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An American National Standard

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

Sponsor
Power Systems Engineering Committee
of the
IEEE Power Engineering Society

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Foreword

(This Foreword is not a part of ANSI/IEEE Std 762-1987, 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 40 years. Initially, only a few terms, such as *forced outage rate* and *scheduled outage rate*, were needed. The increased focus on generating unit performance in recent years has caused regulatory agencies and the industry to place a greater emphasis on performance measures.

These contemporary constraints have amplified the difficulties that evolved from having generating unit statistics compiled by different organizations to meet their own specific needs. In the past these difficulties have included the interpretation of data within a given system by an outside agency and the correlation of data among the various systems.

The current problems have made clear the need for a standard to overcome these difficulties by providing terminology and indexes for use in existing data systems or in future systems. This standard is directed toward allowing for a meaningful exchange of electric generating unit performance data while attempting to retain as much of existing systems as possible.

No attempt is made here to standardize or to recommend methodologies or procedures for the collection of unit performance data. Furthermore, no attempt is made here to address the special requirements of electric generating units limited by fuel supplies, resources such as water (hydro), or environmental restrictions. It is expected that the methods used will continue to vary from system to system according to individual needs. What is attempted is to specify certain common terms and indexes that must be obtainable from each data base to provide for a basis of information exchange.

The task force has attempted to keep the list of terms and indexes as brief as possible. Performance cannot be measured by a single parameter, and several indexes are required to indicate the ability of a generating unit to produce power when called upon. The use of any single index to measure the performance of a unit or a class of units is misleading. This requirement has necessitated the inclusion of all of the terms and indexes as given here.

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%, as described in Appendix C. Other indexes are not based on period hours. For example, in the statistic forced outage rate (see 7.16), (service hours + forced outage hours) is used as a base because forced outage rate is intended to estimate the probability of forced outage during the times when there is no planned or maintenance outage. For other than base load service, further modifications are needed to estimate this probability correctly. It is the intent of the task force to define 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.

This standard was prepared by the Power Plant Productivity Definitions Task Force of the Applications of Probability Methods Subcommittee of the Power Systems Engineering Committee, whose members were as follows:

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The task force wishes to dedicate this work to the memory of Veazey M.Cook, a pioneer in the application of generating unit outage data in system planning studies. The format and many of the terms used in this standard can be traced to Veazey Cook's work.

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CLAUSE PAGE

1. Purpose 1

2. Scope 1

3. Unit States 1

3.1 Active 2
3.2 Deactivated Shutdown 5

4. Capacity Terms 5

4.1 Maximum Capacity (MC) 5
4.2 Dependable Capacity 5
4.3 Available Capacity 6
4.4 Seasonal Derating 6
4.5 Unit Derating 6
4.6 Planned Derating 6
4.7 Unplanned Derating 6
4.8 Installed Nameplate Capacity 6

5. Time Designations and Dates 7

5.1 Available Hours (AH) 7
5.2 Service Hours (SH) 7
5.3 Reserve Shutdown Hours (RSH) 7
5.4 Unavailable Hours (UH) 7
5.5 Planned Outage Hours (POH) 7
5.6 Unplanned Outage Hours (UOH) 8
5.7 Forced Outage Hours (FOH) 8
5.8 Maintenance Outage Hours (MOH) 8
5.9 Deactivated Shutdown Hours (DSH) 8
5.10 Period Hours (PH) 8
5.11 Unit Derated Hours (UNDH) 8
5.12 Planned Derated Hours (PDH) 8
5.13 Unplanned Derated Hours (UDH) 8
5.14 Forced Derated Hours (FDH) 9
5.15 Maintenance Derated Hours (MDH) 9
5.16 Seasonal Derated Hours (SDH) 9
5.17 Equivalent Hours (E) 9
5.18 Deactivation Date 10
5.19 Reactivation Date 10

6. Energy Terms 10

6.1 Actual Generation (AAG) 10
6.2 Maximum Generation (MG) 10
6.3 Available Generation (AG) 10
6.4 Unavailable Generation (UG) 10
6.5 Seasonal Unavailable Generation (SUG) 11
6.6 Reserve Generation (RG) 11
6.7 Derated Generation (DG) 11

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CLAUSE PAGE

7. Performance Indexes 11

7.1 Planned Outage Factor (POF) 11
7.2 Unplanned Outage Factor (UOF) 11
7.3 Forced Outage Factor (FOF) 11
7.4 Maintenance Outage Factor (MOF) 12
7.5 Unavailability Factor (UF) 12
7.6 Availability Factor (AF) 12
7.7 Service Factor (SF) 12
7.8 Seasonal Derating Factor (SDF) 12
7.9 Unit Derating Factor (UDF) 12
7.10 Equivalent Unavailability Factor (EUF) 13
7.11 Equivalent Availability Factor (EAF) 13
7.12 Gross Capacity Factor (GCF) 13
7.13 Net Capacity Factor (NCF) 13
7.14 Gross Output Factor (GOF) 14
7.15 Net Output Factor (NOF) 14
7.16 Forced Outage Rate (FOR) 14
7.17 Equivalent Forced Outage Rate (EFOR) 14
7.18 Mean Service Time to Outage 14
7.19 Mean Outage Duration 15
7.20 Starting Reliability (SR) 15
7.21 Cycling Rate (CR) 15

Annex A Correlation Between Unit State and Capacity Derating Definitions in This Standard and Those Formerly Used by the Industry (Informative) 16

Annex B Transitions Between States (Informative) 17

Annex CRelationships Between Period-Hour-Based Performance Indexes (Informative) 19

Annex D Glossary of Terms and Abbreviations (Informative) 23

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An American National Standard

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

1. Purpose

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

2. Scope

This document standardizes terminology and indexes for reporting electric generating unit reliability, availability, and productivity performance measures. A generating unit includes all equipment up to the high-voltage terminal of the generator step-up transformer.

