IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity

IEEE Power Engineering Society

Sponsored by the
Power System Analysis, Computing, and Economics Committee

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New York, NY 10016-5997, USA

15 March 2007

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Sponsor
Power System Analysis, Computing, and Economics Committee
of the
IEEE Power Engineering Society

Approved 29 December 2006

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Abstract: This standard provides a methodology for the interpretation of electric generating unit performance data from various systems and to facilitate comparisons among different systems. It also standardizes terminology and indexes for reporting electric generating unit reliability, availability, and productivity performance measures. This standard is intended to aid the electric power industry in reporting and evaluating electric generating unit reliability, availability, and productivity while recognizing the power industry's needs, including marketplace competition. Included are equations for equivalent demand forced outage rate ($EFOR_d$), newly identified outage states, discussion of commercial availability, energy weighted equations for group performance indexes, definitions of outside management control (OMC), pooling methodologies, and time-based calculations for group performance indexes.
Keywords: available state, $EFOR_d$, equivalent demand forced outage rate, forced outage, maintenance outage, OMC, outside management control, planned outage, pooling methodology, transition between active states, unavailable state, weighted factor

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Introduction

This introduction is not part of IEEE Std 762-2006, IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity.

Measures of generating unit performance have been defined, recorded, and utilized by the electric power industry for over 60 years. The increased focus on generating unit performance in a competitive marketplace has caused regulatory agencies and the industry to place a greater emphasis on performance measures.

This standard was developed in 1987, based on efforts started in 1980, to provide terminology and indexes for use in existing data systems or in future systems. The focus of this revision is on performance measures to be used in a competitive marketplace.

Some indexes are based on period hours. By use of such a common base, simple additive relationships between various indexes result, and the use of period hours gives sets of indexes that sum to 100%. Other indexes are not based on period hours. This revision of the standard has included terms for units involved in nonbase load operations. The IEEE 762 Working Group defined sufficient data categories (states, times, capacity levels) so that suitable indexes for all types of units can be calculated.

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.

The IEEE 762 Working Group performed an in-depth review of the concept and practices for commercial availability. The working group unanimously agreed that commercial availability should be studied further, but it should not be a part of this standard. It would be best addressed in a new standard. Efforts for developing such a new standard were judged to be outside the scope of the working group's charge and responsibility.

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IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity

1. Overview

Although a generating unit generally includes all equipment from the fuel supply system up to the high-voltage terminals of the generator step-up transformer and the station service transformers, any event preventing the ability of the generating unit to produce electricity at its maximum capacity is covered in the scope of this standard. Sometimes, the generating unit cannot provide the power required to the customer because of problems not related to the power plant equipment. Some examples of these "external events" are transmission system failures, labor strikes, and catastrophic storms.

NOTE—See Annex D for a discussion on these external events.[1]

Reliability in this standard encompasses measures of the ability of generating units to perform their intended function.

Availability measures are concerned with the fraction of time in which a unit is capable of providing service and accounts for outage frequency and duration.

Productivity measures are concerned with the total power produced by a plant with respect to its potential power production. A plant could comprise a unit or a number of units. Therefore, productivity measures consider magnitude of event as well as frequency and duration of event.

This standard was developed for application at the unit level; it does not address applications at the plant component or system level. Because of these exceptions, care should be taken when using this standard below the unit level.

Many of the performance indexes defined in Clause 8 are expressed as either outage rates or factors, and it is important to note the difference. A factor represents the percentage of time in the period of study that a unit occupied a given state, as in availability factor (AF), forced outage factor (FOF), or service factor. A factor may also represent the percentage of a total outcome achieved, as capacity factor represents the ratio of actual to theoretically possible generation. Factors may be added to provide a total accounting for unit states during a given period.

[1] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement this standard.

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By comparison, outage rates provide a measure of the probability, calculated from historical data, of the existence of an outage state any time in the future or under certain conditions.

Attaching the term *equivalent* to any rate or factor, as equivalent availability factor (EAF) or equivalent forced outage rate (EFOR), indicates that both full outages and deratings have been considered in the calculation.

The term demand applied to a rate, as in $EFOR_d$, indicates that the probability of an occurrence has been estimated for periods when the unit is in demand to generate

When statistics are combined for more than one unit, the term *weighted* indicates that data from each unit influence the total in proportion to its size or other indicated weighting factor. See Clause 9 and Clause 10.

1.1 Scope

This document standardizes terminology and indexes for reporting electric generating unit reliability, availability, and productivity performance measures while recognizing the power industry's needs, including marketplace competition. This standard also includes equations for equivalent demand forced outage rate ($EFOR_d$), newly identified outage states, discussion of commercial availability, energy weighted equations for group performance indexes, definitions of outside management control (OMC), pooling methodologies, and time-based calculations for group performance indexes.

1.2 Purpose

This standard is intended to aid the electric power industry in reporting and evaluating electric generating unit reliability, availability, and productivity. It was originally developed to overcome difficulties in the interpretation of electric generating unit performance data from various systems and to facilitate comparisons among different systems. The standard also makes possible the exchange of meaningful data among systems in North America and throughout the world.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

None

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3. Definitions

This clause provides the conceptual definitions of the basic performance indexes while the equations to calculate the indexes are included in Clause 8 or Clause 10. The specific subclause in Clause 8 or Clause 10 is referenced for each defined term.

3.1 availability factor (AF): The fraction of a given operating period in which a generating unit is available without any outages.

NOTE—See 8.6.

3.2 demand forced outage rate (FOR_d): A measure of the probability that a generating unit will not be available due to forced outages when there is demand on the unit to generate.

NOTE—See 8.16.2.

3.3 derating adjusted utilization forced outage probability (DAUFOP): A measure of the probability that a generating unit will not be available when needed (derating included).

NOTE—See 8.17.3.

3.4 equivalent availability factor (EAF): The fraction of a given operating period in which a generating unit is available without any outages and equipment or seasonal deratings.

NOTE—See 8.11.

3.5 equivalent availability factor excluding seasonal deratings (EAF_{XS}): The fraction of a given operating period in which a generating unit is available without any outages and equipment deratings.

NOTE—See 8.11.1.

3.6 equivalent forced outage factor (EFOF): The fraction of a given operating period in which a generating unit is not available due to forced outages and deratings.

NOTE—See 8.20.

3.7 equivalent forced outage rate (EFOR): A measure of the probability that a generating unit will not be available due to forced outages or forced deratings.

NOTE—See 8.17.

3.8 equivalent demand forced outage rate ($EFOR_d$): A measure of the probability that a generating unit will not be available due to forced outages or forced deratings when there is demand on the unit to generate.

NOTE—See 8.17.2.

3.9 equivalent forced outage rate total—generating or other functions ($EFOR_T$): A measure of the probability that a generating unit will not be available due to forced outages or forced deratings including the exposure to nongenerating functions.

NOTE—See 8.17.1.

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3.10 equivalent maintenance outage factor (EMOF): The fraction of a given operating period in which a generating unit is not available due to maintenance outages and maintenance deratings.

NOTE—See 8.21.

3.11 equivalent planned outage factor (EPOF): The fraction of a given operating period in which a generating unit is not available due to planned outages and planned deratings.

NOTE—See 8.18.

3.12 equivalent unavailability factor (EUF): The fraction of a given operating period in which a generating unit is not available due to outages and deratings.

NOTE—See 8.10.

3.13 equivalent unplanned outage factor (EUOF): The fraction of a given operating period in which a generating unit is not available due to forced and maintenance outages and forced and maintenance deratings.

NOTE—See 8.19.

3.14 forced outage factor (FOF): The fraction of a given operating period in which a generating unit is not available due to forced outages.

NOTE—See 8.3.

3.15 forced outage rate (FOR): A measure of the probability that a generating unit will not be available due to forced outages.

NOTE—See 8.16.

3.16 forced outage rate total (FOR_T): A measure of the probability that a generating unit will not be available due to forced outages including the exposure to nongenerating functions.

NOTE—See 8.16.1.

3.17 gross capacity factor (GCF): The gross energy that was produced by a generating unit in a given period as a fraction of the gross maximum generation (GMG). GMG is the period hours (PH) times the gross maximum capacity (GMC).

NOTE—See 8.12.

3.18 gross output factor (GOF): Gross capacity factor (GCF) when the period is applicable only to the in-service state.

NOTE—See 8.14.

3.19 maintenance outage factor (MOF): The fraction of a given operating period in which a generating unit is not available due to maintenance outages.

NOTE—See 8.4.

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3.20 net capacity factor (NCF): The net energy that was produced by a generating unit in a given period as a fraction of the net maximum generation (NMG). NMG is the period hours (PH) times the net maximum capacity (NMC).

NOTE—See 8.13.

3.21 net output factor (NOF): Net capacity factor (NCF) when the period is applicable only to the in-service state.

NOTE—See 8.15.

3.22 planned outage factor (POF): The fraction of a given operating period in which a generating unit is not available due to planned outages.

NOTE—See 8.1.

3.23 starting reliability (SR): A measure of the probability that a generating unit will start successfully when required.

NOTE—See 8.24.

3.24 unavailability factor (UF): The fraction of a given operating period in which a generating unit is not available due to outages.

NOTE—See 8.5.

3.25 utilization forced outage probability (UFOP): A measure of the probability that a generating unit will not be available due to forced outages when there is demand on the unit to generate.

NOTE—See 8.16.3. UFOP is the same as demand forced outage rate (FOR_d) (see 3.2); however, UFOP is used in Canada.

3.26 unplanned outage factor (UOF): The fraction of period a generating unit is not available due to unplanned outages.

NOTE—See 8.2.

3.27 weighted availability factor (WAF): The capacity weighted availability factor for a fleet of units. *See:* **availability factor (AF).**

NOTE—See 10.6.

3.28 weighted demand forced outage rate ($WFOR_d$): The capacity weighted demand forced outage rate for a fleet of units. *See:* **demand forced outage rate (FOR_d).**

NOTE—See 10.16.2.

3.29 weighted derating adjusted utilization forced outage probability (WDAUFOP): The capacity weighted derating adjusted utilization forced outage probability for a fleet of units. *See:* **derating adjusted utilization forced outage probability (DAUFOP).**

NOTE—See 10.17.3.

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3.30 weighted equivalent availability factor (WEAF): The capacity weighted equivalent availability factor for a fleet of units. *See:* **equivalent availability factor (EAF).**

NOTE—See 10.11.

3.31 weighted equivalent availability factor excluding seasonal deratings ($WEAF_{XS}$): The capacity weighted equivalent availability factor excluding seasonal deratings for a fleet of units. *See:* **equivalent availability factor excluding seasonal deratings (EAF_{XS}).**

NOTE—See 10.11.1.

3.32 weighted equivalent forced outage factor (WEFOF): The capacity weighted equivalent forced outage factor for a fleet of units. *See:* **equivalent forced outage factor (EFOF).**

NOTE—See 10.20.

3.33 weighted equivalent forced outage rate (WEFOR): The capacity weighted equivalent forced outage rate for a fleet of units. *See:* **equivalent forced outage rate (EFOR).**

NOTE—See 10.17.

3.34 weighted equivalent demand forced outage rate ($WEFOR_d$): The capacity weighted equivalent demand forced outage rate for a fleet of units. *See:* **equivalent demand forced outage rate ($EFOR_d$).**

NOTE—See 10.17.2.

3.35 weighted equivalent forced outage rate total—generating or other functions ($WEFOR_T$): The capacity weighted equivalent forced outage rate total—generating or other functions for a fleet of units. *See:* **equivalent forced outage rate total—generating or other functions ($EFOR_T$).**

NOTE—See 10.17.1.

3.36 weighted equivalent maintenance outage factor (WEMOF): The capacity weighted equivalent maintenance outage factor for a fleet of units. *See:* **equivalent maintenance outage factor (EMOF).**

NOTE—See 10.21.

3.37 weighted equivalent planned outage factor (WEPOF): The capacity weighted equivalent planned outage factor for a fleet of units. *See:* **equivalent planned outage factor (EPOF).**

NOTE—See 10.18.

3.38 weighted equivalent unavailability factor (WEUF): The capacity weighted equivalent unavailability factor for a fleet of units. *See:* **equivalent unavailability factor (EUF).**

NOTE—See 10.10.

3.39 weighted equivalent unplanned outage factor (WEUOF): The capacity weighted equivalent unplanned outage factor for a fleet of units. *See:* **equivalent unplanned outage factor (EUOF).**

NOTE—See 10.19.

3.40 weighted forced outage factor (WFOF): The capacity weighted forced outage factor for a fleet of units. *See:* **forced outage factor (FOF).**

NOTE—See 10.3.

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3.41 weighted forced outage rate (WFOR): The capacity weighted forced outage rate for a fleet of units. *See:* **forced outage rate (FOR).**

NOTE—See 10.16.

3.42 weighted forced outage rate total—generating or other functions ($WFOR_T$): The capacity weighted forced outage rate total—generating or other functions for a fleet of units. *See:* **forced outage rate total—generating or other functions (FOR_T).**

NOTE—See 10.16.1.

