IEEE Standard Terms for Reporting and Analyzing Outage Occurrences and Outage States of Electrical Transmission Facilities

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Foreword

(This Foreword is not a part of IEEE Std 859-1987, IEEE Standard Terms for Reporting and Analyzing Outage Occurrences and Outage States of Electrical Transmission Facilities.)

Data on outage occurrences of transmission facilities have been collected for many years. Initially, reporting was generally limited to reporting frequency of outage occurrence on transmission lines. Total outage frequency was classified into several general cause categories, but there were no formal definitions for the events and statistics reported beyond those contained in the data forms and instructions. Early efforts did not generally collect data on outage duration, except to classify outages as temporary or permanent according to type of restoration used.

In the 1960's, methods were first proposed for calculating reliability of transmission and distribution “systems” (networks) in terms of the reliability of their individual “components.” This led to the need for more formal definitions of terms to foster uniformity and standardization of language among engineers engaged in reporting, analyzing, and predicting outages of transmission and distribution facilities and interruptions to customers. This resulted in development of IEEE Std 346-1973, IEEE Standard Definitions in Power Operations Terminology Including Terms for Reporting and Analyzing Outages of Electrical Transmission and Distribution Facilities and Interruptions to Customer Service.

More recent developments have shown the need to include definitions for a broader scope of outage events. For example, two general categories of facilities (reportable entities) must be recognized to support presently available models. In one type of model, a transmission system is partitioned functionally into “units” which represent the capability to transfer power between specified points. In the second type of model, a system is partitioned physically into “components.”

Another recent development is the increasing recognition of the importance of “related outage occurrences” in which outage occurrences of two or more facilities are related in some way due to the physical construction of equipment (such as common structure), the electrical interconnection of equipment (common bus, for example), or exposure to a common environment (storms). Achieving clear and unambiguous definitions for related outage occurrences is important for reporting outage occurrences at the transmission unit level. At the component level, an important consideration is the recognition of several modes of failure, particularly for switching, protection, and automatic reclosing equipment.

No attempt is made here to standardize procedures for the collection of outage data. What is attempted is to specify certain common terms and indices to provide a basis of information exchange. The task force has attempted to keep the list of terms and indices as brief as possible.

The indices defined here are intended to serve as estimates for parameters of models which are used in transmission system reliability evaluation. The indices may also be used directly to guide system operation or in assessment of equipment performance. No attempt is made to recommend acceptable equipment reliability levels.

This is a revision of EEE Std 346-1973. However, terms related to distribution system facilities: and interruptions were eliminated from the scope of this document.

This document was prepared by the Transmission and Distribution Outage and Interruption Definitions Task Force. This task force was formed by the PROSD (Performance Records for Optimizing System Design) Working Group, which is under the guidance of the Power System Engineering Committee. The members of the task force were:

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IEEE Standard Terms for Reporting and Analyzing Outage Occurrences and Outage States of Electrical Transmission Facilities

1. Purpose

This standard is intended to aid the electric power industry in reporting and analyzing outage occurrences of transmission facilities. Use of systematic, precise definitions is essential for meaningful exchange of data. It is expected that specific instructions for reporting outages will be developed by the industry based on these definitions.

The outage definitions and indices are intended for use in system planning models, operations and maintenance planning, and system design. The definitions and indices may not be sufficiently detailed to cover the information required for equipment design.

2. Scope

This standard defines terminology and indices for reporting and analyzing outage occurrences of transmission facilities. Outage definitions and indices are given for two general types of facilities —units and components. Units are functional facilities which transfer power between designated points, while components are specific pieces of equipment.

Outage definitions are given both for describing the outage history of a particular facility and for describing groups of individual outage occurrences which are related in some way.

3. Equipment Classifications

3.1 Component

A device which performs a major operating function and which is regarded as an entity for purposes of recording and analyzing data on outage occurrences.

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NOTES:

1 — Some examples of components are line sections, transformers, ac/dc converters, series capacitors or reactors, shunt capacitors or reactors, circuit breakers, line protection systems, and bus sections.

2 — Sometimes it is necessary to subdivide a line section into segments to allow proper calculation of failure rates and exposure data. For example, if a line section is composed of an overhead line segment and an underground line segment, failure and exposure data for each line segment may be recorded separately.

3.1.1 Termination

A facility where a transmission line ends within a terminal, typically at a circuit breaker.

3.1.2 Line Section

A portion of an overhead line or a cable bounded by two terminations, a termination and a tap point, or two tap points.