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 a unit is capable of providing service, and account for outage frequency and duration.

Productivity measures are concerned with the total power produced by a plant with respect to its potential power production. Therefore, productivity measures consider magnitude of outage as well as frequency and duration of outage.

NOTE — This standard was developed for application at the unit level; the definitions are applicable below the unit level in most cases. There are some exceptions, however, such as the definition of *in service*, which applies only at the unit level. Because of these exceptions, care should be taken when using this standard below the unit level.

3. Unit States

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

NOTE — The state definitions are related as shown in Fig 1. The transitions between states are described in Appendix B. The correlation between these definitions and those in use by the industry is shown in Appendix A.

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3.1 Active

The state in which a unit is in the population of units being reported on.

NOTE — A unit generally enters the active state on its service date.

3.1.1 Available

The state in which a unit is capable of providing service, whether or not it is actually in service and regardless of the capacity level that can be provided.

3.1.1.1 In Service

The state in which a unit is electrically connected to the system.

3.1.1.2 Reserve Shutdown

The state in which a unit is available but not in service.

NOTE — This is sometimes referred to as economy shutdown.

3.1.2 Unavailable

The state in which a unit is not capable of operation because of operational or equipment failures, external restrictions, testing, work being performed, or some 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.

3.1.2.1 Planned Outage

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

3.1.2.1.1 Basic Planned Outage

The planned outage state that is originally scheduled and of a predetermined duration.

3.1.2.1.2 Extended Planned Outage

The planned outage state that 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 has forced the extension of the planned outage, is to be classified as Class 1 unplanned outage (see 3.1.2.2.2). Startup failure would result in Class 0 unplanned outage (see 3.1.2.2.1).

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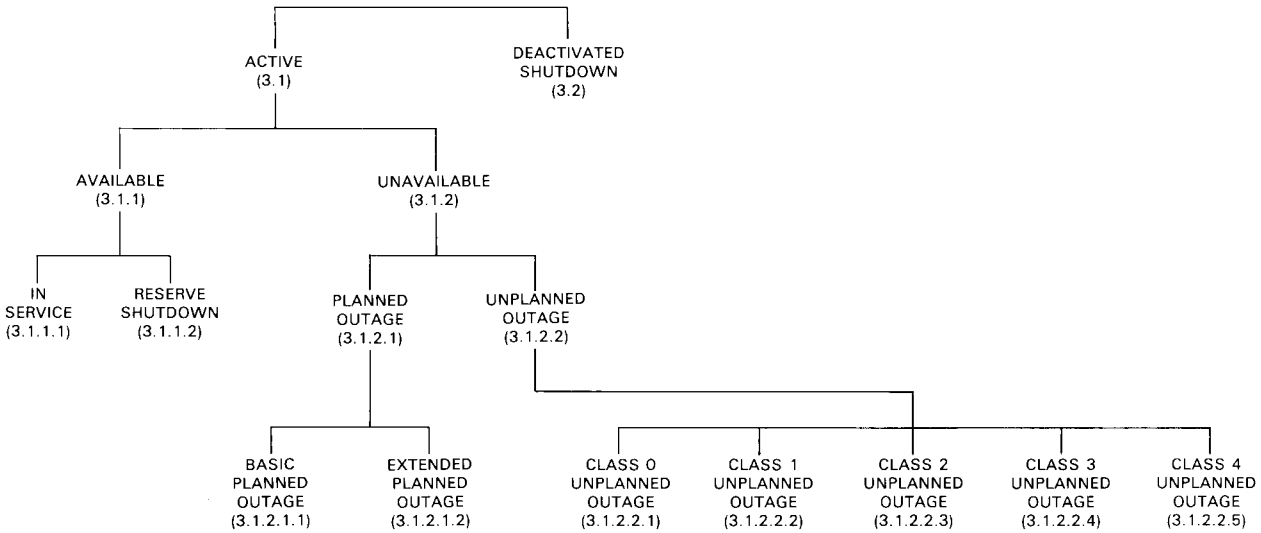

Figure 1—Relation Between Unit States

3.1.2.2 Unplanned Outage

The state in which a unit is unavailable but is not in the planned outage state.

NOTES:

1 — When an unplanned outage is initiated, the outage is to be classified according to one of five classes, as defined in 3.1.2.2.1 through 3.1.2.2.5. Unplanned outage Class 0 applies to a start-up failure and Class 1 applies to a condition requiring immediate outage. Also, unplanned outage starts when planned outage ends but is extended due to unplanned work. Classes 2, 3, and 4 apply to outages where some delay is possible in time of removal of the unit from service. The class (2, 3, or 4) of outage is to be determined by the amount of delay that can be exercised in the time of 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, outage starts when the unit is removed from service or is declared unavailable when it is not in service.

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.

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 — Unlike planned outages, unplanned outages do not have a fixed duration that can be estimated each year.

3.1.2.2.1 Class 0 Unplanned Outage (Starting Failure)

An outage that results from the unsuccessful attempt to place the unit in service (see 3.1.3.1).

3.1.2.2.2 Class 1 Unplanned Outage (Immediate)

An outage that requires immediate removal from the existing state.

NOTE — A Class 1 unplanned outage can be initiated from either the in-service or reserve shutdown states. A Class 1 unplanned outage can also be initiated from the planned outage state. See Note in 3.1.2.1.2.