3.43 weighted maintenance outage factor (WMOF): The capacity weighted maintenance outage factor for a fleet of units. *See:* **maintenance outage factor (MOF).**

NOTE—See 10.4.

3.44 weighted planned outage factor (WPOF): The capacity weighted planned outage factor for a fleet of units. *See:* **planned outage factor (POF).**

NOTE—See 10.1.

3.45 weighted unavailability factor (WUF): The capacity weighted unavailability factor for a fleet of units. *See:* **unavailability factor (UF).**

NOTE—See 10.5.

3.46 weighted utilization forced outage probability (WUFOP): The capacity weighted utilization forced outage probability for a fleet of units. *See:* **utilization forced outage probability (UFOP).**

NOTE—See 10.16.3.

3.47 weighted unplanned outage factor (WUOF): The capacity weighted unplanned outage factor for a fleet of units. *See:* **unplanned outage factor (UOF).**

NOTE—See 10.2.

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4. Unit states

A unit state is a particular unit condition that is important for collecting data on performance.

NOTE—The state definitions are related as shown in Figure 1. The transitions between states are described in Annex B.

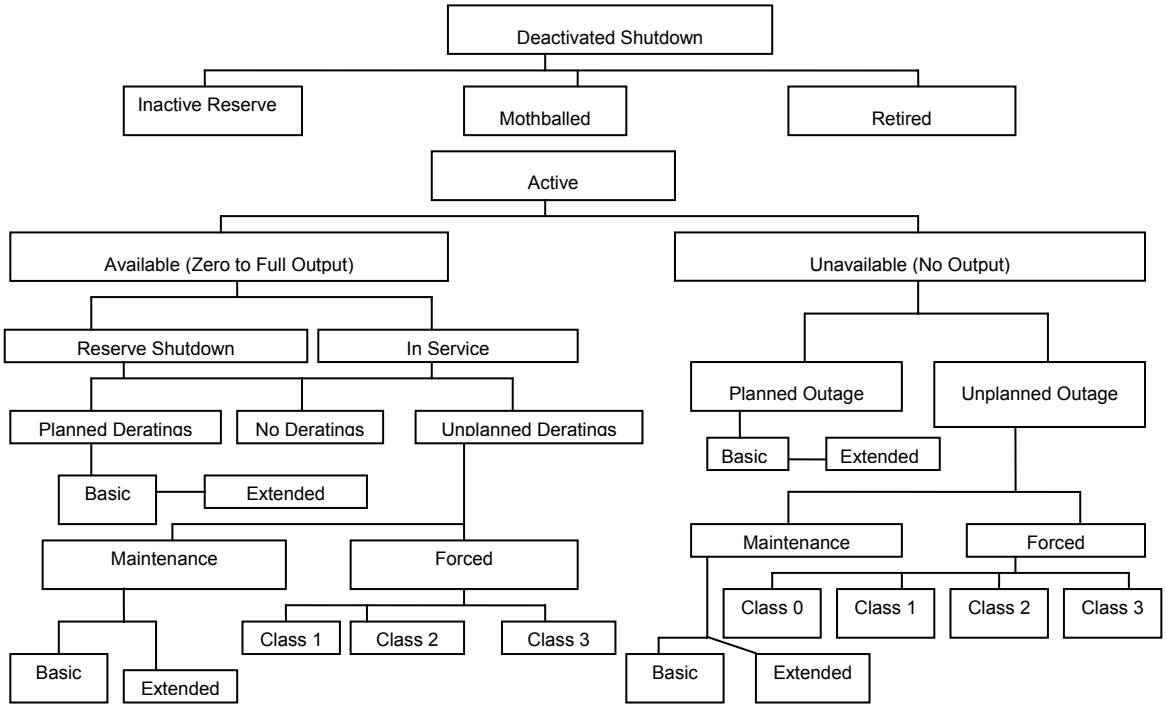

Figure 1—Relation between unit states

4.1 Active

The active state is where a unit is in the population of units being reported.

NOTE—A unit initially enters the active state on its service date and leaves the active state on a deactivation date.

4.1.1 Available

The available state is where a unit is capable of providing service, regardless of whether it is actually in service and regardless of the capacity level that can be provided.

4.1.1.1 In service

The in-service state is where a unit is electrically connected to the system and performing generation function.

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4.1.1.1.1 In-service nongenerating mode

The in-service nongenerating mode state is where a unit is electrically connected to the system and performing nongenerating functions.

NOTE 1—Certain types of units may be performing functions other than generating while being in service and exposed to failure: A pumped storage unit can be in pumping mode, an electrochemical energy storage unit (battery) can be in charging mode, and a combustion turbine or a hydro unit can be in synchronous condensing mode.

NOTE 2—Certain types of generating units may be kept on line at minimum output when there is no demand on the unit to reduce the number of starts.

4.1.1.2 Reserve shutdown

The reserve shutdown state is where a unit is available, but not in service.

NOTE—This state is sometimes referred to as *economy shutdown*.

4.1.2 Unavailable

The unavailable state is where a unit is not capable of operation because of operational or equipment failures, external restrictions (as defined in Annex D), testing, work being performed, or an adverse condition. The unavailable state persists until the unit is made available for operation, either by being synchronized to the system (in-service state) or by being placed in the reserve shutdown state.

4.1.2.1 Planned outage

The planned outage state is where a unit is unavailable due to inspection, testing, nuclear refueling, or overhaul. A planned outage is scheduled well in advance.

4.1.2.1.1 Basic planned outage

The basic planned outage state is the planned outage as originally scheduled and with a predetermined duration.

4.1.2.1.2 Extended planned outage

The extended planned outage state is the extension of the basic planned outage beyond its predetermined duration.

NOTE—Extended planned outage applies only when planned work exceeds predetermined duration. The extension, due to a condition discovered during the planned outage that forces the extension of the planned outage, is classified as a Class 1 unplanned outage (see 4.1.2.2.1.2). A startup failure would result in a Class 0 unplanned outage (see 4.1.2.2.1.1)

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4.1.2.2 Unplanned outage

The unplanned outage state is where a unit is unavailable, but is not in the planned outage state.

NOTE 1—When an unplanned outage is initiated, the outage is classified according to one of five classes, as defined in 4.1.2.2.1.1 through 4.1.2.2.1.4 and 4.1.2.2.2.1 and 4.1.2.2.2.2. A Class 0 unplanned outage applies to a startup failure, and Class 1 applies to a condition requiring immediate outage. Also, an unplanned outage starts when a planned outage ends, but is extended due to unplanned work. Class 2, Class 3, and maintenance outage apply to outages where some delay is possible in removing the unit from service. The class (2, 3, or maintenance) of outage is determined by the amount of delay that can be exercised in the removal of the unit. The class of outage is not made more urgent if the time of removal is advanced due to favorable conditions of system reserves or availability of replacement capacity for the predicted duration of the outage. However, an unplanned outage starts when the unit is removed from service or is declared unavailable when it is not in service.

NOTE 2—During the time the unit is in the unplanned outage state, the outage class is determined by the outage class that initiates the state.

NOTE 3—In some cases, the opportunity exists during unplanned outages to perform some of the repairs or maintenance that would have been performed during the next planned outage. If the additional work extends the outage beyond that required for the unplanned outage, the remaining outage should be reported as a planned outage.

4.1.2.2.1 Forced outage

A forced outage cannot be deferred beyond the end of the next weekend.

4.1.2.2.1.1 Class 0 unplanned outage (starting failure)

A Class 0 unplanned outage results from the unsuccessful attempt to place the unit in service (see 4.1.3.1).

4.1.2.2.1.2 Class 1 unplanned outage (immediate)

A Class 1 unplanned outage requires immediate removal from the existing state.

NOTE—A Class 1 unplanned outage can be initiated from either the in-service state or reserve shutdown state. A Class 1 unplanned outage can also be initiated from the planned outage state. See the note in 4.1.2.1.2.

4.1.2.2.1.3 Class 2 unplanned outage (delayed)

A Class 2 unplanned outage does not require immediate removal from the in-service state, but requires removal within 6 h.

4.1.2.2.1.4 Class 3 unplanned outage (postponed)

A Class 3 unplanned outage can be postponed beyond 6 h, but requires that a unit be removed from the in-service state before the end of the next weekend.

NOTE—Class 2 and Class 3 can be initiated only from the in-service state.

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4.1.2.2.2 Maintenance outage

A maintenance outage can be deferred beyond the end of the next weekend, but requires that a unit be removed from the available state or another unplanned outage state before the next planned outage.

4.1.2.2.2.1 Basic maintenance outage

The basic maintenance outage state is the maintenance outage as originally anticipated, and it may or may not be of a predetermined duration.

4.1.2.2.2.2 Extended maintenance outage

The extended maintenance outage state is the extension of the basic maintenance outage beyond its anticipated duration.

NOTE—Extended maintenance outage applies only when the maintenance work exceeds anticipated duration. The extension, due to a condition discovered during the maintenance outage that forces the extension of the maintenance outage, is classified as a Class 1 unplanned outage (see 4.1.2.2.1.2). A startup failure would result in a Class 0 unplanned outage (see 4.1.2.2.1.1).

4.1.3 Unit starts

4.1.3.1 Attempted unit start

An attempted unit start is the action to bring a unit from shutdown to the in-service state. Repeated initiations of the starting sequence without accomplishing corrective repairs are counted as a single attempt.

4.1.3.2 Starting failure

Starting failure is the inability to bring a unit from some unavailable state or reserve shutdown state to the in-service state within a specified period. The specified period may be different for individual units. Repeated failures within the specified starting period are counted as a single starting failure.

4.1.3.3 Actual unit start

The actual unit state is the occurrence of bringing a unit from some unavailable state or the reserve shutdown state to the in-service state within a specified period. The specified period may be different for individual units.

4.2 Deactivated shutdown

The deactivated shutdown state is where a unit is unavailable for service for an extended period of time for reasons not related to the equipment.

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4.2.1 Inactive reserve

The inactive reserve state is where a unit is unavailable for service, but can be brought back into service in a relatively short period of time, typically measured in days.

4.2.2 Mothballed

The mothballed state is where a unit is unavailable for service, but can be brought back into service with appropriate amount of notification, typically weeks or months.

4.2.3 Retired

The retired state is where a unit is unavailable for service and not expected to return to service in the future.

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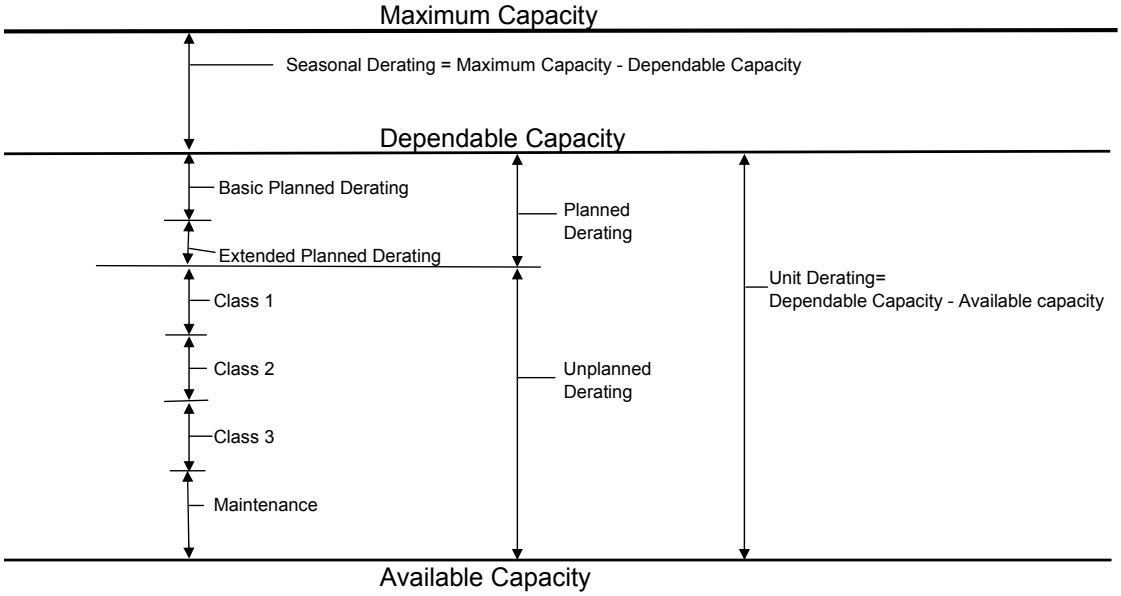
5. Capacity terms

Terms that involve capacity can be expressed as gross or net quantities.

NOTE—The capacity definitions are related as shown in Figure 2. The correlation between the capacity-derating definitions in this clause and partial-outage definitions in use by industry is shown in Annex A.



NOTE—All capacity and deratings are to be expressed on either gross or net basis.

Figure 2—Unit capacity levels

5.1 Maximum capacity (MC)

The maximum capacity is the capacity that a unit can sustain over a specified period of time. The maximum capacity can be expressed as gross maximum capacity (GMC) or net maximum capacity (NMC). To establish this capacity, formal demonstration is required. The test should be repeated periodically. This demonstrated capacity level shall be corrected to generating conditions for which there should be minimum ambient restriction. When a demonstration test has not been conducted, the estimated maximum capacity of the unit shall be used.