3.2 Subcomponent

A part or portion of a component which is relevant for quantifying exposure to outage occurrences, or failures, or both, or for identifying the cause of an outage occurrence or failure.

3.2.1 Line Segment

A portion of a line section that has a particular type of construction or is exposed to a particular type of failure, and therefore which may be regarded as a single entity for the purpose of reporting and analyzing failure and exposure data.

NOTE — A line segment is a subcomponent of a line section.

3.3 Unit

A group of components which are functionally related and are regarded as an entity for purposes of recording and analyzing data on outage occurrences.

NOTES:

1 — A unit can be defined in a number of ways. For example, it may be:

1)A group of components which constitute an operating entity bounded by automatic fault interrupting devices which isolate it from other such entities for faults on any component within the group.
2)A group of components protected by and within the sensing zone of a particular system of protective relays. Examples include a transformer or an overhead line and associated terminal facilities switched with it.
3)A group of components including a transmission line, one or more transformers supplied by the line, and a subtransmission or distribution network radially supplied from the transformer. These components are so configured that the subtransmission network is in the outage state during outage occurrences of the transmission line.

2 — A unit maybe single-terminal, two-terminal or multi-terminal. A multi-terminal unit is connected to three or more terminals.

3 — It is recognized that certain components (for example, circuit breakers) may be part of more than one unit.

4 — Different types of units include mission unit (overhead or cable), transformer unit, bus unit, and special units that consist of any equipment protected by separate breakers, such as shunt capacitors.

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3.4 Terminal

A functional facility (substation, generating station, or load center) which includes components such as bus sections, circuit breakers, and protection systems where transmission units terminate.

4. Component and Unit States and Events

Except as noted, the terms in this section apply to either “component” or “unit” performance reporting. However, it is assumed that in any particular context one viewpoint or the other is adopted, as in some instances a term may apply in one viewpoint but not another.

4.1 State

Component or unit state is a particular condition or status of a component or a unit which is important for outage reporting purposes.

4.1.1 In-Service State

The component or unit is energized and fully connected to the system.

4.1.2 Outage State

The component or unit is not in the in-service state; that is, it is partially or fully isolated from the system.

NOTES:

1 — A unit may be in the outage state due to a failure of a component within the unit or due to the outage occurrence of another unit or component.

2 — A two-terminal transformer disconnected on one or both sides is in the outage state.

3 — A three-terminal overhead transmission line disconnected from one terminal is, as a unit, in the outage stage. However, the two overhead line sections still carrying power are, as components, in the in-service state. A circuit breaker which is not energized on either side is in the outage state. Whether the circuit breaker is open or closed does not affect its in-service/outage state status.

4.1.2.1 Complete Outage State

The component or unit is completely de-energized or is connected so that it is not serving any of its functions within the power system.

4.1.2.2 Partial Outage State

The component or unit is at least partially energized, or is not fully connected to all of its terminals, or both, so that it is not serving some of its functions within the power system.

NOTE — A unit composed of a three-terminal line would be in the partial outage state if it were disconnected from one terminal with two line sections still carrying power.

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4.2 Changes in State

4.2.1 Outage Occurrence

The change in the state of one component or one unit from the in-service state to the outage state.

NOTES:

1 — The noun “outage” is commonly used to mean outage occurrence. When used as a predicate adjective, “outaged” is ambiguous (for example, “The unit is outaged”) and more specific terminology is suggested (for example, “The unit is in an outage state,” or “The unit experiences an outage occurrence”).

2 — If redundant components are used, a component outage occurrence may not imply a unit outage occurrence, depending on the failure mode or switching procedure. Examples of component outage occurrences not related to any unit outage occurrence include one circuit breaker in a ring bus configuration isolated for maintenance, and one of two line protection systems d riva for testing.

4.2.2 Outage Event

An event involving the outage occurrence of one or more units or components.

4.2.2.1 Single Outage Event

An outage event involving only one component or one unit.

4.2.2.2 Multiple Outage Event

An outage event involving two or more components, or two or more units.

4.2.2.2.1 Related Multiple Outage Event

A multiple outage event in which one outage occurrence is the consequence of another outage occurrence, or in which multiple outage occurrences were initiated by a single incident, or both.

Each outage occurrence in a related multiple outage event is classified as either a primary outage or a secondary outage depending on the relationship between that outage occurrence and its initiating incident.