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3.1.2.2.3 Class 2 Unplanned Outage (Delayed)

An outage that does not require immediate removal from the in-service state but requires removal within 6 h.

3.1.2.2.4 Class 3 Unplanned Outage (Postponed)

An outage that 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 — Classes 2 and 3 can only be initiated from the inservice state.

3.1.2.2.5 Class 4 Unplanned Outage (Deferred)

An outage that will allow a unit outage to be deferred beyond the end of the next weekend but requires that a unit be removed from the available state before the next planned outage.

3.1.2.3 Repair Urgency

When a planned or unplanned outage is initiated, the urgency with which repair activities are carried out is classified according to one of three classes as defined in 3.1.2.3.1 through 3.1.2.3.3.

3.1.2.3.1 Maximum Effort

Repairs were accomplished in the shortest possible time.

3.1.2.3.2 Normal Effort

Repairs were carried out with normal repair crews working normal shifts.

3.1.2.3.3 Low-Priority Effort

Repairs were carried out with less than a normal effort.

3.1.3 Starting Attempt

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.

3.1.3.1 Starting Failure

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 to be counted as a single starting failure.

3.1.3.2 Starting Success

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.

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3.2 Deactivated Shutdown

The state in which a unit is unavailable for service for an extended period of time because of its removal for economy or reasons not related to the equipment. Under this condition, a unit generally requires weeks of preparation to make it available.

4. Capacity Terms

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

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

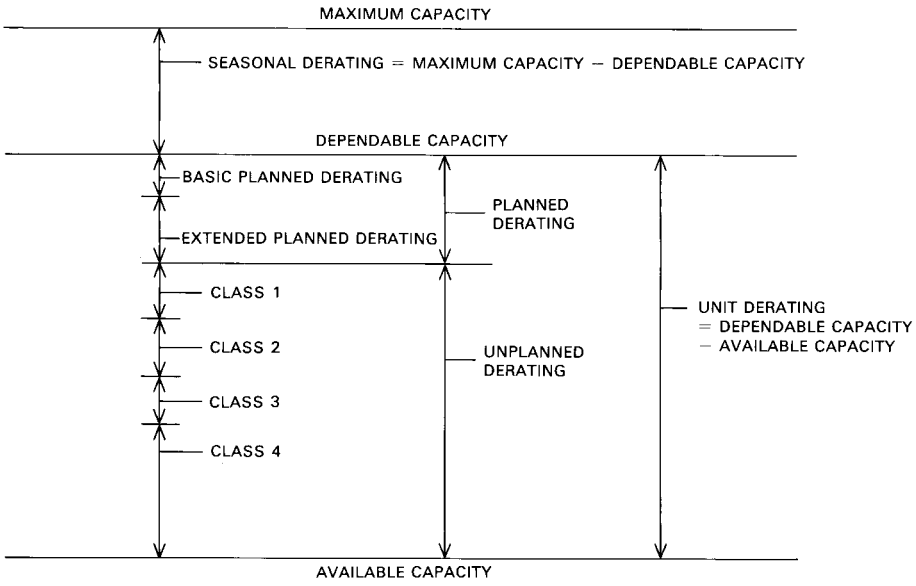

Figure 2—Unit Capacity Levels

4.1 Maximum Capacity (MC)

The maximum 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.

4.2 Dependable Capacity

The maximum capacity, modified for ambient limitations for a specified period of time, such as a month or a season.

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4.3 Available Capacity

The dependable capacity, modified for equipment limitation at any time.

4.4 Seasonal Derating

The difference between maximum capacity and dependable capacity.

4.5 Unit Derating

The difference between dependable capacity and available capacity.

4.6 Planned Derating

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

4.6.1 Basic Planned Derating

The planned derating that is originally scheduled and of predetermined duration.

4.6.2 Extended Planned Derating

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

4.7 Unplanned Derating

That 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 4.7.1 through 4.7.4.

4.7.1 Unplanned Derating, Class 1 (Immediate)

A derating that requires an immediate action for the reduction of capacity.

4.7.2 Unplanned Derating, Class 2 (Delayed)

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

4.7.3 Unplanned Derating, Class 3 (Postponed)

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

4.7.4 Unplanned Derating, Class 4 (Deferred)

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

4.8 Installed Nameplate Capacity

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.

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

5. Time Designations and Dates

NOTE — The time spent in the various unit states defined in Section 3 is defined in 5.1 through 5.10. See Fig 3. In 5.11 through 5.16, the time a unit was subject to the various categories of unit derating defined in Section 4. is defined. Derated time is accumulated only during the available, inservice, and reserve shutdown states.

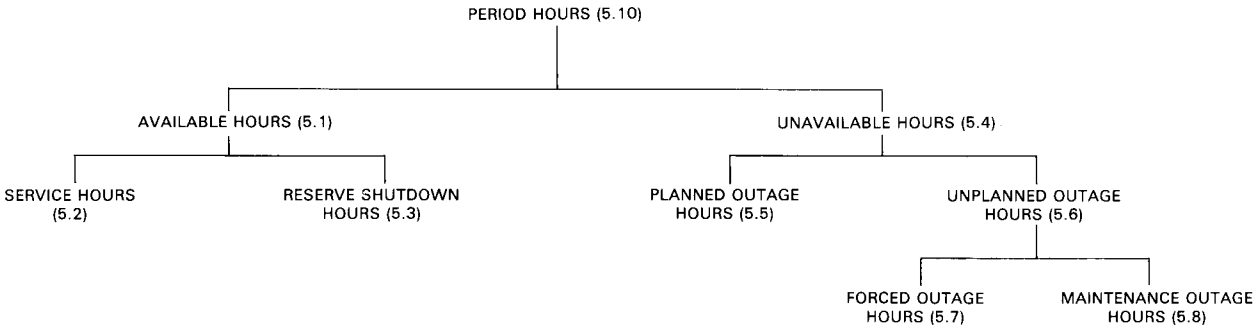

Figure 3—Time Spent in Various Unit States

5.1 Available Hours (AH)

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

NOTE — Available hours is the sum of service hours and reserve shutdown hours, or may be computed from period hours minus unavailable hours (see 5.4).