NOTE—In practice, many organizations define the ambient conditions for testing capacity rating in different seasons (e.g., summer and winter). The conditions may be based on the average over several years at the time of peak demand or some other criteria, and in general, conditions better or worse than the defined criteria can occur. The maximum capacity rating is typically the capacity achieved in the cooler season, such as winter.

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5.2 Dependable capacity

The dependable capacity is the maximum capacity when modified for ambient limitations for a specified period of time, such as a month or a season. (See Annex C.)

5.3 Available capacity

The available capacity is the dependable capacity when modified for equipment limitation at any time. (See Annex C.)

5.4 Seasonal derating

Seasonal derating is the difference between maximum capacity and dependable capacity during a specified season.

5.5 Unit derating

Unit derating is the difference between dependable capacity and available capacity.

5.6 Planned derating

Planned derating is the portion of a unit derating that is scheduled well in advance.

5.6.1 Basic planned derating

A basic planned derating is the planned derating as originally scheduled and with a predetermined duration.

5.6.2 Extended planned derating

An extended planned derating that is the extension of the basic planned derating beyond its predetermined duration.

5.7 Unplanned derating

Unplanned derating is the portion of the unit derating that is not a planned derating. Unplanned derating events are classified according to the urgency with which the derating needs to be initiated, as defined in 5.7.1 through 5.7.4.

5.7.1 Class 1 unplanned derating (immediate)

A Class 1 unplanning derating requires an immediate action for the reduction of capacity.

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5.7.2 Class 2 unplanned derating (delayed)

A Class 2 unplanning derating does not require an immediate reduction of capacity, but requires a reduction of capacity within 6 h.

5.7.3 Class 3 unplanned derating (postponed)

A Class 3 unplanning derating can be postponed beyond 6 h, but requires a reduction of capacity before the end of the next weekend.

5.7.4 Maintenance derating

A maintenance derating can be deferred beyond the end of the next weekend, but requires a reduction of capacity before the next planned outage.

5.7.4.1 Basic maintenance derating

A basic maintenance derating is the maintenance derating as originally scheduled and with a predetermined duration.

5.7.4.2 Extended maintenance derating

An extended maintenance derating is the extension of the basic maintenance derating beyond its predetermined duration.

5.8 Installed nameplate capacity

The installed nameplate capacity is the full-load continuous gross capacity of a unit under specified conditions, as calculated from the electric generator nameplate based on the rated power factor. Nameplate capacity can be calculated by multiplying the megavoltampere rating by the power factor.

NOTE—The nameplate rating of the electric generator may not be indicative of the unit maximum or dependable capacity because another item or equipment (such as the turbine) may limit unit output.

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6. Time designations and dates

NOTE—The time spent in the various unit states defined in Clause 4 is defined in 6.1 through 6.11. See Figure 3. In 6.12 through 6.17, the time a unit was subject to the various categories of unit derating defined in Clause 5 is defined. Derated time is accumulated only during the available, in-service, and reserve shutdown states.

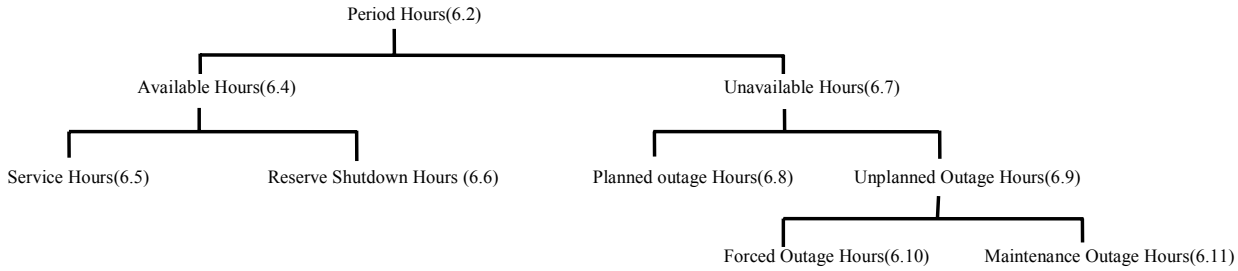

Figure 3—Time spent in various unit states

6.1 Total hours (TH)

The phrase *total hours* represents the number of hours in a reporting period with starting and ending dates as defined by the civil calendar.

6.2 Period hours (PH) or active hours (ACTH)

The phrase *period hours* or *active hours* represents the number of hours a unit was in the active state.

NOTE 1—The use of the term *period hours* to denote hours in the active state is historic in the industry. Localized data collection of the performance of a set of units during a reporting period such as a month implicitly collected data on only the units that were active during the month. If a unit entered or left the active state during the month, it might not be reported as its performance was deemed unrepresentative.

NOTE 2—The need to restrict hours in the denominator of several of the indexes defined below to hours in the active state arises when pooling unit performance over longer reporting periods, commonly several years, to serve as a projection of the performance of similar units into the future. Over such long periods, it may be important not to ignore any active state hours to calculate accurate individual or pooled performance indexes when the data contain new units entering service or old units being mothballed or retired.

NOTE 3—The use of period hours in computing performance indexes is continued in this standard, but users must be clear that they include only hours in the active state.

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6.3 Deactivated shutdown hours (DSH)

The phrase *deactivated shutdown hours* represents the number of hours a unit was in the deactivated shutdown state.

NOTE—Period hours and deactivated shutdown hours add up to total hours.

6.4 Available hours (AH)

The phrase *available hours* represents the number of hours a unit was in the available state.

NOTE—Available hours are the sum of service hours and reserve shutdown hours, or they may be computed from period hours minus unavailable hours (see 6.7).

6.5 Service hours (SH)

The phrase *service hours* represents the number of hours a unit was in the in-service state (see 4.1.1.1).

6.5.1 Service hours nongenerating (SHNG)

The phrase *service hours nongenerating* represents the number of hours a unit is in the in-service nongenerating mode (see 4.1.1.1.1).

6.6 Reserve shutdown hours (RSH)

The phrase *reserve shutdown hours* represents the number of hours a unit was in the reserve shutdown state.

6.7 Unavailable hours (UH)

The phrase *unavailable hours* represents the number of hours a unit was in the unavailable state.

NOTE—Unavailable hours are the sum of planned outage hours and unplanned outage hours, or they may be the sum of planned outage hours, forced outage hours, and maintenance outage hours.

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6.8 Planned outage hours (POH)

The phrase *planned outage hours* represents the number of hours a unit was in the basic or extended planned outage state.

6.9 Unplanned outage hours (UOH)

The phrase *unplanned outage hours* represents the number of hours a unit was in a Class 0, Class 1, Class 2, Class 3, or maintenance outage state.

6.10 Forced outage hours (FOH)

The phrase *forced outage hours* represents the number of hours a unit was in a Class 0, Class 1, Class 2, or Class 3 unplanned outage state.

6.10.1 Demand factor (*f*)

The demand factor is used to estimate forced outage hours overlapping the period of demand for the unit to operate.

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

$$r = \text{Average forced outage duration} = \frac{FOH}{\text{Number of forced outages}}$$

$$\frac{1}{r} = \text{Repair rate}$$

$$T = \text{Average reserve shutdown time} = \frac{RSH}{\text{number of reserve shutdowns}}$$

$$\frac{1}{T} = \text{Rate of recall from reserve shutdown}$$

$$D = \text{Average demand time (duty cycle time)} = \frac{SH}{\text{Number of demand occurrences}}$$

$$\frac{1}{D} = \text{Rate of departure from the in-service state}$$

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Accurate computation of *T* requires collecting the number of reserve shutdowns. If the number of reserve shutdowns is not available, the following approximations may be used; this assumes that all attempts to start are from a reserve shutdown state and none are from a forced or scheduled outage state.

$$T = \frac{RSH}{\text{Number of attempted starts to generate}}$$

The number of demand occurrences is presumably equal to the number of attempted starts to generate, but if this is not available, the following approximation may be used:

$$D = \frac{SH}{\text{Number of successful starts to generate}}$$

This method is documented in the IEEE paper by Ringlee [B9].[2] In this paper, it was proposed to estimate *T* from the following:

$(T + D) = AH$ / number of attempted starts

The performance indexes of some generators have been based on this method since 1980, and the North American Electric Reliability Council Generator Availability Data System (NERC GADS) [B8] started using this method in 2000.

NOTE—See Annex G for limiting conditions.

$$FOH_d = f \times FOH$$

6.10.2 Forced outage hours overlapping the period of demand for the unit to operate (FOH_d)

The FOH_d is the number of hours a unit was in a Class 0, Class 1, Class 2, or Class 3 unplanned outage state AND the unit would have operated had it been available.

If periods of demand are not recorded, FOH_d may be estimated using the demand factor defined in 6.10.1. The demand factor is applicable to traditional demand for economic or reliable system operation.

NOTE—FOH_d 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.

[2] Numbers in brackets correspond to the numbers in the bibliography in Annex H.

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6.11 Maintenance outage hours (MOH)

The phrase *maintenance outage hours* represents the number of hours a unit was in a maintenance outage state.

6.12 Unit derated hours (UNDH)

The phrase *unit derated hours* represents the available hours during which a unit derating was in effect.

6.12.1 In-service unit derated hours (IUNDH)

The phrase *in-service unit derated hours* represents the in-service hours during which a unit derating was in effect.

6.12.2 Reserve shutdown unit derated hours (RSUNDH)

The phrase *reserve shutdown unit derated hours* represents the reserve shutdown hours during which a unit derating was in effect.

6.13 Planned derated hours (PDH)

The phrase *planned derated hours* represents the available hours during which a basic or extended planned derating was in effect.

6.13.1 In-service planned derated hours (IPDH)

The phrase *in-service planned derated hours* represents the in-service hours during which a basic or extended planned derating was in effect.

6.13.2 Reserve shutdown planned derated hours (RSPDH)

The phrase *reserve shutdown planned derated hours* represents the reserve shutdown hours during which a basic or extended planned derating was in effect.

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6.14 Unplanned derated hours (UDH)

The phrase *unplanned derated hours* represents the available hours during which an unplanned derating was in effect.

6.14.1 In-service unplanned derated hours (IUDH)

The phrase *in-service unplanned derated hours* represents the in-service hours during which an unplanned derating was in effect.

6.14.2 Reserve shutdown unplanned derated hours (RSUDH)

The phrase *reserve shutdown unplanned derated hours* represents the reserve shutdown hours during which an unplanned derating was in effect.

6.15 Forced derated hours (FDH)

The phrase *forced derated hours* represents the available hours during which a Class 1, Class 2, or Class 3 unplanned derating was in effect.

6.15.1 In-service forced derated hours (IFDH)

The phrase *in-service forced derated hours* represents the in-service hours during which a Class 1, Class 2, or Class 3 unplanned derating was in effect.

$$IFDH = \sum_{i=1}^{n} IFD_i \times Hours_i$$

where

IFD_i is in-service forced derating
n is number of Class 1, Class 2, or Class 3 derating occurrences

6.15.2 Reserve shutdown forced derated hours (RSFDH)

The phrase *reserve shutdown forced derated hours* represents the reserve shutdown hours during which a Class 1, Class 2, or Class 3 unplanned derating was in effect.

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6.16 Maintenance derated hours (MDH)

The phrase *maintenance derated hours* represents the available hours during which a maintenance derating was in effect.

6.16.1 In-service maintenance derated hours (IMDH)

The phrase *in-service maintenance derated hours* represents the in-service hours during which a maintenance derating was in effect.

6.16.2 Reserve shutdown maintenance derated hours (RSMDH)

The phrase *reserve shutdown maintenance derated hours* represents the reserve shutdown hours during which a maintenance derating was in effect.

6.17 Seasonal derated hours (SDH)

The phrase *seasonal derated hours* represents the available hours during which a seasonal derating was in effect.

NOTE—Seasonal derated hours are not included in planned derated hours, but they are included in calculating the EAF.

6.18 Equivalent hours (E)

The phrase *equivalent hours* represents the number of hours a unit was in a time category involving unit derating, expressed as equivalent hours of full outage at maximum capacity. Both unit derating and maximum capacity shall be expressed on a consistent basis, gross or net. Equivalent hours can be calculated for each of the time categories in 6.12 through 6.17. The symbol designation for the equivalent hours is formed by adding an E in front of the symbol for the corresponding time designation. For example, equivalent unit derated hours (UNDH) is designated EUNDH. Formulas for equivalent hours can be derived from the following general equation:

$$E(\ ) = \frac{\sum_{i=1}^{n} D_i(\ ) \times T_i}{MC}$$

where

$E(\ )$ is equivalent hours in the time category represented by parentheses, which can be any one of the time categories in 6.11 through 6.16

$D_i(\ )$ is the derating for the time category shown in parentheses, after the ith change in either available capacity (unit deratings) or dependable capacity (seasonal deratings).

