planned Outage Factor	(POH + EPDH) x NMC	PH x NMC
83	WEFOF	Weighted Equivalent Forced Outage Factor	(FOH + EFDH) x NMC	PH x NMC
84	WESOF	Weighted Equivalent Scheduled Outage Factor	(MOH + POH + EMDH + EPDH) x NMC	PH x NMC
85	WEUOF	Weighted Equivalent Unplanned Outage Factor	(FOH + MOH + EFDH + EMDH) x NMC	PH x NMC
86	WFOR	Weighted Forced Outage Rate	FOH x NMC	(FOH + SH + SYNCHRS + PUMPHRS) x NMC
88	WEFOR	Weighted Equivalent Forced Outage Rate	(FOH + EFDH) x NMC	(FOH + SH + SYNCHRS + PUMPHRS + EFDHRS) x NMC
90	WEPOR	Weighted Equivalent Planned Outage Rate	(POH + EPDH) x NMC	(POH + SH + SYNCHRS + PUMPHRS + EPDHRS) x NMC
91	WEMOR	Weighted Equivalent Maintenance Outage Rate	(MOH + EMDH) x NMC	(MOH + SH + SYNCHRS + PUMPHRS + EMDHRS) x NMC
92	WEUOR	Weighted Equivalent Unplanned Outage Rate	(FOH + MOH + EFDH + EMDH) x NMC	(FOH + MOH + SH + SYNCHRS + PUMPHRS + EFDHRS + EMDHRS) x NMC

N/D Method

Unique Numerator/Denominator cross reference:

Unique Numerators/Denominators
ACTSU
ATTSU
(EFDH + EMDH + EPDH) x NMC
ESEDH x NMC
(FOH + EFDH) x NMC
(FOH + MOH + EFDH + EMDH) x NMC
(FOH + MOH + POH + EFDH + EMDH + EPDH) x NMC
(FOH + MOH + POH) x NMC
(FOH + MOH + SH + SYNCHRS + PUMPHRS + EFDHRS + EMDHRS) x NMC
(FOH + MOH) x NMC
(FOH + SH + SYNCHRS + PUMPHRS + EFDHRS) x NMC
(FOH + SH + SYNCHRS + PUMPHRS) x NMC
FOH x NMC
GAG
(MOH + EMDH) x NMC
(MOH + POH + EMDH + EPDH) x NMC
(MOH + SH + SYNCHRS + PUMPHRS + EMDHRS) x NMC
MOH x NMC
NAG
(PH - FOH - MOH - POH - EFDH - EMDH - EPDH - ESEDH) x NMC
(PH - FOH - MOH - POH) x NMC
PH x GMC
PH x NMC
(POH + EPDH) x NMC
(POH + MOH) x NMC
(POH + SH + SYNCHRS + PUMPHRS + EPDHRS) x NMC
POH x NMC
SH x GMC
SH x NMC

N/D Method

Except for those based on demand, factors and rates can be calculated in just three (3) steps:

- Calculate the numerator (N) term
- Calculate the denominator (D) term
- Divide N/D and multiply by 100 to get percent

EFORd requires nine (9!) steps to calculate:

- Calculate grouped unit data using method #2
- Calculate five (5) intermediate terms r, T, D, f, p
- Calculate the numerator (N) term
- Calculate the denominator (D) term
- Divide N/D and multiply by 100 to get percent

N/D Method

Because factors/rates not based on demand are all calculated the same way, you can set up a procedure that will manage which intermediate calculations go into the numerator and denominator and use the same formula to calculate them all: N/D.

It looks like this:

Factor or Rate = $\frac{N}{D}$ x 100 = $\frac{Numerator}{Denominator}$ x 100 = $\frac{sumif(index,key,numerator)}{sumif(index,key,denominator)}$ x 100

Where:

index = lookup value on each data row in the calculation

key = lookup value for data rows to be included in the calculation

numerator = intermediate calculation for the numerator

denominator = intermediate calculation for the denominator

x 100 = conversion factor to get percent

Calculating EFORd

NERC 89: WEFORd = Weighted Equivalent Forced Outage Rate Demand

$$\textbf{WEFORd} = \frac{\sum_{n=1}^{m}[(FOHd_n + EFDHd_n)\ x\ NMC_n]}{\sum_{n=1}^{m}[(SH_n + FOHd_n)\ x\ NMC_n)]}\ \textbf{x 100}$$

WEFORd = probability of being on forced outage or derate when demanded to run.