5.2 Service Hours (SH)

The number of hours a unit was in the in-service state.

5.3 Reserve Shutdown Hours (RSH)

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

5.4 Unavailable Hours (UH)

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 the sum of planned outage hours, forced outage hours, and maintenance outage hours.

5.5 Planned Outage Hours (POH)

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

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5.6 Unplanned Outage Hours (UOH)

The number of hours a unit was in a Class 0, 1, 2, 3, or 4 unplanned outage state.

5.7 Forced Outage Hours (FOH)

The number of hours a unit was in a Class 0, 1, 2, or 3 unplanned outage state.

5.8 Maintenance Outage Hours (MOH)

The number of hours a unit was in a Class 4 unplanned outage state.

5.9 Deactivated Shutdown Hours (DSH)

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

5.10 Period Hours (PH)

The number of hours a unit was in the active state.

5.11 Unit Derated Hours (UNDH)

The available hours during which a unit derating was in effect.

5.11.1 In-Service Unit Derated Hours (IUNDH)

The in-service hours during which a unit derating was in effect.

5.11.2 Reserve Shutdown Unit Derated Hours (RSUNDH)

The reserve shutdown hours during which a unit derating was in effect.

5.12 Planned Derated Hours (PDH)

The available hours during which a basic or extended planned derating was in effect.

5.12.1 In Service PlAnned Derated Hours (IPDH)

The in-service hours during which a basic or extended planned derating was in effect.

5.12.2 Reserve Shutdown Planned Derated Hours (RSPDH)

The reserve shutdown hours during which a basic or extended planned derating was in effect.

5.13 Unplanned Derated Hours (UDH)

The available hours during which an unplanned derating was in effect.

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5.13.1 In-Service Unplanned Derated Hours (IUDH)

The in-service hours during which an unplanned derating was in effect.

5.13.2 Reserve Shutdown Unplanned Derated Hours (RSUDH)

The reserve shutdown hours during which an unplanned derating was in effect.

5.14 Forced Derated Hours (FDH)

The available hours during which a Class 1, 2, or 3 unplanned derating was in effect.

5.14.1 In-Service Forced Derated Hours (IFDH)

The in-service hours during which a Class 1, 2, or 3 unplanned derating was in effect.

5.14.2 Reserve Shutdown Forced Derated Hours (RSFDH)

The reserve shutdown hours during which a Class 1, 2, or 3 unplanned derating was in effect.

5.15 Maintenance Derated Hours (MDH)

The available hours during which a Class 4 unplanned derating was in effect.

5.15.1 In-Service Maintenance Derated Hours (IMDH)

The in-service hours during which a Class 4 unplanned derating was in effect.

5.15.2 Reserve Shutdown Maintenance Derated Hours (RSMDH)

The reserve shutdown hours during which a Class 4 unplanned derating was in effect.

5.16 Seasonal Derated Hours (SDH)

The available hours during which a seasonal derating was in effect.

5.17 Equivalent Hours (E)

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 5.11through 5.16. 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 is designated EUNDH). Equivalent hours can be calculated from the following equation:

$$E(\ ) = \frac{\Sigma D(\ )_i T_i}{\mathrm{MC}}$$

where

$E(\ )$ = equivalent hours in the time category represented by parentheses, which can be any one of the time categories in 5.11 through 5.16

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

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.

T_i = 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 = maximum capacity

5.18 Deactivation Date

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

5.19 Reactivation Date

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

6. Energy Terms

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

6.1 Actual Generation (AAG)

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).

6.2 Maximum Generation (MG)

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 = period hours · maximum capacity
= PH · MC
GMG = PH · GMC
NMG = PH · NMC

6.3 Available Generation (AG)

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

6.4 Unavailable Generation (UG)

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.

UG = (planned outage hours + unplanned outage hours + equivalent unit derated hours) · maximum capacity
= (POH + UOH + EUNDH) · MC

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6.5 Seasonal Unavailable Generation (SUG)

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 = equivalent seasonal derated hours · maximum capacity
= ESDH · MC

6.6 Reserve Generation (RG)

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.

6.7 Derated Generation (DG)

The generation that was not available due to unit deratings.

DG = equivalent unit derated hours · maximum capacity
= EUNDH · MC

7. Performance Indexes

Appendix C discusses the relationships among the performance indexes that are based on period hours.

NOTE — All per unit performance indexes are expressed in percentage.