T_i is the number of hours accumulated in the time category of interest between the ith and the $(i + 1)$th change in either available capacity (unit deratings) or dependable capacity (seasonal deratings)

MC is maximum capacity

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NOTE—In order to apportion equivalent hours among the various time categories, appropriate ground rules shall be established in the reporting system so that after each change in either available capacity or dependable capacity, the sum of all subcategories of unit derating is equal to the unit derating.

6.18.1 Equivalent forced derated hours (EFDH)

EFDH is the forced derated hours (see 6.15) converted to equivalent hours in accordance with 6.18.

$$EFDH = \frac{\sum_{i=1}^{n} FD_i \times T_i}{MC}$$

where

FD_i is forced derated states

6.18.2 Equivalent reserve shutdown forced derated hours (ERSFDH)

ERSFDH is the reserve shutdown forced derated hours (see 6.15.2) converted to equivalent hours in accordance with 6.18.

NOTE—Reserve shutdown forced derated hours are, by definition, not during a period of demand for the unit to operate.

$$ERSFDH = \frac{\sum_{i=1}^{n} RSFD_i \times T_i}{MC}$$

where

$RSFD_i$ is reserve shutdown forced derated states

6.18.3 Equivalent forced derated hours overlapping period of demand for the unit to generate ($EFDH_d$)

$EFDH_d$ is the in-service forced derated hours (see 6.15.1) converted to equivalent hours in accordance with 6.18.

$$EFDH_d = EFDH - ERSFDH$$

NOTE—Accurately determining $EFDH_d$ requires collecting data so that in-service deratings are separated from reserve shutdown deratings. 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.

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If in-service forced derated hours and reserve shutdown foced derated hours are not separately recorded, a method used by NERC GADS to estimate $EFDH_d$ from EFDH is as follows. Deratings are assumed to be uniformly distributed during the available hours. $EFDH_d$ is calculated by using a factor f_p:

$$EFDH_d = f_p \times EFDH$$

where

$f_p = SH / AH$

6.18.4 Equivalent planned derated hours (EPDH)

EPDH is the planned derated hours (see 6.13) converted to equivalent hours in accordance with 6.18.

$$EPDH = \frac{\sum_{i=1}^{n} PD_i \times T_i}{MC}$$

where

PD_i is planned derated states

6.18.5 Equivalent maintenance derated hours (EMDH)

EMDH is the maintenance derated hours (see 6.16) converted to equivalent hours in accordance with 6.18.

$$EMDH = \frac{\sum_{i=1}^{n} MD_i \times T_i}{MC}$$

where

MD_i is maintenance derated states

6.18.6 Equivalent unit derated hours (EUNDH)

EUNDH is the unit derated hours (see 6.12) converted to equivalent hours in accordance with 6.18.

$$EUNDH = \frac{\sum_{i=1}^{n} UND_i \times T_i}{MC}$$

where

UND_i is unit derated states

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6.19 Service date (SD)

The service date is when a unit was initially placed in the active state.

NOTE—A unit may have generated power on a test basis before its service date.

6.20 Deactivation date

The deactivation date is when a unit was placed into the deactivated shutdown state.

6.21 Reactivation date

The reactivation date is when a unit was returned to the active state from the deactivated shutdown state.

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7. Energy terms

Similar to capacity terms, energy terms can be expressed as gross or net quantities.

NOTE—Maximum generation = available generation + unavailable generation + seasonal unavailable generation = actual generation + reserve generation + unavailable generation + seasonal unavailable generation.

7.1 Actual generation (AAG)

Actual generation is the energy that was generated by a unit in a given period. Actual generation can be expressed as gross actual generation (GAAG) or net actual generation (NAAG).

7.2 Maximum generation (MG)

Maximum generation is the energy that could have been produced by a unit in a given period of time if operated continuously at maximum capacity. Maximum generation can be expressed as gross maximum generation (GMG) or net maximum generation (NMG).

$$MG = PH \times MC$$

$$GMG = PH \times GMC$$

$$NMG = PH \times NMC$$

where

PH is period hours
MC is maximum capacity

7.3 Available generation (AG)

Available generation is the energy that could have been generated by a unit in a given period if operated continuously at its available capacity.

7.4 Unavailable generation (UG)

Unavailable generation is the difference between the energy that would have been generated if operating continuously at dependable capacity and the energy that would have been generated if operating continuously at available capacity. This is the energy that could not be generated by a unit due to planned and unplanned outages and unit deratings.

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$$UG = (POH + UOH + EUNDH) \times MC$$

where

POH is planned outage hours
UOH is unplanned outage hours
EUNDH is equivalent unit derated hours
MC is maximum capacity

7.5 Seasonal unavailable generation (SUG)

Seasonal unavailable generation is the difference between the energy that would have been generated if operating continuously at maximum capacity and the energy that would have been generated if operating continuously at dependable capacity, calculated only during the time the unit was in the available state.

$$SUG = ESDH \times MC$$

where

ESDH is equivalent seasonal derated hours
MC is maximum capacity

7.6 Reserve generation (RG)

Reserve generation is the energy that a unit could have produced in a given period, but did not because it was not required by the system. This is the difference between available generation and actual generation.

$$RG = AG - AAG$$

where

AG is available generation
AAG is actual generation

7.7 Derated generation (DG)

Derated generation is the generation that was not available due to unit deratings.

$$DG = EUNDH \times MC$$

where

EUNDH is equivalent unit derated hours
MC is maximum capacity

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8. Performance indexes of an individual unit

Historically, the individual unit performance indexes have been used to assess electric generating unit reliability, availability, and productivity. However, individual unit performance indexes are related to both unweighted (time-based) calculations for group performance indexes shown in Clause 9 and capacity weighted calculations for group performance indexes shown in Clause 10. Both Clause 9 and Clause 10 equations are built upon the individual unit performance indexes. Annex C discusses the relationships among the performance indexes that are based on period hours (PH).

8.1 Planned outage factor (POF)

$$POF = \left(\frac{POH}{PH} \right) \times 100$$

8.2 Unplanned outage factor (UOF)

$$UOF = \left(\frac{UOH}{PH} \right) \times 100$$

8.3 Forced outage factor (FOF)

$$FOF = \left(\frac{FOH}{PH} \right) \times 100$$

8.4 Maintenance outage factor (MOF)

$$MOF = \left(\frac{MOH}{PH} \right) \times 100$$

8.5 Unavailability factor (UF)

$$UF = \left(\frac{UH}{PH} \right) \times 100$$

$$UF = \left(\frac{POH + MOH + FOH}{PH} \right) \times 100$$

$$UF = \left(\frac{POH + UOH}{PH} \right) \times 100$$

8.6 Availability factor (AF)

$$AF = \left(\frac{AH}{PH} \right) \times 100$$

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8.7 Service factor (SF)

$$SF = \left(\frac{SH}{PH} \right) \times 100$$

8.8 Seasonal derating factor (SDF)

The seasonal derating factor is the fraction of maximum generation (MG) that could not be produced due to seasonal deratings.

$$SDF = \left(\frac{SUG}{MG} \right) \times 100$$

$$SDF = \left(\frac{ESDH}{PH} \right) \times 100$$

8.9 Unit derating factor (UDF)

The unit derating factor is the fraction of maximum generation (MG) that could not be produced due to unit deratings.

$$UDF = \left(\frac{DG}{MG} \right) \times 100$$

$$UDF = \left(\frac{EUNDH}{PH} \right) \times 100$$

8.10 Equivalent unavailability factor (EUF)

The equivalent unavailability factor is the fraction of maximum generation (MG) that could not be produced due to unit deratings and planned and unplanned outages.

$$EUF = \left(\frac{UG}{MG} \right) \times 100$$

$$EUF = \left(\frac{POH + MOH + FOH + EUNDH}{PH} \right) \times 100$$

8.11 Equivalent availability factor (EAF)

The EAF is the fraction of maximum generation that could be provided if limited only by outages and deratings:

$$EAF = \left(\frac{AG}{MG} \right) \times 100$$

$$EAF = \left(\frac{AH - (EUNDH + ESDH)}{PH} \right) \times 100$$

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8.11.1 EAF excluding seasonal deratings (EAFxs)

$$EAFxs = \frac{AH - EUNDH}{PH} \times 100$$

8.12 Gross capacity factor (GCF)

$$GCF = \left(\frac{GAAG}{GMG} \right) \times 100$$

8.13 Net capacity factor (NCF)

$$NCF = \left(\frac{NAAG}{NMG} \right) \times 100$$

NOTE—NCF calculated using this equation can be negative during a period when the unit is shut down. For meaningful pooling of data on several units, NCF can be defined to be zero when the unit is shut down.

8.14 Gross output factor (GOF)

$$GOF = \left(\frac{GAAG}{SH \times GMC} \right) \times 100$$

8.15 Net output factor (NOF)

$$NOF = \left(\frac{NAAG}{SH \times NMC} \right) \times 100$$

8.16 Forced outage rate (FOR)

$$FOR = \left(\frac{FOH}{FOH + SH} \right) \times 100$$

8.16.1 Forced outage rate total—generating or other functions (FOR_T)

$$FOR_T = \left(\frac{FOH}{(FOH + SH + SHNG)} \right) \times 100$$

8.16.2 Demand forced outage rate (FOR_d)

$$FOR_d = \left(\frac{FOH_d}{FOH_d + SH} \right) \times 100$$

where

FOH_d is as defined in 6.10.2

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NOTE—When FOH_d is determined directly from recorded periods of demand as noted in 6.10.2, service hours (SH) in the above equation should include only those under the specified demand condition.

8.16.3 Utilization forced outage probability (UFOP)

$$UFOP = \left(\frac{f \times (FO + FEMO + FEPO)}{f \times (FO + FEMO + FEPO) + O + O(FD) + O(SD)} \right)$$

where

f	is demand factor calculated using the equation in 6.10.1
FO	is forced outage (h)
FEMO	is forced extension of maintenance outage (h)
FEPO	is forced extension of planned outage (h)
O	is operating (h)
O(FD)	is operating under a forced derating (h)
O(SD)	is operating under a scheduled derating (h)

This index is defined by the Canadian Electricity Association Equipment Reliability Information System (CEA-ERIS) [B5]. Forced outage hours (FOH), as defined in this standard, are equal to FO + FEMO + FEPO. Service hours (SH), as defined in this standard, are equal to O + O(FD) + O(SD).

8.17 Equivalent forced outage rate (EFOR)

$$EFOR = \left(\frac{FOH + EFDH}{SH + FOH + ERSFDH} \right) \times 100$$

8.17.1 Equivalent forced outage rate total—generating or other functions ($EFOR_T$)

$$EFOR_T = \left(\frac{FOH + EFDH}{SH + SHNG + FOH + ERSFDH} \right) \times 100$$

8.17.2 Equivalent demand forced outage rate ($EFOR_d$)

$$EFOR_d = \left(\frac{FOH_d + EFDH_d}{FOH_d + SH} \right) \times 100$$

where

FOH_d	is as defined in 6.10.2
$EFDH_d$	is as defined in 6.18.3

NOTE—When $EFDH_d$ is determined directly from recorded periods of demand as noted in 6.18.3, service hours (SH) in the above equation should include only those under the specified demand condition.

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8.17.3 Derating adjusted utilization forced outage probability (DAUFOP)

When deratings during the in-service state are separately available, CEA-ERIS [B5] collects "Operating under a Forced Derating" data separately, and these data can be used directly to estimate $EFDH_d$ using the equivalent derating hours concept. This estimate is used to calculate DAUFOP, which is conceptually similar to $EFOR_d$. DAUFOP is currently used by some generators in Canada.

$$DAUFOP = \frac{\left[f \times (FO + FEMO + FEPO) + O(FD)adj \right]}{\left[f \times (FO + FEMO + FEPO) + O + O(FD) + O(SD) \right]}$$

where

f	is demand factor calculated using the equation in 6.10.1
FO	is forced outage (h)
$FEMO$	is forced extension of maintenance outage (h)
$FEPO$	is forced extension of planned outage (h)
O	is operating (h)
$O(FD)$	is operating under a forced derating (h)
$O(SD)$	is operating under a scheduled derating (h)
$O(FD)adj$	is operating under a forced derating hours adjusted for equivalent outage time similar to EFDH. This can be directly computed from the database, and there is no need to estimate it by multiplying all forced derating hours by the factor f_p.

NOTE—See Annex G for limiting conditions.

