

## Appendix F: Performance Indexes and Equations

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### General Information

Appendix F discusses the relationships among the performance indexes calculated from the event and performance data outlined in Sections III and IV. The basis for these relationships is IEEE Standard No. 762 “Definitions for Use in Reporting Electric Generating Unit Reliability, Availability and Productivity.”

All calculations are subject to the following adjustments:

1. All events must be adjusted for Daylight Savings Time (DST) if a unit is in a time zone to which it applies.
2. All events must be adjusted for the time period under analysis. Example: To analyze August for an event that starts in July and ends in September exclude the portions of the event outside August.
2. Derate events must be adjusted for shadowing by outages and by dominant derates. See Appendix G.

### Summary of Various Time and Energy Factors Used by Indexes

1.	Service Hours - SH	Sum of all unit Service Hours.
2.	Synchronous Condensing Hours	Sum of all hours the unit is in the synchronous condensing mode. The units are considered to be in non-generating service operation.
3.	Pumping Hours	Sum of all hours the pumped storage unit is in pumping mode. The units are considered to be in non-generating service operation.
4.	Available Hours - AH	Sum of all Service Hours (SH) + Reserve Shutdown Hours (RSH) + Pumping Hours + Synchronous Condensing Hours
5.	Planned Outage Hours - POH	Sum of all hours experienced during Planned Outages (PO) + Planned Outage Extensions (PE) of any Planned Outages (PO).
6.	Unplanned Outage Hours - UOH	Sum of all hours experienced during Forced Outages (U1, U2, and U3) + Startup Failures (SF) + Maintenance Outages (MO) + Maintenance Outage Extensions (ME) of any Maintenance Outages (MO).
7.	Forced Outage Hours - FOH	Sum of all hours experienced during Forced Outages (U1, U2, and U3) + Startup Failures (SF).
8.	Maintenance Outage Hours - MOH	Sum of all hours experienced during Maintenance Outages (MO) + Maintenance Outage Extensions (ME) of any Maintenance Outages (MO).
9.	Unavailable Hours - UH	Sum of all Planned Outage Hours (POH) + Forced Outage Hours (FOH) + Maintenance Outage Hours (MOH).
10.	Scheduled Outage Hours - SOH	Sum of all hours experienced during Planned Outages (PO) + Maintenance Outages (MO) + Scheduled Outage

		Extensions (ME and PE) of any Maintenance Outages (MO) and Planned Outages (PO).
11.	Period Hours - PH	Number of hours in the period being reported that the unit was in the active state.
12.	Equivalent Seasonal Derated Hours - ESEDH	<p>(Net Maximum Capacity (NMC) - Net Dependable Capacity (NDC)) x Available Hours (AH) / Net Maximum Capacity (NMC)</p> $\frac{(NMC - NDC) \times AH}{NMC}$
13a.	Equivalent Forced Derated Hours - EFDH	<p>Each individual Forced Derating (D1, D2, and D3) transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of the reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.</p> $\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{NMC}$ <p>NOTE: Includes Forced Deratings (D1, D2, and D3) during Reserve Shutdowns (RS). See calculation 13f (EFDHRS), Page F-4, for comparison.</p>
13b.	Equivalent Maintenance Derated Hours - EMDH	<p>Each individual Maintenance Derating (D4, DM of D4) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.</p> $\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{NMC}$ <p>NOTE: Includes Maintenance Deratings (D4) during Reserve Shutdowns (RS). See calculation 13h (EMDHRS), Page F-5, for comparison.</p>
13c.	Equivalent Planned Derated Hours - EPDH	<p>Each individual Planned Derating (PD, DP of PD) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.</p> $\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{NMC}$

NOTE: Includes Planned Deratings (PD) during Reserve Shutdowns (RS).

See calculation 13g (EPDHRS), Page F-4, for comparison.

13d. Equivalent Scheduled Derated Hours - ESDH

Each individual Planned Derating (PD, DP of PD) and Maintenance Derating (D4, DM of D4) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.

$$\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{\text{NMC}}$$

13e. Equivalent Unplanned Derated Hours - EUDH

Each individual Unplanned Derating (D1, D2, D3, D4, and DM of D4) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.

$$\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{\text{NMC}}$$

NOTE: Includes Unplanned Deratings (D1, D2, D3, D4, and DM of D4) during Reserve Shutdowns (RS).

13f. Equivalent Forced Derated Hours During Reserve Shutdowns - EFDHRS

Each individual Forced Derating (D1, D2, and D3) or the portion of any Forced Derating which occurred during a Reserve Shutdown (RS) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of the reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.

$$\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{\text{NMC}}$$

13g. Equivalent Planned Derated Hours During Reserve Shutdowns - EPDHRS

Each individual Planned Derating (PD) or the portion of any Planned Derating which occurred during a Reserve Shutdown (RS) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of the reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.

$$\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{\text{NMC}}$$

- 13h. Equivalent Maintenance Derated Hours During Reserve Shutdowns - EMDHRS
- Each individual Maintenance Derating (D4) or the portion of any Maintenance Derating which occurred during a Reserve Shutdown (RS) is transformed into equivalent full outage hour(s). This is calculated by multiplying the actual duration of the derating (hours) by the size of the reduction (MW) and dividing by the Net Maximum Capacity (NMC). These equivalent hour(s) are then summed.

$$\frac{\text{Derating Hours} \times \text{Size of Reduction}^*}{\text{NMC}}$$

*\* Size of Reduction is determined by subtracting the Net Available Capacity (NAC) from the Net Dependable Capacity (NDC). In cases of multiple deratings, 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.*

14. Number of Planned Outages (PO) which occur from in-service state only
- A count of the number of all Planned Outages (PO) reported on the GADS Event Report (07). (Since Planned Outage Extensions (PE) of Planned Outages are considered part of the original Planned Outage (PO), they are not included in this count.)
15. Number of Unplanned Outages (MO, U1, U2, and U3) which occur from in-service state only
- A count of the number of all Unplanned Outages (U1, U2, U3, and MO) reported on the GADS Event Report (07). (IEEE Standard 762 does not include Startup Failures (SF) in this count.)
16. Number of Forced Outages (U1, U2, and U3) which occur from in-service state only
- A count of the number of all Unplanned (Forced) Outages (U1, U2, U3) reported on the GADS Event Report (07). (IEEE Standard 762 does not include Startup Failures (SF) in this count.)
17. Number of Maintenance Outages (MO) which occur from in-service state only
- A count of the number of all Maintenance Outages (MO) reported on the GADS Event Report (07). (Since Maintenance Outage Extensions (ME) of Maintenance Outages are considered part of the original Maintenance Outage (MO), they are not included in this count.)

## Performance Indexes

The following sections describe performance indexes used to measure the performance of generating units. The sections are divided into:

1. Unweighted (time-based) methods for calculating single unit statistics.
2. Unweighted (time-based) methods for calculating pooled (grouped) unit statistics.
3. Weighted (capacity-based) methods for calculating pooled (grouped) unit statistics.
4. Unweighted (time-based) methods for calculating statistics excluding problems outside management control for single unit and pooled (grouped) unit statistics.
5. Weighted (capacity-based) methods for calculating statistics excluding problems outside management control for pooled (grouped) unit statistics.

## Calculation Notes

Please note that when you are calculating a single generating unit's performance statistics, it does not matter much if you use unweighted or weighted statistics. If the weighting (NMC) does not vary over the analysis time period it will cancel out and not matter. If NMC varies over the analysis time period it will make a small difference. The real difference between the unweighted and weighted statistics is in pooled (grouped) sets of generating units. In these cases, a group of units of similar size will show only small differences, but a group of units where the MW size is very different (greater than 50 MW), the statistics will be very different.

With unweighted statistics, all units are considered equal in outage impact. In the unweighted equations, no MW size is introduced into the equations and the results are based on time, not energy produced or not produced. In such cases, a 50 MW gas turbine and a 1,000 MW nuclear unit have the same impact on the resulting statistics.

With weighted statistics, the larger MW size unit in the group has more impact on the final statistics than a smaller generating unit. That is because the MW size of the unit (NMC) is part of the equation. In these cases, a 1,000 MW nuclear unit would have 20 times impact on the final outcome of the calculation than would its 50 MW gas turbine companion.