Where:

- FOHd = f x FOH
- EFDHd = EFDH - EFDHRS if RSH > 0 or EFDHd = p x EFDH if RSH = 0
- p = SH/AH
- f = (1/r + 1/T)/(1/r + 1/T + 1/D)
- r = FOH/ #FO
- T = RSH/ATTSU
- D = SH/ACTSU

Event types involved: U1, U2, U3, SF, D1, D2, D3, RS.

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$$WEFOR_d = \left(\frac{\sum_{i=1}^{n}[(FOH_{di} + EFDH_{di}) \times NMC_i]}{\sum_{i=1}^{n}[(SH_i + FOH_{di}) \times NMC_i]} \right) \times 100$$

Calculating EFORd

Below is a step by step guide for calculating WEFORd using data pooling method #2.

1) Calculate grouped data sums and sumproducts.

```
SUM(FO) = sumif(index, key, FO)
SUM(ACTSU) = sumif(index, key, ACTSU)
SUM(ATTSU) = sumif(index, key, ATTSU)
SUM(RSH) = sumif(index, key, RSH)
SUM(SH) = sumif(index, key, SH)
SUMPRODUCT(FOH, NMC) = sumif(index, key, FOH x NMC)
SUMPRODUCT(RSH, NMC) = sumif(index, key, RSH x NMC)
SUMPRODUCT(SH, NMC) = sumif(index, key, SH x NMC)
SUMPRODUCT(EFDH, NMC) = sumif(index, key, EFDH x NMC)
```

2) Calculate a single value for 1/r for the time period in question:

```
IF SUMPRODUCT(FOH, NMC) > 0 THEN
   1/r = SUM(FO) / SUMPRODUCT(FOH, NMC)
ELSE
   1/r = 0
ENDIF
```

3) Calculate a single value for 1/T for the time period in question:

```
IF SUMPRODUCT(RSH, NMC) > 0 THEN
   1/T = SUM(ATTSU) / SUMPRODUCT(RSH, NMC)
ELSE
   1/T = 0
ENDIF
```

4) Calculate a single value for 1/D for the time period in question:

```
IF SUMPRODUCT(SH, NMC) > 0 THEN
   1/D = SUM(ACTSU) / SUMPRODUCT(SH, NMC)
ELSE
   1/D = 0
ENDIF
```

5) Calculate a single value for f for the time period in question:

```
IF SUM(RSH) < 1 THEN
   f = 1
ELSEIF SUM(SH) = 0 THEN
   f = 1
ELSEIF (1/ r + 1/T + 1 /D) > 0 THEN
   f = (1/r + 1/T)/( 1/r + 1/T + 1/D)
ELSE
   f = 0
ENDIF
```

6) Calculate a single value for p for the time period in question:

```
IF (SUM(SH) + SUM(RSH)) > 0 THEN
   p = SUM(SH) / (SUM(SH) + SUM(RSH))
ELSE
   p = 0
ENDIF
```

7) Calculate a single value for the numerator for the time period in question:

```
N = f x SUMPRODUCT(FOH, NMC)
     + p x SUMPRODUCT(EFDH, NMC)
```

8) Calculate a single value for the denominator for the time period in question:

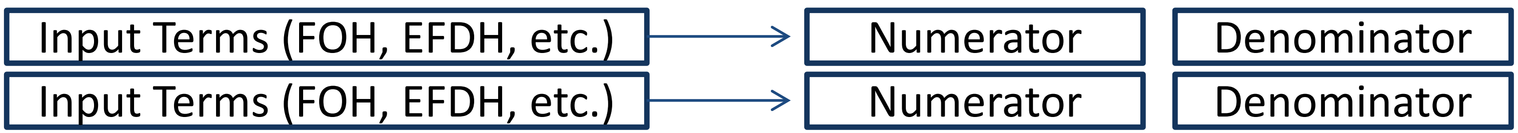
```
D = SUMPRODUCT(SH, NMC)
     + f x SUMPRODUCT(FOH, NMC)
```

9) Calculate the EFORd for the time period in question:

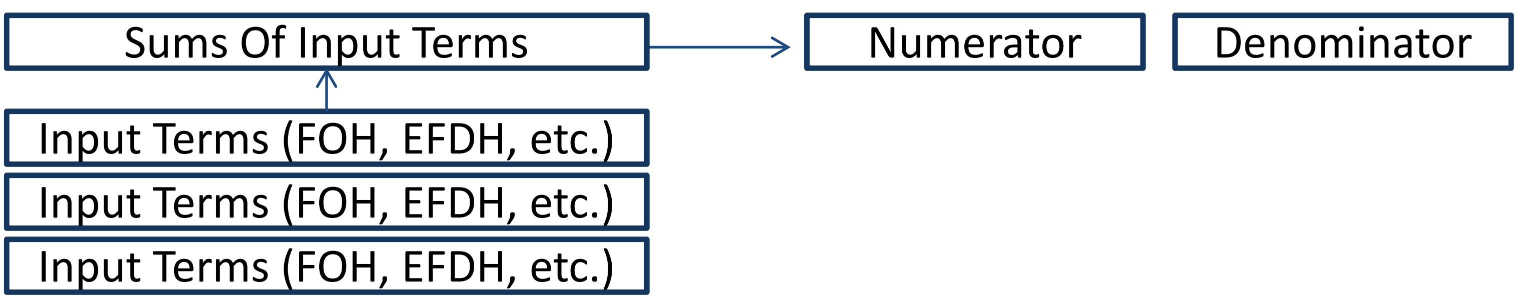
```
IF D > 0 THEN
   EFORd = (N / D) x 100
ELSE
   EFORd = 0
ENDIF
```

Worked Examples

- Factor/Rate examples that go directly from input terms (FOH, etc.) to numerators and denominators using row by row calculations.



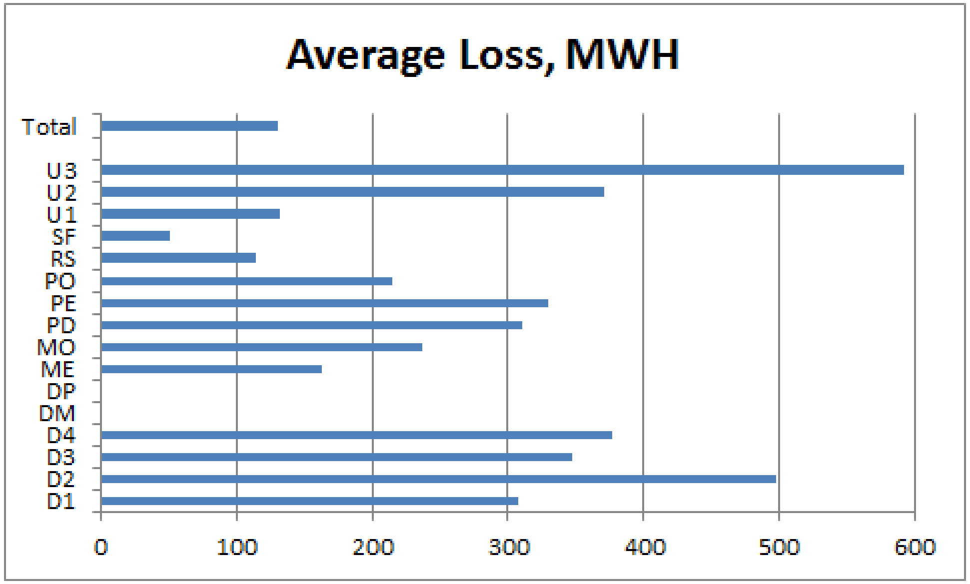
- EFORd examples using grouped unit data that first go from input terms (FOH, etc.) to sums of input terms and then from the sums of input terms to numerators and denominators in a single row calculation.



Homework Assignment

- Calculate the average hourly cost, in LMWH, of each active event type - D1, D2, D3, D4, DM, ME, MO, PD, PE, PO, RS, SF, U1, U2, and U3. Account for shadowed derates and choose a long enough time period to include winter and summer and all event types, if possible. If you can share your results, bring them to the next GADS Data Reporting workshop for some advanced training.

Event Type	Average Loss, MWH
D1	307.01
D2	498.63
D3	346.89
D4	376.79
DM	0.00
DP	0.00
ME	162.89
MO	237.01
PD	310.87
PE	329.34
PO	214.59
RS	114.17
SF	50.38
U1	131.99
U2	370.44
U3	592.75
Total	130.30



Q & A?

Parting quote from IEEE Std 762:

It should be noted that even the use of all the indexes and terms cannot identify the underlying and sometimes compelling reasons for lost performance.

And remember: only YOU can prevent GADS data errors!