8.17.4 Derating adjusted forced outage rate (DAFOR)

DAFOR is the ratio of equivalent forced outage time to the sum of equivalent forced outage time plus total equivalent operating time.

$$DAFOR = \left(\frac{FO + FEMO + FEPO + O(FD)adj + ABNO(FD)adj}{FO + FEMO + FEPO + ABNO(FD)adj + O + O(FD) + O(SD)} \right) \times 100$$

where

f	is demand factor calculated using the equation in 6.10.1
FO	is forced outage (h)
$FEMO$	is forced extension of maintenance outage (h)
$FEPO$	is forced extension of planned outage (h)
O	is operating (h)
$O(FD)$	is operating under a forced derating (h)
$O(SD)$	is operating under a scheduled derating (h)
$O(FD)adj$	is operating under a forced derating hours adjusted for equivalent outage time similar to EFDH. This can be directly computed from the database, and there is no need to estimate it by multiplying all forced derating hours by the factor f_p.
$ABNO(FD)adj$	is equivalent to ERSFDH as defined under 6.18.2

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8.18 Equivalent planned outage factor (EPOF)

$$\left(\frac{POH + EPDH}{PH}\right)\times 100$$

8.19 Equivalent unplanned outage factor (EUOF)

$$\left(\frac{FOH + EFDH + MOH + EMDH}{PH}\right)\times 100$$

8.20 Equivalent forced outage factor (EFOF)

$$\left(\frac{FOH + EFDH}{PH}\right)\times 100$$

8.21 Equivalent maintenance outage factor (EMOF)

$$\left(\frac{MOH + EMDH}{PH}\right)\times 100$$

8.22 Mean service time to outage

In 8.22.1, 8.22.2, and 8.22.3, only forced outages occurring from the in-service state are considered. The name for the index could be "mean service time to in-service forced outage." However, for simplification, in-service is not included in the name.

Indexes similar to 8.22.1, 8.22.2, and 8.22.3 can also be calculated for outages that occur during reserve shutdown state.

8.22.1 Mean service time to forced outage (MSTFO)

$$MSTFO = \frac{\text{SH}}{\text{Number of Class 0,1, 2, and 3 unplanned outages that occur from in-service state}}$$

$$\text{Unit failure rate} = \frac{1}{MSTFO}$$

8.22.2 Mean service time to maintenance outage (MSTMO)

$$MSTMO = \frac{\text{SH}}{\text{Number of maintenance outages that occur from in-service state}}$$

8.22.3 Mean service time to planned outage (MSTPO)

$$MSTPO = \frac{\text{SH}}{\text{Number of planned outages that occur from in-service state}}$$

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8.23 Mean outage duration

NOTE—Outage hours and number of outages in 8.23 include outages that occur from in-service state only.

8.23.1 Mean forced outage duration (MFOD)

$$MFOD = \frac{\text{FOH}}{\text{Numbers of Class 0, 1, 2, and 3 unplanned outages that occur from in-service state}}$$

8.23.2 Mean maintenance outage duration (MMOD)

$$MMOD = \frac{\text{MOH}}{\text{Number of maintenance outages that occur from in-service state}}$$

8.23.3 Mean planned outage duration (MPOD)

$$MPOD = \frac{\text{POH}}{\text{Number of planned outages that occur from in-service state}}$$

8.24 Starting reliability (SR)

$$SR = \left(\frac{\text{Number of actual unit starts}}{\text{Number of attempted unit starts}} \right) \times 100$$

8.24.1 Probability of starting failure (P_s)

Probability of a starting failure (P_s) is a measure of probability that a generating unit will be unable to serve a load during all or part of a demand period.

$$P_s = \frac{\text{Total start failures}}{\text{Number of attempted unit starts}}$$

8.25 Cycling rate (CR) or average run time (ART)

$$CR = \frac{\text{Number of actual unit starts}}{\text{Service hours}}$$

$$ART = 1/CR$$

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9. Unweighted (time-based) calculations for group performance indexes

Past editions of IEEE Std 762 addressed performance indexes only at the generating unit level (Clause 8).

However, there are many reasons one would need to "pool" or group units together into cumulative indexes. Such group indexes, representing the performance of, for example, a plant, a fleet of like-units, a company, or a holding company, are important for analysis and management information. These group calculations, although not in this standard in the past, have been widely used in the industry.

This clause provides the unweighted grouping, which gives the same weight to each unit in the group, regardless of each unit's size. See Clause 10 for similar equations that weight the units.

Both weighted grouping and unweighted grouping of performance indexes have valid applications.

NOTE 1—Special energy-weighted equations are not necessary for "energy terms" (i.e., GCF, NCF, GOF, NOF) because these factors are inherently energy-weighted. These equations are the same as 8.12 through 8.15. However, when calculating for a group of units (or a unit that has a varying capacity value over time), do not simply average these factors. Apply the equations in 9.12 through 9.15 for correct group performance measures.

NOTE 2—The Σ sign refers to summing the terms over each unit in the group, 1 to *n*.

9.1 Planned outage factor (POF)

$$POF = \frac{\sum_{i=1}^{n} POH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

9.2 Unplanned outage factor (UOF)

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

9.3 Forced outage factor (FOF)

$$FOF = \frac{\sum_{i=1}^{n} FOH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

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9.4 Maintenance outage factor (MOF)

$$MOF = \frac{\sum_{i=1}^{n} MOH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

9.5 Unavailability factor (UF)

$$UF = \frac{\sum_{i=1}^{n} (POH_i + MOH_i + FOH_i)}{\sum_{i=1}^{n} PH_i} \times 100$$

9.6 Availability factor (AF)

$$AF = \frac{\sum_{i=1}^{n} AH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

9.7 Service factor (SF)

$$SF = \frac{\sum_{i=1}^{n} SH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

9.8 Seasonal derating factor (SDF)

$$SDF = \frac{\sum_{i=1}^{n} ESDH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

9.9 Unit derating factor (UDF)

$$UDF = \frac{\sum_{i=1}^{n} EUNDH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

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9.10 Equivalent unavailability factor (EUF)

$$EUF = \frac{\sum_{i=1}^{n}(POH_i + MOH_i + FOH_i + EUNDH_i)}{\sum_{i=1}^{n} PH_i} \times 100$$

9.11 Equivalent availability factor (EAF)

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

9.11.1 EAF excluding seasonal deratings (EAFxs)

$$EAFxs = \frac{\sum_{i=1}^{n} AH_i - \sum_{i=1}^{n} EUNDH_i}{\sum_{i=1}^{n} PH_i} \times 100$$

9.12 Gross capacity factor (GCF)

$$GCF = \frac{\sum_{i=1}^{n} GAAG_i}{\sum_{i=1}^{n} GMC_i PH_i} \times 100$$

9.13 Net capacity factor (NCF)

$$NCF = \frac{\sum_{i=1}^{n} NAAG_i}{\sum_{i=1}^{n} NMC_i PH_i} \times 100$$

9.14 Gross output factor (GOF)

$$GOF = \frac{\sum_{i=1}^{n} GAAG_i}{\sum_{i=1}^{n} GMC_i SH_i} \times 100$$

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9.15 Net output factor (NOF)

$$NOF = \frac{\sum_{i=1}^{n} NAAG_i}{\sum_{i=1}^{n} NMC_i SH_i} \times 100$$

9.16 Forced outage rate (FOR)

$$FOR = \frac{\sum_{i=1}^{n} FOH_i}{\sum_{i=1}^{n} (FOH_i + SH_i)} \times 100$$

9.16.1 Forced outage rate total—generating or other functions (FOR_T)

$$FOR_T = \frac{\sum_{i=1}^{n} FOH_i}{\sum_{i=1}^{n} (FOH_i + SH_i + SHNG_i)} \times 100$$

9.16.2 Demand forced outage rate (FOR_d)

$$FOR_d = \frac{\sum_{i=1}^{n} FOH_{di}}{\sum_{i=1}^{n} (FOH_{di} + SH_i)} \times 100$$

9.16.3 Utilization forced outage probability (UFOP)

$$UFOP = \frac{\sum_{i=1}^{n} f_i \times (FO_i + FEMO_i + FEPO_i)}{\sum_{i=1}^{n} f_i \times (FO_i + FEMO_i + FEPO_i) + O_i + O(FD)_i + O(SD)_i)}$$

9.17 Equivalent forced outage rate (EFOR)

$$EFOR = \left[\frac{\sum_{i=1}^{n} FOH_i + EFDH_i}{\sum_{i=1}^{n} FOH_i + SH_i + ERSFDH_i} \right] \times 100$$

9.17.1 Equivalent forced outage rate total—generating or other functions ($EFOR_T$)

$$EFOR_T = \left[\frac{\sum_{i=1}^{n} (FOH_i + EFDH_i)}{\sum_{i=1}^{n} (FOH_i + SH_i + SHNG_i + ERSFDH_i)} \right] \times 100$$

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9.17.2 Equivalent demand forced outage rate ($EFOR_d$)

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

9.17.3 Derating adjusted utilization forced outage probability (DAUFOP)

$$DAUFOP = \frac{\sum_{i=1}^{n} f_i \times (FO_i + FEMO_i + FEPO_i) + \sum_{i=1}^{n} O(FD) adj_i}{\sum_{i=1}^{n} f_i \times (FO_i + FEMO_i + FEPO_i) + O_i + O(FD)_i + O(SD)_i)}$$

NOTE—The Canadian Electricity Association (CEA) does not report this index for a group of units.

9.18 Equivalent planned outage factor (EPOF)

$$EPOF = \frac{\sum_{i=1}^{n} (POH_i + EPDH_i)}{\sum_{i=1}^{n} PH_i} \times 100$$

9.19 Equivalent unplanned outage factor (EUOF)

$$EUOF = \frac{\sum_{i=1}^{n} (FOH_i + EFDH_i + MOH_i + EMDH_i)}{\sum_{i=1}^{n} PH_i} \times 100$$

9.20 Equivalent forced outage factor (EFOF)

$$EFOF = \frac{\sum_{i=1}^{n} (FOH_i + EFDH_i)}{\sum_{i=1}^{n} PH_i} \times 100$$

9.21 Equivalent maintenance outage factor (EMOF)

$$EMOF = \frac{\sum_{i=1}^{n} (MOH_i + EMDH_i)}{\sum_{i=1}^{n} PH_i} \times 100$$

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9.22 Starting reliability (SR)

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

9.23 Cycling rate (CR) or average run time (ART)

$$CR = \frac{\sum_{i=1}^{n} (\text{Number of actual unit starts})_i}{\sum_{i=1}^{n} SH_i}$$

$$ART = 1 / CR$$

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10. Capacity-weighted calculations for group performance indexes

When measuring the performance of a fleet of units of dissimilar size and/or duty cycle, capacity-weighting is sometimes believed to better reflect the contribution of each unit to the fleet's composite indexes.

Without weighting, smaller, infrequently run units will have the same impact on the performance indexes as larger, baseload units. However, there are also valid applications for using unweighted performance indexes, even for group statistics (see Clause 9 for unweighted performance indexes).

To weight a performance measure, one does not simply take each unit's performance measure (EFOR, for example) and multiply that measure by the weight, add these products up, and divide by the sum of the weights. Each term in the equation must be multiplied by the weight, and then all those products must be summed over *all the units* before the rest of the calculation is performed.

NMC is the most common weight used in pooling performance indexes and is used in the formulas in this clause. However, other weights are appropriate in some cases, particularly weights which consider the service period of the unit as well as its size.

Capacity-weighted equations are not necessary for capacity and output factors (i.e., GCF, NCF, GOF, NOF) because these factors are inherently energy-weighted. These equations are similar to those shown 8.12 through 8.15. However, when calculating these factors for a group of units (or a unit that has a varying capacity value over time), do not simply average these factors. Apply the equations in 10.12 through 10.15 for correct group performance measures.

NOTE—The Σ sign refers to summing the terms over each unit in the group, 1 to *n*.

10.1 Weighted planned outage factor (WPOF)

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

10.2 Weighted unplanned outage factor (WUOF)

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

10.3 Weighted forced outage factor (WFOF)

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

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10.4 Weighted maintenance outage factor (WMOF)

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

10.5 Weighted unavailability factor (WUF)

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

10.6 Weighted availability factor (WAF)

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

10.7 Weighted service factor (WSF)

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

10.8 Weighted seasonal derating factor (WSDF)

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

10.9 Weighted unit derating factor (WUDF)

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

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10.10 Weighted equivalent unavailability factor (WEUF)

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

10.11 Weighted equivalent availability factor (WEAF)

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

10.11.1 Weighted EAF excluding seasonal deratings (WEAFxs)

$$WEAFxs = \frac{\sum_{i=1}^{n} (AH_i \times NMC_i) - \sum_{i=1}^{n} (EUNDH_i \times NMC_i)}{\sum_{i=1}^{n} (PH_i \times NMC_i)} \times 100$$

10.12 Gross capacity factor (GCF)

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

10.13 Net capacity factor (NCF)

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

10.14 Gross output factor (GOF)

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

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10.15 Net output factor (NOF)

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

10.16 Weighted forced outage rate (WFOR)

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

10.16.1 Weighted forced outage rate total—generating or other functions ($WFOR_T$)

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

10.16.2 Weighted demand forced outage rate ($WFOR_d$)

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

10.16.3 Weighted utilization forced outage probability (WUFOP)

$$WUFOP = \frac{\sum_{i=1}^{n} f_i \times NMC_i \times (FO_i + FEMO_i + FEPO_i)}{\sum_{i=1}^{n} f_i \times NMC_i \times (FO_i + FEMO_i + FEPO_i) + O_i + O(FD)_i + O(SD)_i)}$$

10.17 Weighted equivalent forced outage rate (WEFOR)

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

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10.17.1 Weighted equivalent forced outage rate total—generating or other functions ($WEFOR_T$)

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

10.17.2 Weighted equivalent demand forced outage rate ($WEFOR_d$)

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

10.17.3 Weighted derating adjusted utilization forced outage probability (WDAUFOP)

$$WDAUFOP = \frac{\sum_{i=1}^{n} f_i \times NMC_i \times (FO_i + FEMO_i + FEPO_i) + \sum_{i=1}^{n} NMC_i \times O(FD)adj_i}{\sum_{i=1}^{n} f_i \times NMC_i \times (FO_i + FEMO_i + FEPO_i) + O_i + O(FD)_i + O(SD)_i)}$$

NOTE—CEA does not report this index for a group of units.