## Data Pooling Notes

When grouping a fleet of units of dissimilar size and/or duty cycle, weighting puts the proper relative weight of each unit's contribution into the fleet's composite statistics.

Using the unweighted equations currently in the IEEE 762 Standard (Section 9), an older, smaller, and little-run unit will have just as much weight as a newer, larger, base-load unit. The effect of this could unrealistically and disproportionately swing the fleet unweighted averages too high (for a very high availability on a small unit) or too low (for a very low availability on a small unit).

However, the current IEEE 762 Standard's unweighted equations should not be abandoned even for group statistics. There are valid applications for this method as well. (One being purely to evaluate equipment reliability and availability regardless of size).

The weighted calculations, although primarily needed for grouping units' performance indexes, may apply to individual units as well. The effect depends on how much a unit's net maximum capacities (NMC) changes during the time period in question.

**SPECIAL NOTE:** To weight an equation, one does not simply take each unit's EFOR, for example, and multiply the EFOR by the NMC, add them up and divide by the sum of the NMCs. Each term in the equation must be multiplied by the NMC and then all the products are summed over all the units.

## Unweighted (time-based) Methods for Calculating Single Unit Statistics

1. Planned Outage Factor – POF

$$\text{POF} = \frac{\text{POH}}{\text{PH}} \times 100\%$$

2. Unplanned Outage Factor – UOF

$$\text{UOF} = \frac{\text{UOH}}{\text{PH}} \times 100\%$$

$$\text{UOF} = \frac{\text{FOH} + \text{MOH}}{\text{PH}} \times 100\%$$

3. Forced Outage Factor – FOF

$$\text{FOF} = \frac{\text{FOH}}{\text{PH}} \times 100\%$$

4. Maintenance Outage Factor – MOF

$$\text{MOF} = \frac{\text{MOH}}{\text{PH}} \times 100\%$$

5. Scheduled Outage Factor – SOF

$$\text{SOF} = \frac{\text{SOH}}{\text{PH}} \times 100\%$$

$$\text{SOF} = \frac{\text{MOH} + \text{POH}}{\text{PH}} \times 100\%$$

6. Unavailability Factor – UF

$$\text{UF} = \frac{\text{UH}}{\text{PH}} \times 100\%$$

$$\text{UF} = \frac{\text{FOH} + \text{MOH} + \text{POH}}{\text{PH}} \times 100\%$$

7. Availability Factor – AF

$$\text{AF} = \frac{\text{AH}}{\text{PH}} \times 100\%$$

$$\text{AF} = \frac{\text{RSH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours}}{\text{PH}} \times 100\%$$

8. Service Factor – SF

$$\text{SF} = \frac{\text{SH}}{\text{PH}} \times 100\%$$

9. Seasonal Derating Factor – SEDF

$$\text{SEDF} = \frac{\text{ESEDH}}{\text{PH}} \times 100\%$$

10. Unit Derating Factor – UDF

$$\text{UDF} = \frac{\text{EPDH} + \text{EUDH}}{\text{PH}} \times 100\%$$

$$\text{UDF} = \frac{\text{EPDH} + \text{EMDH} + \text{EFDH}}{\text{PH}} \times 100\%$$

11. Equivalent Unavailability Factor – EUF

$$\text{EUF} = \frac{\text{UOH} + \text{POH} + \text{EUDH} + \text{EPDH}}{\text{PH}} \times 100\%$$

$$\text{EUF} = \frac{\text{FOH} + \text{SOH} + \text{EFDH} + \text{ESDH}}{\text{PH}} \times 100\%$$

$$\text{EUF} = \frac{\text{FOH} + \text{MOH} + \text{POH} + \text{EFDH} + \text{EMDH} + \text{EPDH}}{\text{PH}} \times 100\%$$

12. Equivalent Availability Factor – EAF

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

$$\text{EAF} = \frac{\text{AH} - \text{EPDH} - \text{EFDH} - \text{EMDH} - \text{ESEDH}}{\text{PH}} \times 100\%$$

13. Gross Capacity Factor – GCF

$$\text{GCF} = \frac{\text{Gross Actual Generation}}{\text{PH} \times \text{GMC}} \times 100\%$$

14. Net Capacity Factor – NCF

$$\text{NCF} = \frac{\text{Net Actual Generation}}{\text{PH} \times \text{NMC}} \times 100\%$$

Note: Net capacity factor calculated using this equation can be negative during a period when the unit is shutdown.

15. Gross Output Factor – GOF

$$\text{GOF} = \frac{\text{Gross Actual Generation}}{\text{SH} \times \text{GMC}} \times 100\%$$

16. Net Output Factor – NOF

$$\text{NOF} = \frac{\text{Net Actual Generation}}{\text{SH} \times \text{NMC}} \times 100\%$$

17. Equivalent Maintenance Outage Factor – EMOF

$$\text{EMOF} = \frac{\text{MOH} + \text{EMDH}}{\text{PH}} \times 100\%$$

18. Equivalent Planned Outage Factor – EPOF

$$\text{EPOF} = \frac{\text{POH} + \text{EPDH}}{\text{PH}} \times 100\%$$

19. Equivalent Forced Outage Factor – EFOF

$$\text{EFOF} = \frac{\text{FOH} + \text{EFDH}}{\text{PH}} \times 100\%$$

20. Equivalent Scheduled Outage Factor – ESOF

$$\text{ESOF} = \frac{\text{SOH} + \text{ESDH}}{\text{PH}} \times 100\%$$

$$\text{ESOF} = \frac{\text{MOH} + \text{POH} + \text{EMDH} + \text{EPDH}}{\text{PH}} \times 100\%$$

21. Equivalent Unplanned Outage Factor – EUOF

$$\text{EUOF} = \frac{\text{UOH} + \text{EUDH}}{\text{PH}} \times 100\%$$

$$\text{EUOF} = \frac{\text{MOH} + \text{FOH} + \text{EMDH} + \text{EFDH}}{\text{PH}} \times 100\%$$

(NOTE: This EUOF is identical to the Unit Capability Loss Factor except this equation includes all events, including those outside plant management control.)

22. Forced Outage Rate – FOR

$$\text{FOR} = \frac{\text{FOH}}{\text{FOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours}} \times 100\%$$

23. Forced Outage Rate Demand – FORd (See Notes 1 and 2 at the end of this section.)

$$\text{FORd} = \frac{\text{FOHd}}{\text{FOHd} + \text{SH}} \times 100\%$$

Where:  $\text{FOHd} = f \times \text{FOH}$

NOTE: FOHd is the number of hours a unit was in a U1, U2, U3, or SF AND the unit would have operated had it been available. FOHd can be determined directly if periods of demand are recorded. Demand can be defined as the traditional demand for the generating unit for economic or reliable operation of the system, or it can be any other user-defined condition, such as specific weather condition, load level, or energy price. When FOHd is determined directly from recorded periods of demand, service hours (SH) in the above equation should include only those under the specified demand condition. If periods of demand are not recorded, FOHd may be estimated using the demand factor  $f$ . The demand factor is applicable to traditional demand for economic or reliable system operation.



$$f = \left( \frac{1}{r} + \frac{1}{T} \right) / \left( \frac{1}{r} + \frac{1}{T} + \frac{1}{D} \right)$$

$r$  = Average forced outage duration = (FOH) / (# of FO occurrences)  
 $D$  = Average demand time = (SH) / (# of unit actual starts)  
 $T$  = Average reserve shutdown time = (RSH) / (# of unit attempted starts)

24. Equivalent Forced Outage Rate – EFOR

$$\text{EFOR} = \frac{\text{FOH} + \text{EFDH}}{\text{FOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EFDHRS}} \times 100\%$$

25. Equivalent Forced Outage Rate demand – EFORD (See Notes 1 and 2 at the end of this section.)

$$\text{EFORD} = \frac{\text{FOHd} + \text{EFDHd}}{\text{SH} + \text{FOHd}} \times 100\%$$

Where:  $\text{FOHd} = f \times \text{FOH}$

$\text{EFDHd} = (\text{EFDH} - \text{EFDHRS})$  if reserve shutdown events reported, or

$= (\text{fp} \times \text{EFDH})$  if no reserve shutdown events reported – an approximation.