1) Primary outage: An outage occurrence within a related multiple outage event which occurs as a direct consequence of the initiating incident and is not dependent on any other outage occurrence.
   NOTE — A primary outage of a component or a unit may be caused by a fault on equipment within the unit or component or repair of a component within the unit.
2) Secondary outage: An outage occurrence which is the result of another outage occurrence.
   NOTES:
   1 — Secondary outages of components or units may be caused by repair of other components or units requiring physical clearance, failure of a circuit breaker to clear a fault, or a protective relay system operating incorrectly and overreaching into the normal tripping zone of another unit.
   2 — Some secondary outages are solely the result of system configuration; for example, two components connected in series will always go out of service together. These secondary outages may be given special treatment when compiling outage data.
   3 — At present, primary outages have been referred to in the industry as independent outage occurrences, and secondary outages as dependent or related outage occurrences.
3) Common-mode outage event: A related multiple outage event consisting of two or more primary outage occurrences initiated by a single incident or underlying cause where the outage occurrences are not consequences of each other.

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NOTE — Primary outage occurrences in a common-mode outage event are referred to as common-mode outage occurrences or simply common-mode outages.

Examples of common-mode outage events are a single lightning stroke causing tripouts of both circuits on a common tower, and an external object causing the outage of two circuits on the same right-of-way.

4.2.2.2.2 Multiple Independent Outages

Outage occurrences each having distinct and separate initiating incidents where no outage occurrence is the consequence of any other, but the outage states overlap.

4.3 Outage Initiation

Outage occurrences are initiated either automatically or manually.

4.3.1 Automatic Outage

An outage occurrence which results from automatic operation of switching devices.

4.3.2 Manual Outage

An outage occurrence which results from intentional or inadvertent operator controlled opening of switching devices.

4.4 Outage Type

Outage occurrences are classified by type according to the urgency with which the outage occurrence is initiated and by how the equipment is restored to service.

4.4.1 Forced Outage

An automatic outage, or a manual outage that cannot be deferred.

4.4.1.1 Transient Forced Outage

A forced outage where the unit or component is undamaged and is restored to service automatically.

4.4.1.2 Temporary Forced Outage

A forced outage where the unit or component is undamaged and is restored to service by manual switching operations without repair but possibly with on-site inspection.

4.4.1.3 Permanent Forced Outage

A forced outage where the component or unit is damaged and cannot be restored to service until repair or replacement is completed.

NOTE — Repairs can be further classified by urgency as high, normal, and low urgency repairs.

4.4.1.4 System Related Outage

A forced outage which results from system effects or conditions and is not caused by an event directly associated with the component or unit being reported.

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NOTE — Line outage occurrences due to cascading, out of step conditions, and so forth, are all examples of system related outages.

4.4.2 Scheduled Outage

An intentional manual outage that could have been deferred without increasing risk to human life, risk to property, or damage to equipment.

NOTE — A manual outage is classified as scheduled ff it is possible to defer the outage occurrence when such deferment is desirable. Otherwise, the outage occurrence is a forced outage. Deferring an outage occurrence may be desirable, for example, to prevent overload of facilities or an interruption of service to consumers.

4.4.2.1 Operations Related Outage

A scheduled outage in which the unit or component is removed from service to improve system operating conditions.

4.5 Failure

The inability of a component to perform its required function.

4.5.1 Failure of Continuously Required Function

The inability of a component to perform a function which is continuously required.

NOTE — Continuously required functions include carrying current, providing electrical isolation, and abstaining from tripping in the absence of a signal. Examples of inability to perform continuously required functions are component short circuit, component open circuit, switching equipment opening without proper command, and switching equipment dosing without proper command.

4.5.2 Failure of Response Function

The inability of a component to perform a function which is required as a response to system conditions or to a manually or automatically initiated command.

NOTE — Response functions include responding to fault conditions (protective systems), to command (circuit breakers), and to manual operation (disconnect switches). Inabilities to perform a response function do not cause an immediate interruption of power flow as they can be disclosed by subsequent inspection or by failure to respond to conditions as intended. This type of failure has been referred to as dormant failure, latent failure, and unrevealed failure. Examples are switching equipment failing to open on command, switching equipment failing to close on command, and protection system tripped incorrectly (over-reach during fault).

5. State Times

5.1 Service Time

The accumulated time one or more components or units are in the in-service state during the reporting period.

5.2 Outage Time

The accumulated time one or more components or units are in the outage state during the reporting period.

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5.3 Reporting Period Time

The duration of the reporting period (equals service time plus outage time).

5.4 Outage Duration

The period from the initiation of an outage occurrence until the component or unit is returned to the in-service state.