7.1 Planned Outage Factor (POF)

$$POF = \frac{\text{planned outage hours}}{\text{period hours}} \cdot 100$$
$$= \frac{POH}{PH} \cdot 100$$

7.2 Unplanned Outage Factor (UOF)

$$UOF = \frac{\text{unplanned outage hours}}{\text{period hours}} \cdot 100$$
$$= \frac{UOH}{PH} \cdot 100$$

7.3 Forced Outage Factor (FOF)

$$FOF = \frac{\text{forced outage hours}}{\text{period hours}} \cdot 100$$
$$= \frac{FOH}{PH} \cdot 100$$

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7.4 Maintenance Outage Factor (MOF)

$$MOF = \frac{\text{maintenance outage hours}}{\text{period hours}} \cdot 100$$

$$= \frac{MOH}{PH} \cdot 100$$

7.5 Unavailability Factor (UF)

$$UF = \frac{\text{unavailable hours}}{\text{period hours}} \cdot 100$$

$$= \frac{UH}{PH} .100$$

$$= \frac{POH + MOH + FOH}{PH} \cdot 100$$

$$= \frac{POH + UOH}{PH} \cdot 100$$

7.6 Availability Factor (AF)

$$AF = \frac{\text{available hours}}{\text{period hours}} .100$$

$$= \frac{AH}{PH} .100$$

7.7 Service Factor (SF)

$$SF = \frac{\text{service hours}}{\text{period hours}} .100$$

$$= \frac{SH}{PH} .100$$

7.8 Seasonal Derating Factor (SDF)

The fraction of maximum generation that could not be produced due to seasonal deratings:

$$SDF = \frac{\text{seasonal unavailable generation}}{\text{maximum generation}} .100$$

$$= \frac{SUG}{MG} .100$$

$$= \frac{ESDH}{PH} .100$$

7.9 Unit Derating Factor (UDF)

The fraction of maximum generation that could not be produced due to unit deratings:

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$$\text{UDF} = \frac{\text{unit derated generation}}{\text{maximum generation}} .100$$

$$= \frac{\text{DG}}{\text{MG}} .100$$

$$= \frac{\text{EUNDH}}{\text{PH}} .100$$

7.10 Equivalent Unavailability Factor (EUF)

The fraction of maximum generation that could not be produced due to unit deratings and planned and unplanned outages:

$$\text{EUF} = \frac{\text{unit unavailable generation}}{\text{maximum generation}} .100$$

$$= \frac{\text{UG}}{\text{MG}} .100$$

$$= \frac{\text{POH} + \text{MOH} + \text{FOH} + \text{EUNDH}}{\text{PH}} .100$$

7.11 Equivalent Availability Factor (EAF)

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

$$\text{EAF} = \frac{\text{available generation}}{\text{maximum generation}} .100$$

$$= \frac{\text{AG}}{\text{MG}} .100$$

$$= \frac{\text{AH} - (\text{EUNDH} + \text{ESDH})}{\text{PH}} .100$$

7.12 Gross Capacity Factor (GCF)

$$\text{GCF} = \frac{\text{gross actual generation}}{\text{gross maximum generation}} .100$$

$$= \frac{\text{GAAG}}{\text{GMG}} .100$$

7.13 Net Capacity Factor (NCF)

$$\text{NCF} = \frac{\text{net actual generation}}{\text{net maximum generation}} .100$$

$$= \frac{\text{NAAG}}{\text{NMG}} .100$$

NOTE — Net capacity factor calculated using this equation can be negative during a period when the unit is shutdown. For meaningful pooling of data on several units, net capacity factor can be defined to be zero when the unit is shutdown.

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7.14 Gross Output Factor (GOF)

$$GOF = \frac{\text{gross actual generation}}{\text{service hours . gross maximum capacity}} .100$$

$$= \frac{GAAG}{SH \,.\, GMC} .100$$

7.15 Net Output Factor (NOF)

$$NOF = \frac{\text{net actual generation}}{\text{service hours . net maximum capacity}} .100$$

$$= \frac{NAAG}{SH \,.\, NMC} .100$$

7.16 Forced Outage Rate (FOR)

$$FOR = \frac{\text{forced outage hours}}{\text{forced outage hours + service hours}} .100$$

$$= = \frac{FOH}{FOH + SH} .100$$

7.17 Equivalent Forced Outage Rate (EFOR)

$$EFOR = \frac{\text{forced outage hours + sum of equivalent forced derated hours}}{\text{service hours + forced outage hours + sum of equivalent reserve shutdown forced derated hours}} .100$$

$$= \frac{FOH + EFDH}{SH + FOH + ERSFDH} .100$$

7.18 Mean Service Time to Outage

7.18.1 Mean Service Time to Forced Outage (MSTFO)

$$MSTFO = \frac{\text{service hours}}{\text{number of Class 1, 2, and 3 unplanned outages that occur fro}}$$

7.18.2 Mean Service Time to Maintenance Outage (MSTMO)

$$MSTMO = \frac{\text{service hours}}{\text{number of Class 4 unplanned outages that occur from in-servic}}$$

7.18.3 Mean Service Time to Planned Outage (MSTPO)

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

NOTE — In 7.18.1, only forced outages occurring from in-service state are considered. The name for the index could be “mean service time to *in-service* forced outage.” However, for simplicity in-service is not included in the name. This note is also applicable to 7.18.2 and 7.18.3.

Indexes similar to 7.18.1, 7.18.2, and 7.18.3 can also be calculated for outages that occur during reserve shutdown state.

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7.19 Mean Outage Duration

7.19.1 Mean Forced Outage Duration (MFOD)

$$\text{MFOD} = \frac{\text{forced outage hours}}{\text{numbers of Class 1, 2, and 3 unplanned outages}}$$

7.19.2 Mean Maintenance Outage Duration (MMOD)

$$\text{MMOD} = \frac{\text{maintenance outage hours}}{\text{number of Class 4 unplanned outages}}$$

7.19.3 Mean Planned Outage Duration (MPOD)

$$\text{MPOD} = \frac{\text{planned outage hours}}{\text{number of planned outages}}$$

NOTE — Similar to 7.18, outage hours and number of outages in 7.19 include outages that occur from in-service state only.