$\text{fp} = (\text{SH} / \text{AH})$

NOTE: FOHd is the number of hours a unit was in a U1, U2, U3, or SF AND the unit would have operated had it been available. FOHd can be determined directly if periods of demand are recorded. Demand can be defined as the traditional demand for the generating unit for economic or reliable operation of the system, or it can be any other user-defined condition, such as specific weather condition, load level, or energy price. When FOHd is determined directly from recorded periods of demand, service hours (SH) in the above equation should include only those under the specified demand condition. If periods of demand are not recorded, FOHd may be estimated using the demand factor  $f$ . The demand factor is applicable to traditional demand for economic or reliable system operation.

$$f = \left( \frac{1}{r} + \frac{1}{T} \right) / \left( \frac{1}{r} + \frac{1}{T} + \frac{1}{D} \right)$$

$r$  = Average forced outage duration = (FOH) / (# of FO occurrences)  
 $D$  = Average demand time = (SH) / (# of unit actual starts)  
 $T$  = Average reserve shutdown time = (RSH) / (# of unit attempted starts)

26. Equivalent Planned Outage Rate – EPOR

$$\text{EPOR} = \frac{\text{POH} + \text{EPDH}}{\text{POH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EPDHRS}} \times 100\%$$

27. Equivalent Maintenance Outage Rate – EMOR

$$\text{EMOR} = \frac{\text{MOH} + \text{EMDH}}{\text{MOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EMDHRS}} \times 100\%$$

28. Equivalent Unplanned Outage Rate – EUOR

$$\text{EUOR} = \frac{\text{UOH} + \text{EUDH}}{\text{UOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EUDHRS}} \times 100\%$$

$$\text{EUOR} = \frac{\text{FOH} + \text{EFDH} + \text{MOH} + \text{EMDH}}{\text{FOH} + \text{MOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EFDHRS} + \text{EMDHRS}} \times 100\%$$

29. Average Run Time – ART

$$\text{ART} = \frac{\text{SH}}{\text{Actual Unit Starts}}$$

30. Starting Reliability – SR

$$SR = \frac{\text{Actual Unit Starts}}{\text{Attempted Unit Starts}} \times 100\%$$

**Mean Service Time to Outage:**

31a. Mean Service Time to Planned Outage – MSTPO

$$MSTPO = \frac{SH}{\text{Number of Planned Outages which occur from in-service state only}}$$

31b. Mean Service Time to Unplanned Outage – MSTUO

$$MSTUO = \frac{SH}{\text{Number of Unplanned Outages which occur from in-service state only}}$$

31c. Mean Service Time to Forced Outage – MSTFO

$$MSTFO = \frac{SH}{\text{Number of Forced Outages which occur from in-service state only}}$$

31d. Mean Service Time to Maintenance Outage – MSTMO

$$MSTMO = \frac{SH}{\text{Number of Maintenance Outages which occur from in-service state only}}$$

**Mean Outage Duration:**

32a. Mean Planned Outage Duration – MPOD

$$MPOD = \frac{\text{Planned Outage Hours which occur from in-service state only}}{\text{Number of Planned Outages which occur from in-service state only}}$$

32b. Mean Unplanned Outage Duration – MUOD

$$MUOD = \frac{\text{Unplanned Outage Hours which occur from in-service state only}}{\text{Number of Unplanned Outages which occur from in-service state only}}$$

32c. Mean Forced Outage Duration – MFOD

$$MFOD = \frac{\text{Forced Outage Hours which occur from in-service state only}}{\text{Number of Forced Outages which occur from in-service state only}}$$

32d. Mean Maintenance Outage Duration – MMOD

$$MMOD = \frac{\text{Maintenance Outage Hours which occur from in-service state only}}{\text{Number of Maintenance Outages which occur from in-service state only}}$$

## Unweighted (time-based) methods for calculating pooled (grouped) unit statistics

33. Planned Outage Factor – POF

$$\text{POF} = \frac{\Sigma \text{POH}}{\Sigma \text{PH}} \times 100\%$$

34. Unplanned Outage Factor – UOF

$$\text{UOF} = \frac{\Sigma (\text{FOH} + \text{MOH})}{\Sigma \text{PH}} \times 100\%$$

35. Forced Outage Factor – FOF

$$\text{FOF} = \frac{\Sigma \text{FOH}}{\Sigma \text{PH}} \times 100\%$$

36. Maintenance Outage Factor – MOF

$$\text{MOF} = \frac{\Sigma \text{MOH}}{\Sigma \text{PH}} \times 100\%$$

37. Scheduled Outage Factor – SOF

$$\text{SOF} = \frac{\Sigma (\text{POH} + \text{MOH})}{\Sigma \text{PH}} \times 100\%$$

38. Unavailability Factor – UF

$$\text{UF} = \frac{\Sigma (\text{POH} + \text{MOH} + \text{FOH})}{\Sigma \text{PH}} \times 100\%$$

39. Availability Factor – AF

$$\text{AF} = \frac{\Sigma \text{AH}}{\Sigma \text{PH}} \times 100\%$$

$$\text{AF} = \frac{\Sigma (\text{SH} + \text{RSH} + \text{Symchronous Condensing Hours} + \text{Pumping Hours})}{\Sigma \text{PH}} \times 100\%$$

40. Service Factor – SF

$$\text{SF} = \frac{\Sigma \text{SH}}{\Sigma \text{PH}} \times 100\%$$

41. Seasonal Derating Factor – SEDF

$$\text{SEDF} = \frac{\Sigma \text{ESEDH}}{\Sigma \text{PH}} \times 100\%$$

42. Unit Derating Factor – UDF

$$\text{UDF} = \frac{\Sigma (\text{EUDH} + \text{EPDH})}{\Sigma \text{PH}} \times 100\%$$

$$\text{UDF} = \frac{\Sigma (\text{EFDH} + \text{EMDH} + \text{EPDH})}{\Sigma \text{PH}} \times 100\%$$

43. Equivalent Unavailability Factor – EUF

$$\text{EUF} = \frac{\Sigma (\text{POH} + \text{UOH} + \text{EUDH} + \text{EPDH})}{\Sigma \text{PH}} \times 100\%$$

$$\text{EUF} = \frac{\Sigma (\text{SOH} + \text{FOH} + \text{ESDH} + \text{EFDH})}{\Sigma \text{PH}} \times 100\%$$

$$\text{EUF} = \frac{\Sigma (\text{POH} + \text{MOH} + \text{FOH} + \text{EFDH} + \text{EMDH} + \text{EPDH})}{\Sigma \text{PH}} \times 100\%$$

44. Equivalent Availability Factor – EAF

$$\text{EAF} = \frac{\Sigma (\text{AH} - \text{EUDH} - \text{EPDH} - \text{ESEDH})}{\Sigma \text{PH}} \times 100\%$$

$$\text{EAF} = \frac{\Sigma (\text{AH} - \text{EFDH} - \text{EMDH} - \text{EPDH} - \text{ESEDH})}{\Sigma \text{PH}} \times 100\%$$

45. Gross Capacity Factor – GCF \*

$$\text{GCF} = \frac{\Sigma (\text{Gross Actual Generation})}{\Sigma (\text{GMC} \times \text{PH})} \times 100\%$$

46. Net Capacity Factor – NCF \*

$$\text{NCF} = \frac{\Sigma (\text{Net Actual Generation})}{\Sigma (\text{NMC} \times \text{PH})} \times 100\%$$

47. Gross Output Factor – GOF \*

$$\text{GOF} = \frac{\Sigma (\text{Gross Actual Generation})}{\Sigma (\text{GMC} \times \text{SH})} \times 100\%$$

48. Net Output Factor – NOF \*

$$\text{NOF} = \frac{\Sigma (\text{Net Actual Generation})}{\Sigma (\text{NMC} \times \text{SH})} \times 100\%$$

49. Equivalent Maintenance Outage Factor – EMOF

$$\text{EMOF} = \frac{\Sigma (\text{MOH} + \text{EMDH})}{\Sigma \text{PH}} \times 100\%$$

\*These are “energy term” (GCF, NCF, GOF, NOF) statistics, and are inherently energy-weighted. These equations are the same as IEEE-762 9.12 – 9.15. When calculating for a group of units (or a unit that has a varying capacity value over time), do not average the capacities shown in the denominators. Follow the equations.