10.18 Weighted equivalent planned outage factor (WEPOF)

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

10.19 Weighted equivalent unplanned outage factor (WEUOF)

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

10.20 Weighted equivalent forced outage factor (WEFOF)

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

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10.21 Weighted equivalent maintenance outage factor (WEMOF)

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

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Annex A

(informative)

Correlation between unit state and capacity derating definitions

Table A.1 correlates the definitions used in this edition of IEEE Std 762 with the definitions used by the previous edition of this standard.

Table A.1—Current and former terms

IEEE Std 762-2006	IEEE Std 762-1987
Available	No change
In service	No change
In-service nongenerating mode	Not defined
Reserve shutdown	No change
Unavailable	No change
Basic planned outage	No change
Extended planned outage	No change
Unplanned outage	No change
Class 0 (starting failure)	No change
Class 1 (immediate)	No change
Class 2 (delayed)	No change
Class 3 (postponed)	No change
Basic maintenance outage	Class 4 (deferred)
Extended maintenance outage	Not defined
Deactivated shutdown	No change
Seasonal derating	No change
Unit derating	No change
Planned derating (basic or extended)	No change
Unplanned derating	No change
Class 1 (immediate)	No change
Class 2 (delayed)	No change
Class 3 (postponed)	No change
Maintenance derating	Class 4 (maintenance derating)
Actual unit starts	Starting successes

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Annex B

(informative)

Transitions between active states

An active unit is either available or unavailable, per Clause 4, which defines these two primary unit states:

— Available (see 4.1.1)

— Unavailable (see 4.1.2)

These two states are mutually exclusive and exhaustive. A unit will be in exactly one of these states at all times. Thus, these states divide calendar time into no overlapping segments.

The available and unavailable states are each divided into additional, mutually exclusive states. The available state is divided into in-service and reserve shutdown states, and the unavailable state is divided into planned and unplanned outage states. These four secondary states, together with the deactivated shutdown state, also form a mutually exclusive and exhaustive set.

Finally, the planned outage state is divided into basic and extended planned outage states. Also, the unplanned outage state is divided into five outage classes, according to the urgency with which the outage is initiated. Like the other states, the unplanned outage classes are defined to be mutually exclusive. The unplanned outage state "maintenance" can be further divided into basic and extended states.

The unit state structure can also be described by starting with the lowest level states. Thus, there are ten basic states:

These basic states are defined to be mutually exclusive and exhaustive. By grouping various basic states together, each of the secondary and primary states can be formed.

a) In service
b) Reserve shutdown
c) Planned outage (basic)
d) Planned outage (extended)
e) Unplanned outage Class 0
f) Unplanned outage Class 1
g) Unplanned outage Class 2
h) Unplanned outage Class 3
i) Maintenance outage (basic)
j) Maintenance outage (extended)

Table B.1 shows the transitions between contiguous states that are permissible. However, detailed definitions for the transition events in Table B.1 have not been included in this standard. In the actual reporting of generating unit performance, the transition event occurrence times are in fact reported. From these times, the state duration times are then calculated. Therefore, the reporting instructions that implement the collection of unit performance data should give careful consideration to defining precisely and clearly the exact point in time at which the various transitions take place.

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Table B.1—State transition matrix

FROM State	TO State								
	Class 1	**Class 2**	**Class 3**	**Class 0**	**Maintenance**	**Planned**	**Extended**	**RS**	**Derating**
Class 1 Unplanned Outage (Immediate)	Yes	No	No	Yes	Yes	Yes	No	Yes	
Class 2 Unplanned Outage (Delayed)	Yes	No	No	Yes	Yes	Yes	No	Yes	
Class 3 Unplanned Outage (Postponed)	Yes	No	No	Yes	Yes	Yes	No	Yes	
Class 0 Unplanned Outage (Starting Failure)	Yes	No	No	Yes	Yes	Yes	No	Yes	
Maintenance Outage	Yes	No	No	Yes	Yes	Yes	Yes	Yes	
Planned Outage	Yes	No	No	Yes	No	Yes	Yes	Yes	
Extended – Planned or Maintenance	Yes	No	No	Yes	No	No	Yes	Yes	
Reserve Shutdown (RS)	Yes	No	No	Yes	Yes	Yes	No	Yes	
D1 – Derating Immediate	*IEEE Std 762 does not recognize transition to/of deratings from/to other event types except as shown.*								No
D2 – Derating Delayed									No
D3 – Derating Postponed									No
D4 – Derating Maintenance									Yes
PD – Derating Planned									Yes
DE – Derating Extended									Yes

"YES" denotes that a change from one unit state to another without intervening synchronization is permissible and the end date of the first state can be the same as the start date of the successive state. "NO" indicates that there is no relationship between states and some period of time must exist between the end of the first state before another state may begin.

When there is no intervening synchronization between states**,** the start time of the successive **s**tate is the same as the end time of the immediately preceding state. The change in unit state typically does not occur until the full term of the preceding state has ended.

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Annex C

(informative)

Relationships between period-hour-based performance indexes

For purposes of measuring and improving the performance of individual generating units, it is common to emphasize measures that are based on period hours. The performance indexes in Clause 8 provide a unified set of period-hour-based indexes (called factors) as follows:

- AF = availability factor
- EAF = equivalent availability factor
- EUF = equivalent unavailability factor
- FOF = forced outage factor
- MOF = maintenance outage factor
- POF = planned outage factor
- SDF = seasonal derating factor
- UDF = unit derating factor
- UF = unavailability factor
- UOF = unplanned outage factor = FOF + MOF

These indexes are unified in the sense that they are related in the following ways:

$$EAF = AF - (UDF + SDF) \tag{C.1}$$

Equivalent availability can be obtained by subtracting the unit derating factor and the seasonal derating factor from the availability factor.

$$\mathrm{EUF} = \mathrm{UF} + \mathrm{UDF} \tag{C.2}$$

Equivalent unavailability can be obtained by adding the unit derating factor, but not the seasonal derating factor, to the unavailability factor.

$$\mathrm{AF} + \mathrm{UF} = 100\% \tag{C.3}$$

The availability and unavailability factors add to 100%.

$$\mathrm{EAF} + \mathrm{EUF} + \mathrm{SDF} = 100\% \tag{C.4}$$

Equivalent availability, equivalent unavailability, and seasonal derating factor also add to 100%. However, equivalent availability and equivalent unavailability alone do not, in general, add to 100% because this sum does not include the effect of seasonal deratings.

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$$UF = POF + UOF \tag{C.5}$$

The unavailability factor is the sum of the planned and unplanned outage factors. (The unplanned outage factor is the sum of maintenance and forced outage factors.)

$$EUF = POF + UOF + UDF \tag{C.6}$$

Substituting Equation (C.5) into Equation (C.2) shows that the equivalent unavailability factor is the sum of the planned and unplanned outage factors and the unit derating factor.

$$SDF + EAF + POF + UOF + UDF = 100\% \tag{C.7}$$

Substituting Equation (C.6) into Equation (C.4) shows that there are four recognized sources of energy loss: planned outages (full), unplanned outages (full), unit deratings, and seasonal deratings. Each energy loss is represented by a separate index: POF, UOF, UDF, and SDF, respectively.

These indexes are defined to be additive. Therefore, the total per-unit energy loss is the sum of the four indexes, and the remaining per-unit energy not lost is called equivalent availability factor (EAF).

In order for the four energy loss indexes to be additive, as in Equation (C.7), it is necessary that the capacity loss due to each source be separated. In other words, for example, a unit cannot be simultaneously subject to full outage and unit derating.

Similarly, a unit cannot be simultaneously subject to both seasonal derating and full outage. In order to achieve nonoverlapping energy definitions, the IEEE 762 Working Group agreed to assign full (maximum) unit capacity to the full outage state. In other words, both unit deratings and seasonal deratings are considered to end when a full outage starts, as far as the calculation of the unit derating factor and the seasonal derating factor are concerned.

In order to further illustrate the relationship between the period-hour-based performance indexes, Figure C.1 shows a capacity versus time diagram (all capacity values must be either gross or net). The total height of the diagram is gross maximum capacity (GMC), and the total width of the diagram is period hours (PH). Thus, the total area Y of the diagram is

$$Y = GMC \times PH$$

This is the total megawatthour of energy that could have been generated during the period if operating continuously at maximum capacity.

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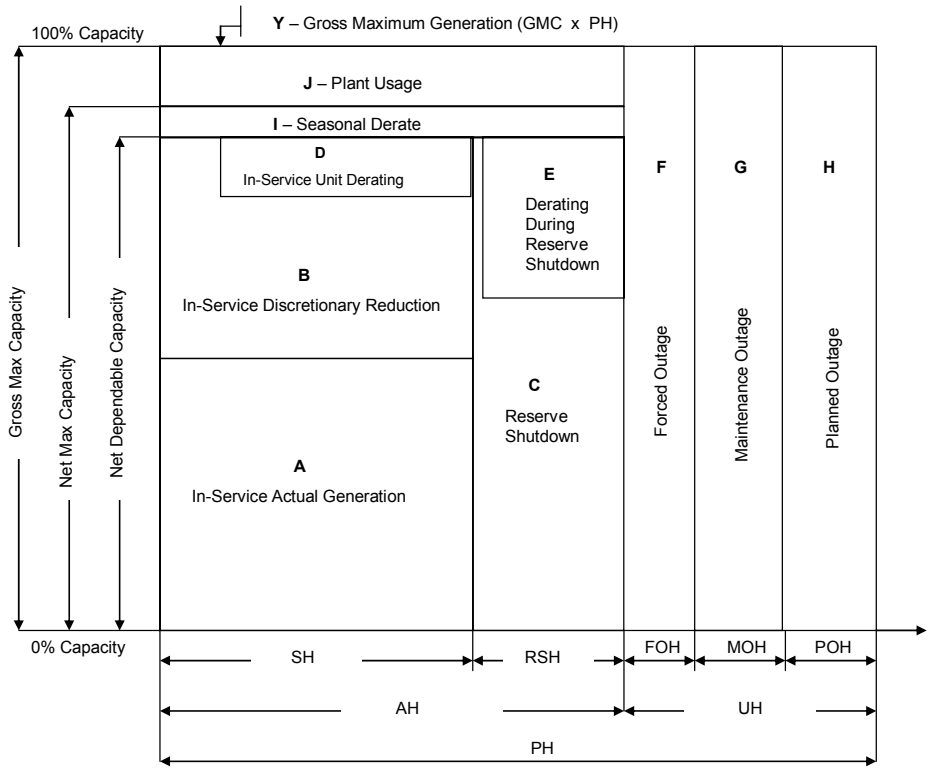

Figure C.1—Area for categories of capacity versus period hours

The area *Y* is divided into several vertical segments by the various time designations in Clause 6. The vertical segments involving available hours are further divided into sections to show the energy associated with seasonal derating, unit derating, discretionary reduction, and actual generation. Because these areas represent energy, all of the performance factors in Clause 8 and Clause 10 that are based on period hours (PH) can be expressed as simple ratios of the areas in Figure C.1 as follows:

Time indexes

$$FOF = \frac{F}{Y} \times 100$$

$$MOF = \frac{G}{Y} \times 100$$

$$UOF = FOF + MOF = \frac{F+G}{Y} \times 100$$

$$POF = \frac{H}{Y} \times 100$$

$$UF = \frac{F+G+H}{Y} \times 100$$

$$AF = \frac{A+B+C+D+E+I}{Y} \times 100$$

$$SF = \frac{SH}{PH} = \frac{(A+B+D)}{Y} \times 100$$

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Energy indexes

$$UDF = \frac{D+E}{Y} \times 100$$

$$EAF = \frac{A+B+C}{Y} \times 100$$

$$EUF = \frac{D+E+F+G+H}{Y} \times 100$$

$$SDF = \frac{I}{Y} \times 100$$

$$GCF = \frac{(A+J)}{Y} \times 100$$

$$NCF = \frac{A}{Y} \times 100$$

$$CapacityFactor = \frac{A}{Y} \times 100$$

NOTE--Capacity factor is GCF or NCF depending on gross or net basis used for capacity.