7.20 Starting Reliability (SR)

$$\text{SR} = \frac{\text{number of starting successes}}{[\text{number of starting successes} + \text{number of starting failures}]} .100$$

7.21 Cycling Rate (CR)

$$\text{CR} = \frac{\text{starting successes}}{\text{service hours}}$$

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Annex A
Correlation Between Unit State and Capacity Derating Definitions in This Standard and Those Formerly Used by the Industry

(Informative)

(These Appendixes are not a part of ANSI/IEEE Std 762-1987, EEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity.)

This standard	Former Industry Definitions
Available	No change
In service	No change
Reserve shutdown	No change
Unavailable	No change
Basic planned outage	No change
Extended planned outage	Not defined
Unplanned outage	Not defined
Class 0 (starting failure)	Forced outage
Class 1 (immediate)	
Class 2 (less than 6 h) delayed	
Class 3 (more than 6 h; before the end of the next weekend) postponed	
Class 4 (after the next weekend before the next planned outage) deferred	Maintenance outage
Deactivated shutdown	Not defined
Seasonal derating	Not defined
Unit derating	Not defined
Unplanned derating	Not defined
Class 1 (immediate)	Forced partial outage
Class 2 (less than 6 h) delayed	
Class 3 (more than 6 hr; before the end of the next weekend) postponed	
Class 4 (after the next weekend before the next planned outage) maintenance derating	Scheduled partial outage
Planned derating (basic or extended)	

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Annex B
Transitions Between States

(Informative)

Section 3 defines three primary unit states:

1) Available
2) Unavailable
3) Deactivated shutdown

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

1) In service
2) Reserve shutdown
3) Basic planned outage
4) Extended planned outage
5) Class 0 unplanned outage
6) Class 1 unplanned outage
7) Class 2 unplanned outage
8) Class 3 unplanned outage
9) Class 4 unplanned outage
10) Deactivated shutdown

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

Once a unit is in a state, it remains in that state until a transition event occurs that causes the unit to move to another state. The possible transition events can be shown by use of a state transition matrix. Figure B.1 shows a state transition matrix for the ten basic states. The left side of the matrix shows the possible unit states before a transition event. The top row of the matrix shows the (same) possible unit states after a transition event. Thus, each (nondiagonal) element of the matrix can be used to describe a transition event from the state on the left to the top state. Figure B.1 shows the transition events that are possible according to the definitions in Section 3. The elements denoted by "x" are not possible.

By looking on a particular row of Fig B.1, the possible transition events that can terminate a state can be seen. By looking at a particular column of Fig the possible transition events that can initiate a state can be seen.

Detailed definitions for the transition events in Fig have not been included in this standard. However, in actual reporting generating unit performance, it is the transition event occurrence times that are in fact reported, from which 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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STATE BEFORE TRANSITION	STATE AFTER TRANSITION										
	IN SERVICE	RESERVE SHUTDOWN	BASIC PLANNED OUTAGE	EXTENDED PLANNED OUTAGE	CLASS 0 UNPLANNED OUTAGE	CLASS 1 UNPLANNED OUTAGE	CLASS 2 UNPLANNED OUTAGE	CLASS 3 UNPLANNED OUTAGE	CLASS 4 UNPLANNED OUTAGE	DEACTIVATED SHUTDOWN
						SHUTDOWN FOR UNPLANNED OUTAGE				SHUTDOWN TO DEACTIVATE
						IMMEDIATE	DELAYED	POSTPONED	DEFERRED	
IN SERVICE		SHUTDOWN FOR ECONOMY	SHUTDOWN FOR PLANNED OUTAGE	X	X					
RESERVE SHUTDOWN	STARTING SUCCESS		BEGIN PLANNED OUTAGE	X	STARTING FAILURE	COMPONENT FAILURE FOUND DURING SHUTDOWN	X	X	BEGIN MAINTENANCE OUTAGE	BEGIN DEACTIVATION
BASIC PLANNED OUTAGE	STARTING SUCCESS	END PLANNED OUTAGE		EXTEND PLANNED OUTAGE	STARTING FAILURE	COMPONENT FAILURE FOUND DURING SHUTDOWN	X	X	BEGIN MAINTENANCE OUTAGE	BEGIN DEACTIVATION
EXTENDED PLANNED OUTAGE	STARTING SUCCESS	END EXTENDED PLANNED OUTAGE	X		STARTING FAILURE	COMPONENT FAILURE FOUND DURING SHUTDOWN	X	X	BEGIN MAINTENANCE OUTAGE	BEGIN DEACTIVATION
CLASS 0 UNPLANNED OUTAGE	STARTING SUCCESS	END CLASS 0 OUTAGE	EXTEND FOR PLANNED WORK	X		X	X	X	X	BEGIN DEACTIVATION
CLASS 1 UNPLANNED OUTAGE	STARTING SUCCESS	END CLASS 1 OUTAGE	EXTEND FOR PLANNED WORK	X	STARTING FAILURE		X	X	X	BEGIN DEACTIVATION
CLASS 2 UNPLANNED OUTAGE	STARTING SUCCESS	END CLASS 2 OUTAGE	EXTEND FOR PLANNED WORK	X	STARTING FAILURE	X		X	X	BEGIN DEACTIVATION
CLASS 3 UNPLANNED OUTAGE	STARTING SUCCESS	END CLASS 3 OUTAGE	EXTEND FOR PLANNED WORK	X	STARTING FAILURE	X	X		X	BEGIN DEACTIVATION
CLASS 4 UNPLANNED OUTAGE	STARTING SUCESS	END CLASS 4 OUTAGE	EXTEND FOR PLANNED WORK	X	STARTING FAILURE	X	X	X		BEGIN DEACTIVATION
DEACTIVATED SHUTDOWN	STARTING SUCCESS	END DEACTIVATED SHUTDOWN	X	X	STARTING FAILURE	X	X	X	X	

"X" indicates that the transfer is not possible.