50. Equivalent Planned Outage Factor – EPOF

$$\text{EPOF} = \frac{\Sigma (\text{POH} + \text{EPDH})}{\Sigma \text{PH}} \times 100\%$$

51. Equivalent Forced Outage Factor – EFOF

$$\text{EFOF} = \frac{\Sigma (\text{FOH} + \text{EFDH})}{\Sigma \text{PH}} \times 100\%$$

52. Equivalent Scheduled Outage Factor – ESOF

$$\text{ESOF} = \frac{\Sigma (\text{SOH} + \text{ESDH})}{\Sigma \text{PH}} \times 100\%$$

$$\text{ESOF} = \frac{\Sigma (\text{MOH} + \text{POH} + \text{EMDH} + \text{EPDH})}{\Sigma \text{PH}} \times 100\%$$

53. Equivalent Unplanned Outage Factor – EUOF

$$\text{EUOF} = \frac{\Sigma (\text{UOH} + \text{EUDH})}{\Sigma \text{PH}} \times 100\%$$

$$\text{EUOF} = \frac{\Sigma (\text{MOH} + \text{FOH} + \text{EMDH} + \text{EFDH})}{\Sigma \text{PH}} \times 100\%$$

54. Forced Outage Rate – FOR

$$\text{FOR} = \frac{\Sigma \text{FOH}}{\Sigma (\text{FOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours})} \times 100\%$$

55. Forced Outage Rate demand – FORd (See Notes 1 and 2 at the end of this section.)

$$\text{FORd} = \frac{\Sigma \text{FOHd}}{\Sigma (\text{FOHd} + \text{SH})} \times 100\%$$

Where:  $\text{FOHd} = f \times \text{FOH}$

NOTE: FOHd is the number of hours a unit was in a U1, U2, U3, or SF AND the unit would have operated had it been available. FOHd can be determined directly if periods of demand are recorded. Demand can be defined as the traditional demand for the generating unit for economic or reliable operation of the system, or it can be any other user-defined condition, such as specific weather condition, load level, or energy price. When FOHd is determined directly from recorded periods of demand, service hours (SH) in the above equation should include only those under the specified demand condition. If periods of demand are not recorded, FOHd may be estimated using the demand factor  $f$ . The demand factor is applicable to traditional demand for economic or reliable system operation.

$$f = \left( \frac{1}{r} + \frac{1}{T} \right) / \left( \frac{1}{r} + \frac{1}{T} + \frac{1}{D} \right)$$

$r$  = Average forced outage duration =  $(\text{FOH}) / (\# \text{ of FO occurrences})$   
 $D$  = Average demand time =  $(\text{SH}) / (\# \text{ of unit actual starts})$   
 $T$  = Average reserve shutdown time =  $(\text{RSH}) / (\# \text{ of unit attempted starts})$

56. Equivalent Forced Outage Rate – EFOR

$$\text{EFOR} = \frac{\Sigma (\text{FOH} + \text{EFDH})}{\Sigma (\text{FOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EFDHRS})} \times 100\%$$

57. Equivalent Forced Outage Rate demand – EFORD (See Notes 1 and 2 at the end of this section.)

$$\text{EFORD} = \frac{\Sigma (\text{FOHd} + \text{EFDHd})}{\Sigma (\text{SH} + \text{FOHd})} \times 100\%$$

Where: FOHd =  $f \times \text{FOH}$

EFDHd = (EFDH – EFDHRS) if reserve shutdown events reported, or  
 = ( $f_p \times \text{EFDH}$ ) if no reserve shutdown events reported – an approximation.  
 $f_p = (\text{SH}/\text{AH})$

NOTE: FOHd is the number of hours a unit was in a U1, U2, U3, or SF AND the unit would have operated had it been available. FOHd can be determined directly if periods of demand are recorded. Demand can be defined as the traditional demand for the generating unit for economic or reliable operation of the system, or it can be any other user-defined condition, such as specific weather condition, load level, or energy price. When FOHd is determined directly from recorded periods of demand, service hours (SH) in the above equation should include only those under the specified demand condition. If periods of demand are not recorded, FOHd may be estimated using the demand factor  $f$ . The demand factor is applicable to traditional demand for economic or reliable system operation.

$$f = \left( \frac{1}{r} + \frac{1}{T} \right) / \left( \frac{1}{r} + \frac{1}{T} + \frac{1}{D} \right)$$

$r$ =Average forced outage duration = (FOH) / (# of FO occurrences)  
 $D$ =Average demand time = (SH) / (# of unit actual starts)  
 $T$ =Average reserve shutdown time = (RSH) / (# of unit attempted starts)

58. Equivalent Planned Outage Rate – EPOR

$$\text{EPOR} = \frac{\Sigma (\text{POH} + \text{EPDH})}{\Sigma (\text{POH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EPDHRS})} \times 100\%$$

59. Equivalent Maintenance Outage Rate – EMOR

$$\text{EMOR} = \frac{\Sigma (\text{MOH} + \text{EMDH})}{\Sigma (\text{MOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EMDHRS})} \times 100\%$$

60. Equivalent Unplanned Outage Rate – EUOR

$$\text{EUOR} = \frac{\Sigma (\text{UOH} + \text{EUDH})}{\Sigma (\text{UOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EUDHRS})} \times 100\%$$

$$\text{EUOR} = \frac{\Sigma (\text{FOH} + \text{EFDH} + \text{MOH} + \text{EMDH})}{\Sigma (\text{FOH} + \text{MOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EFDHRS} + \text{EMDHRS})} \times 100\%$$

61. Average Run Time – ART

$$\text{ART} = \frac{\Sigma \text{SH}}{\Sigma \text{Actual Unit Starts}}$$

62. Starting Reliability – SR

$$\text{SR} = \frac{\Sigma \text{Actual Unit Starts}}{\Sigma \text{Attempted Unit Starts}} \times 100\%$$

### Mean Service Time to Outage:

63a. Mean Service Time to Planned Outage – MSTPO

$$\text{MSTPO} = \frac{\Sigma \text{SH}}{\Sigma \text{Number of Planned Outages which occur from in-service state only}}$$

63b. Mean Service Time to Unplanned Outage – MSTUO

$$\text{MSTUO} = \frac{\Sigma \text{SH}}{\Sigma \text{Number of Unplanned Outages which occur from in-service state only}}$$

63c. Mean Service Time to Forced Outage – MSTFO

$$\text{MSTFO} = \frac{\Sigma \text{SH}}{\Sigma \text{Number of Forced Outages which occur from in-service state only}}$$

63d. Mean Service Time to Maintenance Outage – MSTMO

$$\text{MSTMO} = \frac{\Sigma \text{SH}}{\Sigma \text{Number of Maintenance Outages which occur from in-service state only}}$$

### Mean Outage Duration:

64a. Mean Planned Outage Duration – MPOD

$$\text{MPOD} = \frac{\Sigma \text{Planned Outage Hours which occur from in-service state only}}{\Sigma \text{Number of Planned Outages which occur from in-service state only}}$$

64b. Mean Unplanned Outage Duration – MUOD

$$\text{MUOD} = \frac{\Sigma \text{Unplanned Outage Hours which occur from in-service state only}}{\Sigma \text{Number of Unplanned Outages which occur from in-service state only}}$$

64c. Mean Forced Outage Duration – MFOD

$$\text{MFOD} = \frac{\Sigma \text{Forced Outage Hours which occur from in-service state only}}{\Sigma \text{Number of Forced Outages which occur from in-service state only}}$$

64d. Mean Maintenance Outage Duration – MMOD

$$\text{MMOD} = \frac{\Sigma \text{Maintenance Outage Hours which occur from in-service state only}}{\Sigma \text{Number of Maintenance Outages which occur from in-service state only}}$$

## Weighted (capacity-based) methods for calculating pooled (grouped) unit statistics

65. Weighted Forced Outage Factor – WFOF

$$\text{WFOF} = \frac{\Sigma (\text{FOH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

66. Weighted Maintenance Outage Factor – WMOF

$$\text{WMOF} = \frac{\Sigma (\text{MOH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

67. Weighted Planned Outage Factor – WPOF

$$\text{WPOF} = \frac{\Sigma (\text{POH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