Using the areas in Figure C.1, a hierarchy of capacity limitation factors can be developed as follows:

$$AF = \frac{A+B+C+D+E+I}{Y} \times 100 = \text{average fraction of maximum capacity available,}$$

as limited only by full outages (exclude only areas F, G, and H)

$$EAF = \frac{A+B+C}{Y} \times 100 = \text{average fraction of maximum capacity available,}$$

as limited by full outages, as well as by unit and seasonal deratings
(exclude also areas D, E, and I)

$$CapacityFactor = \frac{A}{Y} \times 100 = \text{average fraction of maximum capacity actually generated}$$

(exclude also areas B and C)

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Annex D

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Outside plant management control

The electric industry in Europe and other parts of the world has changed reporting practices to distinguish losses of generation caused by problems within and outside plant management control. However, after reviewing the approaches used by others, the IEEE 762 Working Group does not feel that such a distinction is necessary in all reporting systems. If such a distinction is to be made within a particular reporting system, the outage events to be excluded or included may be distinguished based on location or cause, or both.

Some causes are internal to the plant operation and equipment while others are external and may be appropriate to exclude when calculating performance indexes for some reporting purposes. This standard does not set nor recommend a particular boundary between the generator and the transmission and/or distribution to determine what equipment is "outside plant management control." Such an equipment boundary for a particular plant or generating unit may include all equipment up to the following:

a) The high-voltage terminals of the generator step-up (GSU) transformer and the station service transformers, as shown in Figure D.1

b) The GSU transformer or distribution system (load) side of the generator-voltage circuit breakers

c) Another location that may be reasonable considering the design and operating practices of the generating unit

It may or may not be appropriate to assume that all problems within the power station boundary are within plant management control. Therefore, rather than attempt to exhaustively identify the responsibilities of plant management, the more feasible approach is to specify certain outage causes as outside plant management control. With this approach, it is necessary within each particular reporting system to clearly establish the outage causes that are and are not deemed to be under plant management control. The following examples are offered as causes that may be considered as external, i.e., outside of plant management control.

— Grid connection or substation failure

— Transmission operating/repair errors

— Acts of terrorism or war

— Acts of nature, such as ice storms, tornadoes, winds, and lightning, whether inside or outside the plant boundary

— Special environmental limitations, such as low cooling pond level, water intake restrictions, opacity or nitrogen oxides (NOx) limit reductions that could not be prevented by operator action. This situation should be limited to acts of nature where the equipment is working within design specifications and not failure to maintain the equipment or operate it correctly.

— Interruption of fuel supply or curtailment of water flows below those reasonably expected. However, if the operator elected to contract for fuels on an interruptible basis allowing the fuel supplier to withhold fuel and sell it to others (e.g., part of the plant fuel cost-saving measure), then the lack of fuel is under management control and is not applicable to this case.

— Strikes or labor disputes, particularly strikes against suppliers or transportation carriers under separate management from the generating plant under consideration. However, grievances within the plant that result in a strike are under plant management control, and lost energy production is

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included as a penalty against the plant. If a strike occurs during an outage, any outage extensions are included as energy losses as long as the unit is incapable of being restarted.

Seasonal variations in gross dependable capacity due to ambient air or cooling water temperature variations are not losses of energy or capacity; therefore, no determination of whether they are outside plant management control need be made.

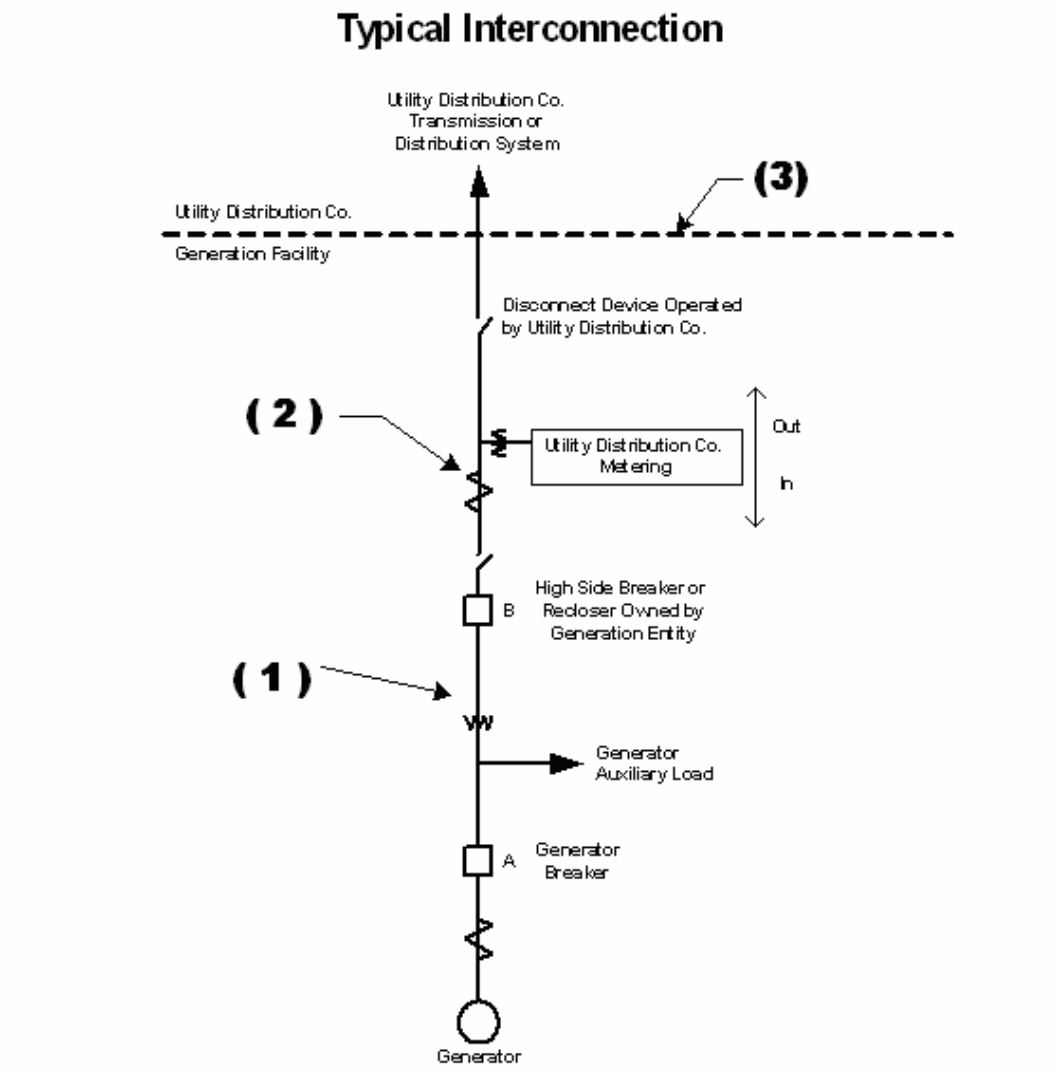

Figure D.1—Physical boundary of outside plant management control

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Annex E

(informative)

Glossary of terms and abbreviations

Abbreviation	Reference	Term
ACTH	6.2	Active hours
AAG	7.1	Actual generation
AF	8.6, 9.6	Availability factor
AG	7.3	Available generation
AH	6.4	Available hours
ART	8.25, 9.23	Average run time
CR	8.25, 9.23	Cycling rate
DAFOR	8.17.4	Derating adjusted forced outage rate
DAUFOP	8.17.3, 9.17.3	Derating adjusted utilization forced outage probability
DG	7.7	Derated generation
DSH	6.3	Deactivated shutdown hours
E	6.18	Equivalent hours
EAF	8.11, 9.11	Equivalent availability factor
EAF_{XS}	8.11.1, 9.11.1	Equivalent availability factor excluding seasonal deratings
EFDH	6.18.1	Equivalent forced derated hours
EFOF	8.20, 9.20	Equivalent forced outage factor
EFOR	8.17, 9.17	Equivalent forced outage rate
$EFOR_d$	8.17.2, 9.17.2	Equivalent demand forced outage rate
$EFOR_T$	8.17.1, 9.17.1	Equivalent forced outage rate total—generating or other functions
EMDH	6.18.5, 8.19, 8.21	Equivalent maintenance derated hours
EMOF	8.21, 9.21	Equivalent maintenance outage factor
EPDH	6.18.4, 8.18	Equivalent planned derated hours
EPOF	8.18, 9.18	Equivalent planned outage factor
ERSFDH	6.18.2	Equivalent reserve shutdown forced derated hours
ESDH	8.11, 9.11, 10.11	Equivalent seasonal derated hours
EUF	8.10, 9.10	Equivalent unavailability factor
EUNDH	6.18.6, 7.4, 7.7, 8.9, 8.10, 8.11, 8.11.1, 9.11, 9.11.1, 10.11, 10.11.1	Equivalent unit derated hours
EUOF	8.19, 9.19	Equivalent unplanned outage factor
f	6.10.1	Demand factor
FDH	6.15	Forced derated hours
FOF	8.3, 9.3	Forced outage factor
FOH	6.10	Forced outage hours
FOR	8.16, 9.16	Forced outage rate
FOR_d	6.10.2, 8.16.2, 9.16.2	Demand forced outage rate
FOR_T	8.16.1, 9.16.1	Forced outage rate total—generating or other functions

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Abbreviation	Reference	Term
GAAG	7.1, 9.12, 9.14, 10.12, 10.14	Gross actual generation
GCF	8.12, 9.12	Gross capacity factor
GMC	5.1	Gross maximum capacity
GMG	7.2	Gross maximum generation
GOF	8.14, 9.14, 10.14	Gross output factor
IFDH	6.15.1	In-service forced derated hours
IMDH	6.16.1	In-service maintenance derated hours
IPDH	6.13.1	In-service planned derated hours
IUDH	6.14.1	In-service unplanned derated hours
IUNDH	6.12.1	In-service unit derated hours
MC	5.1	Maximum capacity
MDH	6.16	Maintenance derated hours
MFOD	8.23.1	Mean forced outage duration
MG	7.2	Maximum generation
MMOD	8.23.2	Mean maintenance outage duration
MOF	8.4, 9.4	Maintenance outage factor
MOH	6.11	Maintenance outage hours
MPOD	8.23.3	Mean planned outage duration
MSTFO	8.22.1	Mean service time to forced outage
MSTMO	8.22.2	Mean service time to maintenance outage
MSTPO	8.22.3	Mean service time to planned outage
NAAG	7.1, 9.13, 9.15, 10.13, 10.15	Net actual generation
NCF	8.13, 9.13	Net capacity factor
NMC	5.1	Net maximum capacity
NMG	7.2	Net maximum generation
NOF	8.15, 9.15, 10.15	Net output factor
PDH	6.13	Planned derated hours
PH	6.2	Period hours
POF	8.1, 9.1	Planned outage factor
POH	6.8	Planned outage hours
RG	7.6	Reserve generation
RSFDH	6.15.2	Reserve shutdown forced derated hours
RSH	6.6	Reserve shutdown hours
RSMDH	6.16.2	Reserve shutdown maintenance derated hours
RSPDH	6.13.2	Reserve shutdown planned derated hours
RSUDH	6.14.2	Reserve shutdown unplanned derated hours
RSUNDH	6.12.2	Reserve shutdown unit derated hours
SD	6.19	Service date
SDF	8.8, 9.8	Seasonal derating factor
SDH	6.17	Seasonal derated hours
SF	8.7, 9.7	Service factor

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Abbreviation	Reference	Term
SH	6.5, 6.10.1, 6.18.3, 8.14, 8.16.1, 8.16.2, 8.16.3, 8.17, 8.22.1, 8.22.2, 8.22.3, 9.15, 9.16.1, 9.16.2	Service hours
SHNG	6.5.1, 8.16.1, 8.7, 9.16.1, 9.17.1, 10.16.1, 10.17.1	Service hours nongenerating
SR	8.24, 9.22	Starting reliability
SUG	7.5	Seasonal unavailable generation
TH	6.1	Total hours
UDH	6.14	Unplanned derated hours
UDF	8.9, 9.9	Unit derating factor
UF	8.5, 9.5	Unavailability factor
UFOP	8.16.3, 9.16.3	Utilization forced outage probability
UG	7.4	Unavailable generation
UH	6.7	Unavailable hours
UNDH	6.12	Unit derated hours
UOF	8.2, 9.2	Unplanned outage factor
UOH	6.9	Unplanned outage hours
WAF	10.6	Weighted availability factor
WDAUFOP	10.17.3	Weighted derating adjusted utilization forced outage probability
WEAF	10.11	Weighted equivalent availability factor
$WEAF_{XS}$	10.11.1	Weighted equivalent availability factor excluding seasonal deratings
WEFOF	10.20	Weighted equivalent forced outage factor
WEFOR	10.17	Weighted equivalent forced outage rate
$WEFOR_d$	10.17.2	Weighted equivalent demand forced outage rate
$WEFOR_T$	10.17.1	Weighted equivalent forced outage rate total—generating or other functions
WEMOF	10.21	Weighted equivalent maintenance outage factor
WEPOF	10.18	Weighted equivalent planned outage factor
WEUF	10.10	Weighted equivalent unavailability factor
WEUOF	10.19	Weighted equivalent unplanned outage factor
WFOF	10.3	Weighted forced outage factor
WFOR	10.16	Weighted forced outage rate
$WFOR_T$	10.16.1	Weighted forced outage rate total—generating or other functions
WMOF	10.4	Weighted maintenance outage factor
WPOF	10.1	Weighted planned outage factor
WSDF	10.8	Weighted seasonal derating factor
WSF	10.7	Weighted service factor
WUDF	10.9	Weighted unit derating factor
WUF	10.5	Weighted unavailability factor
WUFOP	10.16.3	Weighted utilization forced outage probability
WUOF	10.2	Weighted unplanned outage factor

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Annex F

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Pooling methodologies for $EFOR_d$

The purpose of this annex is to review methods currently used for grouping or pooling groups of units for calculating equivalent demand forced outage rate ($EFOR_d$). This annex is limited to $EFOR_d$ only because this indicator is used by many groups as a measure of unit performance for the following:

— Interpreting $EFOR_d$ as probability of forced outage of a unit when needed. Capacity weighted equivalent demand forced outage rate ($WEFOR_d$) is used as an estimator of the mean of the capacity outage probability distribution that is used in loss of load probability (LOLP) calculations. This has been extensively used in analytical methods for LOLP calculations using mean, variance, and additional moments of the distribution.