Figure B.1—State Transition Matrix

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Annex C
Relationships Between Period-Hour-Based Performance Indexes

(Informative)

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 Section 7 provide a unified set of period-hour-based indexes (called factors), as follows:

AF = availability factor

UF = unavailability factor

EAF = equivalent availability factor

EUF = equivalent unavailability factor

FOF = forced outage factor

MOF = maintenance outage factor

UOF = unplanned outage factor = FOF + MOF

POF = planned outage factor

SDF = seasonal derating factor

UDF = unit derating factor

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

$$EAF = AF - (UDF + SDF) \quad \text{(C1)}$$

$$EUF = UF + UDF \quad \text{(C2)}$$

$$AF + UF = 100 \quad \text{(C3)}$$

$$EAF + EUF + SDF = 100 \quad \text{(C4)}$$

$$UF = POF + UOF \quad \text{(C5)}$$

$$EUF = POF + UOF + UDF \quad \text{(C6)}$$

$$EAF + POF + UOF + UDF + SDF = 100 \quad \text{(C7)}$$

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Equation C1 shows that equivalent availability can be obtained by subtracting the unit derating factor and the seasonal derating factor from the availability factor.

Equation C2 shows that equivalent unavailability can be obtained by adding the unit derating factor, but not the seasonal derating factor, to the unavailability factor.

Equation C3 shows that the availability and unavailability factors add to 100%.

Equation C4 shows that the 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.

Equation C5 shows that the unavailability factor is the sum of the planned and unplanned outage factors (unplanned outage factor is the sum of maintenance outage factor and forced outage factor).

Substituting Eq C5 into Eq C2 produces Eq C6, which shows that equivalent unavailability is the sum of the planned and unplanned outage factors and the unit derating factor.

Substituting Eq C6 into Eq C4 produces Eq C7. This last equation 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 in such a way as 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 Eq C7, it is necessary that the capacity loss due to each source be separated. This means, for example, that a unit cannot simultaneously be subject to full outage and unit derating.

Similarly, a unit cannot simultaneously be subject to both seasonal derating and full outage. In order to achieve nonoverlapping energy definitions, the task force agreed to assign full (maximum) unit capacity to the full outage state. This means that 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 (UDF) and the seasonal derating factor (SDF) are concerned.

In order to further illustrate the relationship between the period-hour-based performance indexes, Fig C1 shows capacity versus time diagram (all capacity values must be either gross or net). The total height of the diagram is maximum capacity (MC), and the total width of the diagram is period hours (PH). Thus, the total area *Y* of the diagram is

$$Y = MC \cdot PH$$

This is the total megawatthour (MWh) of energy that could have been generated during the period if operating continuously at MC.

The area *Y* is divided into several vertical segments by the various time designations in Section 5. 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. All of the performance factors in Section 7 that are based on period hours can be expressed as simple ratios of the areas in Fig C.1 as follows:

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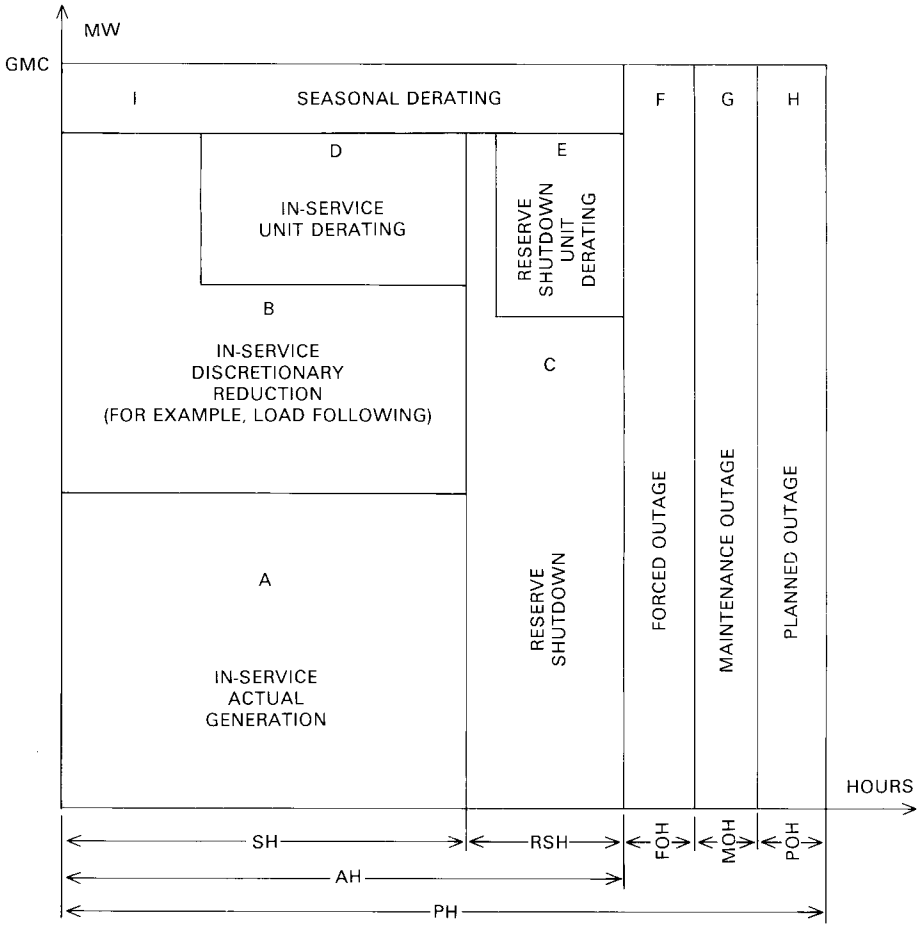