68. Weighted Unplanned Outage Factor – WUOF

$$\text{WUOF} = \frac{\Sigma (\text{UOH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WUOF} = \frac{\Sigma ((\text{FOH} + \text{MOH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

69. Weighted Scheduled Outage Factor – WSOF

$$\text{WSOF} = \frac{\Sigma (\text{SOH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WSOF} = \frac{\Sigma ((\text{POH} + \text{MOH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

70. Weighted Unavailability Factor – WUF

$$\text{WUF} = \frac{\Sigma ((\text{FOH} + \text{MOH} + \text{POH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

71. Weighted Availability Factor – WAF

$$\text{WAF} = \frac{\Sigma (\text{AH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

72. Weighted Service Factor – WSF

$$\text{WSF} = \frac{\Sigma (\text{SH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

73. Weighted Seasonal Derating Factor – WSEDF

$$\text{WSEDF} = \frac{\Sigma (\text{ESEDH} \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$



74. Weighted Unit Derating Factor – WUDF

$$\text{WUDF} = \frac{\Sigma ((\text{EUDH} + \text{EPDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WUDF} = \frac{\Sigma ((\text{EFDH} + \text{EMDH} + \text{EPDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

75. Weighted Equivalent Unavailability Factor – WEUF

$$\text{WEUF} = \frac{\Sigma ((\text{POH} + \text{UOH} + \text{EUDH} + \text{EPDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WEUF} = \frac{\Sigma ((\text{SOH} + \text{FOH} + \text{ESDH} + \text{EFDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WEUF} = \frac{\Sigma ((\text{POH} + \text{MOH} + \text{FOH} + \text{EFDH} + \text{EMDH} + \text{EPDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

76. Weighted Equivalent Availability Factor – WEAFA

$$\text{WEAF} = \frac{\Sigma ((\text{AH} - \text{EUDH} - \text{EPDH} - \text{ESEDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WEAF} = \frac{\Sigma ((\text{AH} - \text{EFDH} - \text{EMDH} - \text{EPDH} - \text{ESEDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

77. Gross Capacity Factor – GCF \*

$$\text{GCF} = \frac{\Sigma (\text{Gross Actual Generation})}{\Sigma (\text{GMC} \times \text{PH})} \times 100\%$$

78. Net Capacity Factor – NCF \*

$$\text{NCF} = \frac{\Sigma (\text{Net Actual Generation})}{\Sigma (\text{NMC} \times \text{PH})} \times 100\%$$

79. Gross Output Factor – GOF \*

$$\text{GOF} = \frac{\Sigma (\text{Gross Actual Generation})}{\Sigma (\text{GMC} \times \text{SH})} \times 100\%$$

80. Net Output Factor – NOF \*

$$\text{NOF} = \frac{\Sigma (\text{Net Actual Generation})}{\Sigma (\text{NMC} \times \text{SH})} \times 100\%$$

\*These are “energy term” (GCF, NCF, GOF, NOF) statistics, and are inherently energy-weighted. These equations are the same as IEEE-762 10.12 – 10.15. When calculating for a group of units (or a unit that has a varying capacity value over time), do not average the capacities shown in the denominators. Follow the equations.

81. Weighted Equivalent Maintenance Outage Factor – WEMOF

$$\text{WEMOF} = \frac{\Sigma ((\text{MOH} + \text{EMDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

82. Weighted Equivalent Planned Outage Factor – WEPOF

$$\text{WEPOF} = \frac{\Sigma ((\text{POH} + \text{EPDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

83. Weighted Equivalent Forced Outage Factor – WEFOF

$$\text{WEFOF} = \frac{\Sigma ((\text{FOH} + \text{EFDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

84. Weighted Equivalent Scheduled Outage Factor – WESOF

$$\text{WESOF} = \frac{\Sigma ((\text{SOH} + \text{ESDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WESOF} = \frac{\Sigma ((\text{MOH} + \text{POH} + \text{EMDH} + \text{EPDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

85. Weighted Equivalent Unplanned Outage Factor – WEUOF

$$\text{WEUOF} = \frac{\Sigma ((\text{UOH} + \text{EUDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

$$\text{WEUOF} = \frac{\Sigma ((\text{MOH} + \text{FOH} + \text{EFDH} + \text{EMDH}) \times \text{NMC})}{\Sigma (\text{PH} \times \text{NMC})} \times 100\%$$

(NOTE: This is identical to the Weighted Unit Capability Loss Factor except this equation includes all events, including those outside plant management control.)

86. Weighted Forced Outage Rate – WFOR

$$\text{WFOR} = \frac{\Sigma (\text{FOH} \times \text{NMC})}{\Sigma ((\text{FOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours}) \times \text{NMC})} \times 100\%$$

87. Weighted Forced Outage Rate demand – WFORd (See Notes 1 and 2 at the end of this section.)

$$\text{WFORd} = \frac{\Sigma (\text{FOHd} \times \text{NMC})}{\Sigma ((\text{FOHd} + \text{SH}) \times \text{NMC})} \times 100\%$$

Where: FOHd =  $f \times \text{FOH}$

NOTE: FOHd is the number of hours a unit was in a U1, U2, U3, or SF AND the unit would have operated had it been available. FOHd can be determined directly if periods of demand are recorded. Demand can be defined as the traditional demand for the generating unit for economic or reliable operation of the system, or it can be any other user-defined condition, such as specific weather condition, load level, or energy price. When FOHd is determined directly from recorded periods of demand, service hours (SH) in the above equation should include only those under the specified demand condition. If periods of demand are not recorded, FOHd may be estimated

using the demand factor  $f$ . The demand factor is applicable to traditional demand for economic or reliable system operation.

$$f = \left( \frac{1}{r} + \frac{1}{T} \right) / \left( \frac{1}{r} + \frac{1}{T} + \frac{1}{D} \right)$$

$r$  = Average forced outage duration = (FOH) / (# of FO occurrences)  
 $D$  = Average demand time = (SH) / (# of unit actual starts)  
 $T$  = Average reserve shutdown time = (RSH) / (# of unit attempted starts)

88. Weighted Equivalent Forced Outage Rate – WEFOR

$$\text{WEFOR} = \frac{\Sigma ((\text{FOH} + \text{EFDH}) \times \text{NMC})}{\Sigma ((\text{FOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EFDHRS}) \times \text{NMC})} \times 100\%$$

89. Weighted Equivalent Forced Outage Rate demand – WEFORd (See Notes 1 and 2 at the end of this section.)

$$\text{WEFORd} = \frac{\Sigma ((\text{FOHd} + \text{EFDHd}) \times \text{NMC})}{\Sigma ((\text{SH} + \text{FOHd}) \times \text{NMC})} \times 100\%$$

Where: FOHd =  $f \times \text{FOH}$

EFDHd = (EFDH – EFDHRS) if reserve shutdown events reported, or

= (fp  $\times$  EFDH) if no reserve shutdown events reported – an approximation.

fp = (SH/AH)

NOTE: FOHd is the number of hours a unit was in a U1, U2, U3, or SF AND the unit would have operated had it been available. FOHd can be determined directly if periods of demand are recorded. Demand can be defined as the traditional demand for the generating unit for economic or reliable operation of the system, or it can be any other user-defined condition, such as specific weather condition, load level, or energy price. When FOHd is determined directly from recorded periods of demand, service hours (SH) in the above equation should include only those under the specified demand condition. If periods of demand are not recorded, FOHd may be estimated using the demand factor  $f$ . The demand factor is applicable to traditional demand for economic or reliable system operation.

$$f = \left( \frac{1}{r} + \frac{1}{T} \right) / \left( \frac{1}{r} + \frac{1}{T} + \frac{1}{D} \right)$$

$r$  = Average forced outage duration = (FOH) / (# of FO occurrences)  
 $D$  = Average demand time = (SH) / (# of unit actual starts)  
 $T$  = Average reserve shutdown time = (RSH) / (# of unit attempted starts)

90. Weighted Equivalent Planned Outage Rate – WEPOR

$$\text{WEPOR} = \frac{\Sigma ((\text{POH} + \text{EPDH}) \times \text{NMC})}{\Sigma ((\text{POH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EPDHRS}) \times \text{NMC})} \times 100\%$$