— Defining "unforced capacity" requirements as used by some entities. Unforced capacity is defined as unit rating multiplied by the quantity (1 – $EFOR_d$). This is also the capacity product traded daily, monthly, and yearly with a clearing price.

Thus, there is a need to know that several different methods are currently being used to calculate this important index.

The user of pooled $EFOR_d$ values should be aware of which units are being pooled. Most pooling is conducted on "peer groups" of similar unit types and megawatt sizes. However, some companies will combine nonhomogeneous units (e.g., base-loaded and peaking, fossil-steam and nuclear) into one group for their own purposes. It is beyond the scope of this standard to provide guidelines about what should constitute a peer group. Therefore, it is up to the user of the $EFOR_d$ pooled statistic to ask questions about what units are in each pooled $EFOR_d$.

Unweighted and weighted pooling methods for $EFOR_d$ are given by 9.17.2 and 10.17.2, respectively. One additional unweighted and two additional capacity-weighted pooling methods are shown that also merit consideration. It should be noted that simply averaging $EFOR_d$ values of a population of units is not considered valid because the denominator for each unit will be different.

F.1 Unweighted pooling

F.1.1 Method I: Pooled unit hours

Pooled $EFOR_d$ values calculated using this method are significantly affected by individual units with extreme $EFOR_d$ that have very few service hours (SH), but relatively many derated hours.

This method of pooling is used in 10.17.2.

$$EFOR_d = \frac{\sum_{i=1}^{n} f_i \times FOH_i + \sum_{i=1}^{n} f_{pi} \times EFDH_i}{\sum_{i=1}^{n} SH_i + \sum_{i=1}^{n} f_i \times FOH_i}$$

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where for unit *i*

$r_i = FOH_i$ / (number of $FO)_i$ = average forced outage duration

$T_i = RSH_i$ / (number of attempted starts)$_i$ = average reserve shutdown time

$D_i = SH_i$ / (number of actual starts)$_i$ = average demand time

$f_i = (1/r_i + 1/T_i) / (1/r_i + 1/T_i + 1/D_i)$ = demand factor

$f_{pi} = SH_i / AH_i$

$f_i \times FOH_i = FOH_{di}$ = forced outage hours overlapping the period of demand for the unit to operate (see 6.10.2)

$f_{pi} \times EFDH_i = EFDH_{di}$ = equivalent forced derated hours overlapping the period of demand for the unit to generate (see 6.18.3)

F.1.2 Method II: Group demand factors, pooled unit hours

By calculating the demand factors over the group's total forced outage hours (FOH), service hours (SH), reserve shutdown hours (RSH), and starts, the demand factor is "smoothed" and not subject to undue influence by one or more units having very high or very low hours or starts. This method may be more appropriate for forecasting performance of a unit similar to units in a group with known similar demand patterns, but significant variations in individual performance. With larger populations or longer study time periods, the difference between the results of Method I and Method II should decrease.

$$EFOR_d = \frac{\left(f_t \times \sum_{i=1}^{n} FOH_i + f_{pt} \times \sum_{i=1}^{n} EFDH_t \right)}{\left(\sum_{i=1}^{n} SH_i + f_t \times \sum_{i=1}^{n} FOH_i \right)}$$

where for the total population *t*

$r_t = \sum FOH / \sum$ number of FO = average forced outage duration

$T_t = \sum RSH / \sum$ number of attempted starts = average reserve shutdown time

$D_t = \sum SH / \sum$ number of actual starts = average demand time

$f_t = (1/r_t + 1/T_t) / (1/r_t + 1/T_t + 1/D_t)$

$f_{pt} = \sum SH / \sum AH$ = equivalent full forced outage hours that occur during times of demand

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F.1.3 Sample calculation of pooled $EFOR_d$ using the unweighted methods

The impact of alternative unweighted $EFOR_d$ pooling methodologies is demonstrated using typical, but hypothetical, data. This comparison of the two pooling methodologies is based on the sample data and calculations found in the following two tables: Table F.1 shows the raw data reported by five steam turbine generating units. Table F.2 shows the intermediate calculated values used to produce the individual unit $EFOR_d$. In the interest of simplicity, it is assumed that data for each unit were complete, allowing the $EFOR_d$ calculation without the need for any substituted values.

Table F.1—Raw data

Unit	Capacity (MW)	SH	RSH	AH	Actual starts	Attempted starts	EFDH	FOH	FO events
48	55	4856	2063	6918	34	34	146.99	773	12
49	75	4556	1963	6519	31	31	110.51	407	5
50	120	3942	3694	7635	36	36	19.92	504	11
51	153	6460	516	6978	17	18	131.03	340	14
52	180	6904	62	6968	14	16	35.81	138	12
Totals	583	26 718	8298	35 018	132	135	444.26	2162	54

Table F.2—Calculated intermediate values

Unit	1/r	1/t	1/D	f	$f \times FOH = FOH_d$	f_p	$f_p \times EFDH = EFDH_d$	$EFOR_d$
48	0.0155	0.0165	0.0070	0.8205	634.247	0.7019	103.178	13.432%
49	0.0123	0.0158	0.0068	0.8049	327.608	0.6989	77.233	8.290%
50	0.0218	0.0097	0.0091	0.7756	390.920	0.5163	10.285	9.259%
51	0.0412	0.0349	0.0026	0.9666	328.630	0.9258	121.303	6.628%
52	0.0870	0.2581	0.0020	0.9942	137.194	0.9908	35.481	2.452%
Totals					1818.598		347.480	

F.1.3.1 Method I

Method I uses the sums of service hours (SH), FOH_d, and $EFDH_d$ and gives a pooled $EFOR_d$ of 7.591%.

$$\frac{(1818.598+347.480)}{(26718+1818.598)} = 7.591\%$$

F.1.3.2 Method II

Method II uses the sums of forced outage hours (FOH), reserve shutdown hours (RSH), service hours (SH), and available hours (AH), and the total numbers of FO, attempted starts, and actual starts to calculate r_t, T_t, and D_t and then f_t and f_{pt}.

$r_t = \sum FOH / \sum$ number of FO = 2162 / 54 = 40.03. $1/r_t$ = 0.0250

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$T_t = \sum RSH / \sum$ number of attempted starts = 8298 / 135 = 61.47. $1/T_t = 0.0163$

$D_t = \sum SH / \sum$ number of actual starts = 26718 / 132 = 202.41. $1/D_t = 0.0049$

$f_t = (1/r_t + 1/T_t) / (1/r_t + 1/T_t + 1/D_t) = (0.0250 + 0.0163) / (0.0250 + 0.0163 + 0.0049) = 0.8930$

$f_{pt} = \sum SH / \sum AH = 26718 / 35018 = 0.7630$

Finally, Method II calculates a pooled $EFOR_d$ of 7.922%.

$$EFOR_d = (f_t \times \sum FOH + f_{pt} \times \sum EFDH) / (\sum SH + f_t \times \sum FOH)$$

$$= (0.8930 \times 2162 + 0.7630 \times 444.26) / (26718 + 0.8930 \times 2162)$$

$$\frac{(1930.734 + 338.961)}{(1930.734 + 26718)} = 7.922\%$$

F.2 Capacity-weighted pooling

These methods weight time values and/or indexes by the capacity of the individual unit. NMC is suggested as the weighting measure in Clause 10. However, the techniques would be the same for any other weight, including those considering the service period of the unit.

In this example, note that there is a strong correlation between unit performance (measured by $EFOR_d$) and unit size. The larger units in the pool have a lower $EFOR_d$. This was done to illustrate the impact of different unweighted and weighted pooling techniques, particularly the fact that larger units will tend to dominate a weighted index. No conclusions should be drawn that larger units perform better than smaller ones in practice.

F.2.1 Method I: Capacity weighted pooled unit hours

This method of pooling is used in 10.17.2.

$$WEFOR_d = \frac{\sum_{i=1}^{n} WFOH_{di} + WEFDH_{di}}{\sum_{i=1}^{n} WFOH_{di} + WSH_i}$$

F.2.2 Method II: Group demand factors, capacity weighted pooled unit hours

$$WEFOR_d = \frac{\left(\left(f_t \times \left(\sum_{i=1}^{n} WFOH_{di}\right)\right) + \left(f_{pt} \times \left(\sum_{i=1}^{n} WEFDH_{di}\right)\right)\right)}{\left(\sum_{i=1}^{n} WSH_i + \left(f_t \times \sum_{i=1}^{n} WFOH_{di}\right)\right)}$$

where

f_t and f_{pt} are defined as for the unweighted method

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F.2.3 Method III: Capacity weighted average of individually calculated $EFOR_d$

$$WEFOR_d = \frac{\sum_{i=1}^{n} (\text{Capacity rating}_i \times EFOR_{d_i})}{\sum_{i=1}^{n} \text{Capacity rating}_i}$$

F.2.4 Sample calculation of pooled $EFOR_d$ using the weighted methods

The raw data are the same as in the first example. Table F.3 shows the weighted values used in the calculations.

Table F.3—Weighted values used in $EFOR_d$ formula

Unit	Capacity (MW)	WSH	WFOH	WEFDH	*f*	$WFOH_d$	f_p	$WEFDH_d$	$WEFOR_d$
48	55	267 080	42 515	8084	0.8205	34 884	0.7019	5675	7.387
49	75	341 700	30 525	8288	0.8049	24 571	0.6989	5792	6.217
50	120	473 040	60 480	2390	0.7756	46 910	0.5163	1234	11.111
51	153	988 380	52 020	20 048	0.9666	50 280	0.9258	18 559	10.140
52	180	1 242 720	24 840	6446	0.9942	24 695	0.9908	6387	4.414
Totals	583	3 312 920	210 380	45 256		181 340		37 647	39.271

Weighted values in Table F.3 are denoted with preceding w to indicate that the value has been weighted by its NMC. Individual unit *f* and f_p values are not weighted.

F.2.4.1 Method I

Method I uses the sums of weighted service hours, forced outage hours, and $EFDH_d$ (designated WSH, WFOH, $WEFDH_d$ in Table F.3) and gives a pooled $WEFOR_d$ of 6.267%.

$$\frac{(181340 + 37647)}{(3312920 + 181340)} = 6.267\%$$

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F.2.4.2 Method II

Method II calculates f_t and f_{pt} in the same manner as for the unweighted case (0.8930 and 0.7630, respectively) and multiplies the total WFOH and WEFDH to calculate $WFOH_d$ and $WEFDH_d$. It then uses the sums of the weighted reported data to represent the weighted average unit and calculates the pooled $EFOR_d$ to be 5.487%.

$$\frac{\left(\left(0.8930\times 181340\right)+\left(0.7630\times 37647\right)\right)}{\left(3312920+\left(0.8930\times 181340\right)\right)}=5.487\%$$

F.2.4.3 Method III

Method III weights the individual $EFOR_d$ values by the unit capacity ($EFOR_d \times MW$) and uses the total capacity to calculate a weighted average $EFOR_d$ as 6.736%.

$$\frac{39.291}{583}=6.736\%$$

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Annex G

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Limiting conditions for forced outage indexes

Typically performance indexes are calculated using performance data over at least a year. However, if any of the variables SH (service hours), FOH (forced outage hours), or RSH (reserve shutdown hours) is zero in a period, one practice has been to assign a default value of 0.001 for computing indexes. Similarly, if any of the variables "number of FOH occurrences," "number of attempted starts," or "number of actual starts" is zero in the period, a value of 1 is assigned for computing indexes. The default values can give meaningless indexes in some cases as indicated in Table G.1. Discretion based on history and other factors may be used to estimate FOR_d and $EFOR_d$ even if they can be calculated using the equations in the standard in some cases.

Table G.1—Limiting conditions for forced outage indexes

Case	SH	FOH	RSH	FOR_d	$EFOR_d$
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

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[4] Information about NERC GADS can be obtained from the North American Electric Reliability Council, 116-390 Village Boulevard, Princeton, New Jersey 08540-5721, USA (http://www.nerc.com).

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