Figure C.1—Relation Between Time and Energy Terms

Time Indexes

$$\text{FOF} = \frac{F}{Y} \cdot 100$$

$$\text{MOF} = \frac{G}{Y} \cdot 100$$

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

$$\text{POF} = \frac{H}{Y} \cdot 100$$

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

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

Energy Indexes

$$\text{UDF} = \frac{D+E}{Y} \cdot 1000$$

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

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

$$\text{SDF} = \frac{I}{Y} \cdot 100$$

$$\text{Capacity Factor} = \frac{A}{Y} \cdot 100$$

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

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

$$\text{AF} = \frac{A + B + C}{+D + E + I} \cdot 100$$

= average fraction of maximum capacity available, as limited only by full outages (exclude only areas *F, G, H*)

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

= 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)*

$$\text{Capacity Factor} = \frac{A}{Y} \cdot 100$$

= average fraction of maximum capacity actually generated (exclude also areas *B* and *C)*

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Annex D
Glossary of Terms and Abbreviations

(Informative)

Abbreviation	Reference	Term
AAG	6.1	Actual Generation
AF	7.6	Availability Factor
AG	6.3	Available Generation
AH	5.1	Available Hours
CR	7.21	Cycling Rate
DG	6.7	Derated Generation
DSH	5.9	Deactivated Shutdown Hours
E	5.17	Equivalent Hours
EAF	7.11	Equivalent Availability Factor
EFOR	7.17	Equivalent Forced Outage Rate
EUF	7.10	Equivalent Unavailability Factor
FDH	5.14	Forced Derated Hours
FOF	7.3	Forced Outage Factor
FOH	5.7	Forced Outage Hours
FOR	7.16	Forced Outage Rate
GAAG	6.1	Gross Actual Generation
GCF	7.12	Gross Capacity Factor
GMC	4.1	Gross Maximum Capacity
GMG	6.2	Gross Maximum Generation
GOF	7.14	Gross Output Factor
IFDH	5.14.1	In-Service Forced Derated Hours
IMDH	5.15.1	In-Service Maintenance Derated Hours
IPDH	5.12.1	In-Service Planned Derated Hours
IUDH	5.13.1	In-Service Unplanned Derated Hours
IUNDH	5.11.1	In-Service Unit Derated Hours
MC	4.1	Maximum Capacity
MDH	5.15	Maintenance Derated Hours
MFOD	7.19.1	Mean Forced Outage Duration
MG	6.2	Maximum Generation
MMOD	7.19.2	Mean Maintenance Outage Duration
MOF	7.4	Maintenance Outage Factor
MOH	5.8	Maintenance Outage Hours
MPOD	7.19.3	Mean Planned Outage Duration
MSTFO	7.18.1	Mean Service Time to Forced Outage
MSTMO	7.18.2	Mean Service Time to Maintenance Outage
MSTPO	7.18.3	Mean Service Time to Planned Outage
NAAG	6.1	Net Actual Generation
NCF	7.13	Net Capacity Factor
NMC	4.1	Net Maximum Capacity
NMG	6.2	Net Maximum Generation
NOF	7.15	Net Output Factor

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Abbreviation	Reference	Term
PDH	5.12	Planned Derated Hours
PH	5.10	Period Hours
POF	7.1	Planned Outage Factor
POH	5.5	Planned Outage Hours
RG	6.6	Reserve Generation
RSFDH	5.14.2	Reserve Shutdown Forced Derated Hours
RSH	5.3	Reserve Shutdown Hours
RSMDH	5.15.2	Reserve Shutdown Maintenance Derated Hours
RSPDH	5.12.2	Reserve Shutdown Planned Derated Hours
RSUDH	5.13.2	Reserve Shutdown Unplanned Derated Hours
RSUNDH	5.11.2	Reserve Shutdown Unit Derated Hours
SDF	7.8	Seasonal Derating Factor
SDH	5.16	Seasonal Derated Hours
SF	7.7	Service Factor
SH	5.2	Service Hours
SR	7.20	Starting Reliability
SUG	6.5	Seasonal Unavailable Generation
UDF	7.9	Unit Derating Factor
UDH	5.13	Unplanned Derated Hours
UF	7.5	Unavailability Factor
UG	6.4	Unavailable Generation
UH	5.4	Unavailable Hours
UNDH	5.11	Unit Derated Hours
UOF	7.2	Unplanned Outage Factor
UOH	5.6	Unplanned Outage Hours

Word Abbreviations

Abbreviation	Word	Abbreviation	Word
A	Availability, available	O	Outage, output
C	Capacity	P	Period, planned
D	Deactivated shutdown,	R	Rate, reliability
	dependable, duration,	RS	Reserve shutdown
	derated, derating	S	Seasonal, service, starting
E	Equivalent	T	Time, to
F	Factor, forced	U	Unavailability, unavailable, unplanned
G	Generation, gross		
H	Hours	AA	Actual
I	In-service	UN	Unit
M	Maximum, mean, maintenance	Y	Years
N	Net	0, 1, 2, 3, 4	Outage postponability class

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