91. Weighted Equivalent Maintenance Outage Rate – WEMOR

$$\text{WEMOR} = \frac{\Sigma ((\text{MOH} + \text{EMDH}) \times \text{NMC})}{\Sigma ((\text{MOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EMDHRS}) \times \text{NMC})} \times 100\%$$

92. Weighted Equivalent Unplanned Outage Rate – WEUOR

$$\text{WEUOR} = \frac{\Sigma ((\text{UOH} + \text{EUDH}) \times \text{NMC})}{\Sigma ((\text{UOH} + \text{SH} + \text{Synchronous Condensing Hours} + \text{Pumping Hours} + \text{EUDHRS}) \times \text{NMC})} \times 100\%$$

**Mean Service Time to Outage:**

93a. Weighted Mean Service Time to Planned Outage – MSTPO

$$\text{WMSTPO} = \frac{\Sigma(\text{SH} \times \text{NMC})}{\Sigma(\text{Number of Planned Outages which occur from in-service state only} \times \text{NMC})}$$

93b. Weighted Mean Service Time to Unplanned Outage – MSTUO

$$\text{WMSTUO} = \frac{\Sigma(\text{SH} \times \text{NMC})}{\Sigma(\text{Number of Unplanned Outages which occur from in-service state only} \times \text{NMC})}$$

93c. Weighted Mean Service Time to Forced Outage – MSTFO

$$\text{WMSTFO} = \frac{\Sigma(\text{SH} \times \text{NMC})}{\Sigma(\text{Number of Forced Outages which occur from in-service state only} \times \text{NMC})}$$

93d. Weighted Mean Service Time to Maintenance Outage – MSTMO

$$\text{WMSTMO} = \frac{\Sigma(\text{SH} \times \text{NMC})}{\Sigma(\text{Number of Maintenance Outages which occur from in-service state only} \times \text{NMC})}$$

**Mean Outage Duration:**

94a. Weighted Mean Planned Outage Duration – MPOD

$$\text{WMPOD} = \frac{\Sigma(\text{Planned Outage Hours which occur from in-service state only} \times \text{NMC})}{\Sigma(\text{Number of Planned Outages which occur from in-service state only} \times \text{NMC})}$$

94b. Weighted Mean Unplanned Outage Duration – MUOD

$$\text{WMUOD} = \frac{\Sigma(\text{Unplanned Outage Hours which occur from in-service state only} \times \text{NMC})}{\Sigma(\text{Number of Unplanned Outages which occur from in-service state only} \times \text{NMC})}$$

94c. Weighted Mean Forced Outage Duration – MFOD

$$\text{WMFOD} = \frac{\Sigma(\text{Forced Outage Hours which occur from in-service state only} \times \text{NMC})}{\Sigma(\text{Number of Forced Outages which occur from in-service state only} \times \text{NMC})}$$

94d. Weighted Mean Maintenance Outage Duration – MMOD

$$\text{WMMOD} = \frac{\Sigma(\text{Maintenance Outage Hours which occur from in-service state only} \times \text{NMC})}{\Sigma(\text{Number of Maintenance Outages which occur from in-service state only} \times \text{NMC})}$$

## Unweighted (time-based) methods for calculating statistics excluding problems outside management control for single unit and pooled unit calculations

**Note:** The equations for calculating unweighted (time-based) performance excluding outside management control (OMC) events are identical to those shown earlier in this Appendix. The only differences are that the events using OMC cause codes are treated as non-curtailling events when analyzing the event records during the time of evaluation. In other words, the OMC events are ignored and not used in the calculations.

The list of OMC cause codes, conditions and method for removing OMC events from the calculations is described in Appendix K.

95.	W/O OMC Planned Outage Factor – XPOF	(See equations 1 and 33.)
96.	W/O OMC Unplanned Outage Factor – XUOF	(See equations 2 and 34.)
97.	W/O OMC Forced Outage Factor – XFOF	(See equations 3 and 35.)
98.	W/O OMC Maintenance Outage Factor – XMOF	(See equations 4 and 36.)
99.	W/O OMC Scheduled Outage Factor – XSOF	(See equations 5 and 37.)
100.	W/O OMC Unavailability Factor – XUF	(See equations 6 and 38.)
101.	W/O OMC Availability Factor – XAF	(See equations 7 and 39.)
102.	W/O OMC Service Factor – XSF	(See equations 8 and 40.)
103.	W/O OMC Unit Derating Factor – XUDF	(See equations 10 and 42.)
104.	W/O OMC Equivalent Unavailability Factor – XEUF	(See equations 11 and 43.)
105.	W/O OMC Equivalent Availability Factor – XEAF	(See equations 12 and 44.)
106.	W/O OMC Equivalent Maintenance Outage Factor – XEMOF	(See equations 17 and 49.)
107.	W/O OMC Equivalent Planned Outage Factor – XEPOF	(See equations 18 and 50.)
108.	W/O OMC Equivalent Forced Outage Factor – XEFOF	(See equations 19 and 51.)
109.	W/O OMC Equivalent Scheduled Outage Factor – XESOF	(See equations 20 and 52.)
110.	W/O OMC Equivalent Unplanned Outage Factor – XEUOF	(See equations 21 and 53.)
111.	W/O OMC Forced Outage Rate – XFOR	(See equations 22 and 54.)
112.	W/O OMC Forced Outage Rate Demand – XFORD	(See equations 23 and 55.)
113.	W/O OMC Equivalent Forced Outage Rate – XEFOR	(See equations 24 and 56.)
114.	W/O OMC Equivalent Forced Outage Rate demand – XEFORD	(See equations 25 and 57.)
115.	W/O OMC Equivalent Planned Outage Rate – XEPOR	(See equations 26 and 58.)
116.	W/O OMC Equivalent Maintenance Outage Rate – XEMOR	(See equations 27 and 59.)
117.	W/O OMC Equivalent Unplanned Outage Rate – XEUOR	(See equations 28 and 60.)
118.	W/O OMC Average Run Time – XART	(See equations 29 and 61.)

Note: Unweighted single unit equations 9 (SEDF), 13-16 (GCF, NCF, GOF, NOF), 30-32 (SR, Mean Service Time to Outage, Mean Outage Duration), and Unweighted pooled unit equations 41 (SEDF), and 45-48 (GCF, NCF, GOF, NOF) do not have W/O OMC versions.

## Weighted (capacity-based) methods for calculating statistics excluding problems outside management control for pooled unit statistics

**Note:** The equations for calculating unweighted (time-based) performance excluding outside management control (OMC) events are identical to those shown earlier in this Appendix. The only differences are that the events using OMC cause codes are treated as non-curtailling events when analyzing the event records during the time of evaluation. In other words, the OMC events are ignored and not used in the calculations.

The list of OMC cause codes, conditions and method for removing OMC events from the calculations is described in Appendix K.

119.	W/O OMC Weighted Forced Outage Factor – XWFOF	(See equation 65.)
120.	W/O OMC Weighted Maintenance Outage Factor – XWMOF	(See equation 66.)
121.	W/O OMC Weighted Planned Outage Factor – XWPOF	(See equation 67.)
122.	W/O OMC Weighted Unplanned Outage Factor – XWUOF	(See equation 68.)
123.	W/O OMC Weighted Scheduled Outage Factor – XWSOF	(See equation 69.)
124.	W/O OMC Weighted Unavailability Factor – XWUF	(See equation 70.)
125.	W/O OMC Weighted Availability Factor – XWAF	(See equation 71.)
126.	W/O OMC Weighted Service Factor – XWSF	(See equation 72.)
127.	W/O OMC Weighted Unit Derating Factor – XWUDF	(See equation 74.)
128.	W/O OMC Weighted Equivalent Unavailability Factor – XWEUF	(See equation 75.)
129.	W/O OMC Weighted Equivalent Availability Factor – XWEAF	(See equation 76.)
	(Also known as the “Unit Capability Factor” (UCF) in Europe and other parts of the world.)	
130.	W/O OMC Weighted Equivalent Maintenance Outage Factor – XWEMOF	(See equation 81.)
131.	W/O OMC Weighted Equivalent Planned Outage Factor – XWEPOF	(See equation 82.)
132.	W/O OMC Weighted Equivalent Forced Outage Factor – XWEFOF	(See equation 83.)
133.	W/O OMC Weighted Equivalent Scheduled Outage Factor – XWESOF	(See equation 84.)
134.	W/O OMC Weighted Equivalent Unplanned Outage Factor – XWEUOF	(See equation 85.)
	(Also known as the “Unit Capability Loss Factor” (UCLF) in Europe and other parts of the world.)	
135.	W/O OMC Weighted Forced Outage Rate – XWFOR	(See equation 86.)
136.	W/O OMC Weighted Forced Outage Rate demand – XWFORD	(See equation 87.)
137.	W/O OMC Weighted Equivalent Forced Outage Rate – XWEFOR	(See equation 88.)
138.	W/O OMC Weighted Equivalent Forced Outage Rate demand – XWEFORD	(See equation 89.)
139.	W/O OMC Weighted Equivalent Planned Outage Rate – XWEPOR	(See equation 90.)
140.	W/O OMC Weighted Equivalent Maintenance Outage Rate – XWEMOR	(See equation 91.)
141.	W/O OMC Weighted Equivalent Unplanned Outage Rate – XWEUOR	(See equation 92.)

Note: Weighted grouped unit equations 73 (WSEDF), 77-80 (GCF, NCF, GOF, NOF) do not have W/O OMC versions.

## Run of River Hydro Equations Using Amplification Code WC (Water Condition)

The Run of River hydro equations take into account outages during time periods where water conditions prohibit the unit from operating. The unit is available during these times and can be put into various outage states while water conditions are unfavorable for operation. The outages are tracked by using the amplification code WC (Water Condition). Several of the time and energy factors used by indexes are modified for these equations. See the Hydro White Paper for more details.

There are two types of Run of River hydro equations:

1) Resource: All applicable equations 1 – 141 that ignore the WC amplification code and all factors are treated normally and calculation results are unchanged.

2) Equipment: All applicable equations 1 – 141 in which U3, MO, and PO outage events with amplification code WC are treated as available hours. The definitions of AH, FOH, MOH, and POH in equations 1 – 141 are replaced with the definitions for  $AH_{WC}$ ,  $FOH_{WC}$ ,  $MOH_{WC}$ , and  $POH_{WC}$  respectively, which account for water conditions. Three new terms  $U3_{WC}$ ,  $MO_{WC}$ , and  $PO_{WC}$  are defined.

## Summary of Run of River Hydro Time and Energy Factors Used by Indexes

4.	Available Hours – $AH_{WC}$	Sum of all Service Hours (SH) + Reserve Shutdown Hours (RSH) + Pumping Hours + Synchronous Condensing Hours + $U3_{WC}$ + $MO_{WC}$ + $PO_{WC}$
5.	Planned Outage Hours - $POH_{WC}$	Sum of all hours experienced during Planned Outages (PO) + Planned Outage Extensions (PE) of any Planned Outages (PO) - $PO_{WC}$
	Planned Outage Hours - $PO_{WC}$	Sum of all hours experienced during Planned Outages (PO) during water conditions (amplification code WC)
7.	Forced Outage Hours – $FOH_{WC}$	Sum of all hours experienced during Forced Outages (U1, U2, and U3) + Startup Failures (SF) - $U3_{WC}$
	Forced Outage Hours – $U3_{WC}$	Sum of all hours experienced during Forced Outages of type U3 during water conditions (amplification code WC)
8.	Maintenance Outage Hours – $MOH_{WC}$	Sum of all hours experienced during Maintenance Outages (MO) + Maintenance Outage Extensions (ME) of any Maintenance Outages (MO) - $MO_{WC}$
	Maintenance Outage Hours – $MO_{WC}$	Sum of all hours experienced during Maintenance Outages (MO) during water conditions (amplification code WC)

## Sample Equations

The Availability Factor (AF) is the percentage of period hours that a unit is available for generation.

$$AF = \frac{AH}{PH} \times 100\%$$

The Availability Factor of a hydro unit from the resource point of view does not account for water conditions and when the AH term is expanded it is the normal equation as expected.

$$AF = AF_{\text{Resource}} = \frac{RSH + SH + \text{Sync Cond Hours} + \text{Pumping Hours}}{PH} \times 100\%$$

The Availability Factor of a hydro unit from the equipment point of view accounts for water conditions and when the AH term is expanded it is modified to account for the outages marked by amplification code WC.

$$AF = \frac{AH_{WC}}{PH} \times 100\%$$

$$HAF = AF_{\text{Equipment}} = \frac{RSH + SH + \text{Sync Cond hours} + \text{Pumping Hours} + U3_{WC} + PO_{WC} + MO_{WC}}{PH} \times 100\%$$

The Unplanned Outage Factor (UOF) is the percentage of period hours that a unit is on unplanned outage.

$$UOF = \frac{UOH}{PH} \times 100\%$$

The Unplanned Outage Factor of a hydro unit from the resource point of view does not account for water conditions and when the UOH term is expanded it is the normal equation as expected.

$$UOF = UOF_{\text{Resource}} = \frac{FOH + MOH}{PH} \times 100\%$$

The Unplanned Outage Factor of a hydro unit from the equipment point of view accounts for water conditions and when the UOH term is expanded it is modified to account for the outages marked by amplification code WC.

$$UOF = \frac{UOH_{WC}}{PH} \times 100\%$$

$$HUOF = UOF_{\text{Equipment}} = \frac{FOH_{WC} + MOH_{WC}}{PH} \times 100\%$$

A capital "H" prefixed to the front of the factor/rate acronym will designate it as a hydro equipment equation that takes water conditions (WC) into account.

All other applicable equations are to be treated in like manner and are not listed in this appendix to save space.



## Note #1 for Appendix F

### INTRODUCTION TO NOTE #1:

The information below comes from IEEE 762 Annex F. This section reviews several different methods for pooling EFOR<sub>d</sub> only. Because of the nature of this equation, it can be pooled in several different methods as shown below.

**PLEASE NOTE THAT after much consideration, NERC-GADS will use Method 2 in all its EFOR<sub>d</sub> calculations.** The reason for method 2 is:

- Consistency – all other GADS equations sum hours in both the denominator and numerator before division.
- Allow calculations of smaller groups. By allowing sums, smaller groups of units can be used to calculate EFOR<sub>d</sub> without experiencing the divide by zero problem (see Note #2 for Appendix F).

## FROM IEEE 762, ANNEX F: EFOR<sub>d</sub> Pooling Sample

A comparison of three EFOR<sub>d</sub> pooling methodologies.

### **Method (I):** Pooled individual Unit Demand Studies

This method can give more weight to individual units with extreme EFOR<sub>d</sub> that have very few service hours, but with longer study time periods, the difference between the results of Methods I and II should be less.

### **Method (II):** Group Demand Studies

This method may be more applicable in studying group statistics on units with known similar demand patterns, especially for forecasting and modeling. By calculating the f-factors over the group's total FOH, SH, RSH, and starts, the f-factor is "smoothed" and not subject to be unduly influenced by an one or more single units statistics that may have very high or very low hours or starts.

**Method (III):** Capacity Weighted Average of individually calculated EFOR<sub>d</sub> used by PJM to calculate pool average "unforced capacity" values for capacity market purposes.

In order to clearly demonstrate how these methods are used, two sets of comparison will be needed – the first uses the unweighted, time-based calculations as shown in Appendix F. The second will use a weighted version of these pooling methods.

### **Time-Based Pooling**

This comparison of the three (3) pooling methodologies is based on the sample data and calculations found in the following two tables. [Table 1](#) shows the raw data reported by 5 steam turbine generating units. [Table 2](#) shows the interim values of the calculations used to produce the individual EFOR<sub>d</sub> for each unit.

**Table 1: Raw Data Used as a Sample**

Unit	Capacity (MW)	SH	RSH	AH	Actual Starts	Attempted Starts	EFDH	FOH	FO Events
48	55	4556	1963	6519	31	31	110.51	407	5
49	57	4856	2063	6919	34	34	146.99	773	12
50	60	6460	516	6976	17	18	131.03	340	14
51	53	3942	3694	7636	36	36	19.92	504	11
52	55	6904	62	6966	14	16	35.81	138	12
<b>Total</b>	<b>280</b>	<b>26718</b>	<b>8298</b>	<b>35016</b>	<b>132</b>	<b>135</b>	<b>444.26</b>	<b>2162</b>	<b>54</b>

**Table 2: Calculated Values Used in EFORD Formula**

Unit	1/r	1/T	1/D	f	f x FOH	fp	fp x EFDH	EFORD x MW	EFORD
48	0.0123	0.0158	0.0068	0.8049	327.608	0.6989	77.233	4.5594	8.29%
49	0.0155	0.0165	0.0070	0.8205	634.247	0.7018	103.163	7.6558	13.43%
50	0.0412	0.0349	0.0026	0.9666	328.630	0.9260	121.338	3.9770	6.63%
51	0.0218	0.0097	0.0091	0.7756	390.920	0.5162	10.283	4.9075	9.26%
52	0.0870	0.2581	0.0020	0.9942	137.194	0.9911	35.491	1.3489	2.45%
Method 1 Summed					1818.598		347.51		7.59%
Method 2 Calculated from reported totals	0.0250	0.0163	0.0049	0.8930	1930.734	0.763	338.98		7.92%
Method 3 Summed								22.4485	8.02%

Using this data, the 3 pooling methods can be shown as follows – Note that methods 1 and 2 are unweighted, time-based calculations.

- **Method 1** uses the sums of SH and the calculated values (f x FOH), (fp x EFDH) giving a pooled EFORD of 7.59%.

$$\frac{(1818.598 + 347.51)}{(26718 + 1818.598)} = 7.59\%$$

- **Method 2** uses the sums of the reported data to represent the average unit and then calculates the pooled EFORD to be 7.92%.

$$\frac{(1930.734 + 338.98)}{(26718 + 1930.734)} = 7.92\%$$

- **Method 3** weights the individual EFORD values with the unit capacity  $\Sigma$  (EFORD x MW) and uses the total capacity ( $\Sigma$  MW) to calculate a numeric average EFORD as 8.02%.

$$\frac{22.4485}{280} = 8.02\%$$

## Weighted Pooling

This method weights all time values by the Net Max Capacity of the individual unit. The raw data is the same as in the first example. Here [Table 3](#) is added to show the weighted values used in the calculations.

Unit	wSH	wFOH	wEFDH	f	wFOHd	fp	wEFDHd	wEFORD
48	250580	22385	6078.05	0.8049	18018.42	0.69888	4247.83	8.29%
49	276792	44061	8378.43	0.8205	36152.06	0.701937	5880.28	13.43%
50	387600	20400	7861.80	0.9666	19717.79	0.925767	7280.28	6.63%
51	208926	26712	1055.76	0.7756	20718.75	0.516306	545.024	9.26%
52	379720	7590	1969.55	0.9942	7545.65	0.990815	1952.02	2.45%
Method 1 Summed	1503618				102152.67		19905.43	7.60%
Method 2 Calculated from reported totals	1503618	121148	25343.59	0.893	108188.97	0.763	19337.73	7.91%
Average wEFORD								8.01%

Weighted values in Table 3 are denoted with preceding w to indicate that the value has been weighted by its NMC. Below we substitute the weighted value for the expanded multiplication – wEFORD in place of (FORd x NMC)

- Method 1** uses the weighted sums of wSH = SH x NMC, wFOHd = f x FOH x NMC, and wEFDHd = fp x EFDH x NMC, giving a pooled wEFORD of 7.60%.

$$\frac{\Sigma(\text{wFOHd} + \text{wEFDHd})}{\text{wSH} + \Sigma(\text{wFOHd})} = \text{wEFORD (pooled)}$$

$$\frac{(102152.67 + 19905.43)}{(1503618 + 102152.67)} = 7.60\%$$

- Method 2** uses the sums of the weighted reported data to represent the weighted average unit and then calculates the pooled EFORD to be 7.91%

$$\frac{(\text{f} \times \Sigma \text{wFOH}) + (\text{fp} \times \Sigma \text{wEFDH})}{\Sigma \text{wSH} + (\text{f} \times \Sigma \text{wFOH})} = \text{wEFORD (pooled)}$$

$$\frac{(0.893 \times 121148) + (0.763 \times 25343.59)}{1503618 + (0.893 \times 121148)} = 7.91\%$$

- Average wEFORD** uses the sum of the weighted unit EFORD values to calculate the numerical average EFORD to be 8.01%.

$$\text{Average EFORD} = \frac{\Sigma (\text{WEFORD})}{\text{Count}(\text{WEFORD})} \times 100\%$$

$$\frac{40.061}{5} = 8.01\%$$

## Another Sample

Compare this sample to the samples earlier, and you will see that the relationship between the methods does not remain constant and is dependent on the distribution of the data.

**Table 4: Raw Data Used as a Sample**

Unit	Capacity (MW)	SH	RSH	AH	Actual Starts	Attempted Starts	EFDH	FOH	FO Events
41	100	183	8576	8759	35	35	0	1	1
42	150	198	8562	8760	31	31	0	0	0
43	125	186	6867	7053	37	38	0	9	2
44	170	105	4128	4233	29	29	0	4528	3
45	180	62	8259	8321	20	20	0	98	1
Total	725	734	36392	37123	152	153	0	4636	7

**Table 5: Calculated Values used in EFORD Formula**

Unit	1/r	1/t	1/D	F	f x FOH	fp	fp x EFDH	EFORD x MW	EFORD
41	1.000	0.004	0.191	0.840	0.840	0.021	0.000	0.457	0.46%
42	0.000	0.004	0.157	0.023	0.000	0.023	0.000	0.000	0.00%
43	0.222	0.006	0.199	0.534	4.804	0.026	0.000	3.147	2.52%
44	0.001	0.007	0.276	0.027	122.623	0.025	0.000	91.581	53.87%
45	0.010	0.002	0.323	0.038	3.691	0.007	0.000	10.114	5.62%
Method 1 Summed					131.959		0.000		15.24%
Method 2 Calculated from reported totals	0.002	0.004	0.207	0.027	124.488	0.020	0.000		14.50%
Method 3 Summed								105.299	14.52%

**Table 6: Weighted Values Used in EFORD Formula**

Unit	wSH	wFOH	wEFDH	F	wFOHd	fp	wEFDHd	wEFORD
41	18300	100	0	0.840	84.000	0.021	0	0.46%
42	29700	0	0	0.023	0	0.023	0	0.00%
43	23250	1125	0	0.534	600.509	0.026	0	2.52%
44	17850	769760	0	0.027	20845.957	0.025	0	53.87%
45	11160	17640	0	0.038	664.418	0.007	0	5.62%
Method 1 Summed	100260				22194.884		0	18.12%
Method 2 Calculated from reported totals	100260	788625	0	0.027	21176.435	0.020	0	17.44%
Average wEFORD								12.49%

Hint: To make the second example calculations work correctly you will need to protect yourself against division by zero with statements like if  $r > 0$  then  $1/r$  else  $1/r = 0$ .

## Note #2 for Appendix F

### INTRODUCTION TO NOTE #2:

Table 7 below comes from IEEE 762 Annex G. In some cases Equivalent Forced Outage Rate – Demand (EFORD) and Forced Outage Rate – Demand (FORd) cannot be calculated or produce a reasonable result regardless of the method used or data sample size. Current industry practice is to calculate the six intermediate terms  $1/r$ ,  $1/T$ ,  $1/D$ ,  $f$ ,  $fp$ , and  $EFDHd$  using data pooling method #2 with divide by zero protection on each calculation. This may force a meaningless answer in some cases and Table 7 shows under what circumstances a meaningful value can always be calculated.

**PLEASE NOTE THAT NERC GADS will follow the recommendations of IEEE 762 Annex G as shown in Table 7 when calculating EFORD numbers. This means that in some GADS reports, there will not be an EFORD number because a calculated EFORD would be meaningless.**

**Table 7: Limiting Conditions for Forced Outage Indexes**

Case	SH	FOH	RSH	FORd	EFORD
Base	>0	>0	>0	Applicable	Applicable
1	0	>0	>0	Cannot be determined	Cannot be determined
2	0	0	>0	Cannot be determined	Cannot be determined
3	0	>0	0	Cannot be determined	Cannot be determined
4	>0	0	>0	0	EFDH/AH
5	>0	0	0	0	EFDH/SH
6	>0	>0	0	FOR	EFOR
7	0	0	0	Cannot be determined	Cannot be determined