NOTES:

1 — Outage durations are commonly summarized for specific types of outages as, for example, permanent forced outage duration, transient forced outage duration, and scheduled outage duration. (See 7.2.2.)

2 — Outage duration is normally equal to the sum of switching time, repair time, and travel and material procurement time, but may be longer for reasons other than unavailability of manpower, equipment, or material.

6. Exposure Parameters

Exposure in this context means vulnerability to hazards which can cause outage occurrences. Enumeration of all design characteristics affecting such vulnerability is beyond the scope of this standard. Some examples are: length of line, use of common structure, common right-of-way, common terminal(s), application of shielding, or localized hazards. However, it is generally understood that the expected number of outages or failures increases with time, or commands to operate, or both. What measure of exposure is relevant depends on the failure mode.

NOTE — Exposure parameters may be aggregated for purposes of calculating average outage indices of a class or population of components or indices.

6.1 Exposure (Time)

The aggregate time during which a component or components which make up a unit are exposed to failures of continuously required functions. (See 4.5.1.)

NOTES:

1 — Exposure time may include only service time, or it may also include outage time, depending on the type of component or unit and mode of failure.

2 — Time is the major measure of exposure for most failure modes (open circuit, short circuit, etc.) of lines and transformers and the switching equipment failure modes “opening without command” and “closing without command.”

6.2 Exposure (Operations)

The number of operations during which a component or components within a unit are exposed to failures of response functions. (See 4.5.2.)

NOTE — For example, the number of commands to open the breaker is the exposure parameter in the case of the circuit breaker failure mode “failure to open on command.”

6.3 Weather

Exposure, whether measured in time or operations, may be subdivided according to the type of weather to which a component or components within a unit is exposed.

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6.3.1 Adverse Weather

Designates weather conditions which cause an abnormally high rate of forced outages for exposed components during the periods that such conditions persist, but do not qualify as major storm disasters. Adverse weather conditions can be defined for a particular system by selecting the proper values and combinations of weather conditions reported: thunderstorms, tornadoes, wind velocities, precipitation, temperature, and so on.

6.3.2 Major Storm Disaster

Designates weather which exceeds design limits of facilities, and which satisfies all of the following:

1) Extensive mechanical damage to facilities
2) More than a specified percentage of customers out of service
3) Service restoration longer than a specified time

NOTE — Typical industry criteria are 10% of customers out of service and 24 hours or more restoration time. Percentage of customers out of service maybe related to a company operating area rather than to an entire company. Examples of major storm disasters are hurricanes and major ice storms.

6.3.3 Normal Weather

Includes all weather not designated as adverse or major storm disaster.

7. Outage Indices

These indices are not meant to be a complete list of those in current use (for example, frequency indices), but are, rather, a list of some of those which are in use.

7.1 Rate Indices

7.1.1 Outage Rate

The number of outage occurrences per unit of service time = number of outage occurrences/service time.

NOTES:

1 — Usually the unit of service time is one year.

2 — Outage rates can be sub-divided by outage types, by the weather prevailing during the service time, or by season. For example:

1)Scheduled outage rate: The number of scheduled outages per unit of service time = number of scheduled outages/ service time. In some studies, scheduled outage rate may be defined as the number of outage occurrences per unit of exposure time (including both service time and outage time).
2)Normal weather forced outage rate: The number of forced outages per unit of service time in normal weather = number of forced outages during normal weather/service time during normal weather.
3)Summer outage rate: The number of outage occurrences per unit of service time during the summer. Summer outage rate = number of outages during the summer/service time during summer.

7.1.2 Failure Rate

The number of failures of a continuously required function per unit of time exposed to such failures = number of failures of a particular type/exposure time.

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NOTES:

1 — Rates for different failure modes can be calculated. The exposure time for each failure mode may be different.

2 — Failure rates can be computed for a specific component, a class of components or units, or per unit of length in the case of lines, common structure, or common right-of-way exposure.

7.1.3 Protective System False Operation Rate

Protective system false operation rate = number of false operations/exposure time.

7.2 Duration Indices

7.2.1 Mean Time to Outage

The mean time to outage occurrence of a specified type = service time/number of outage occurrences of the specified type.

NOTE — There are other indices such as mean time between failure.

7.2.2 Mean Outage Duration

The mean duration of outage occurrences of a specified type = outage time due to outages of a specified type/number of outage occurrences of a specified type.

NOTE — Also referred to as mean time to restoration.

7.3 State Probability Indices

7.3.1 Availability

Availability = service time/reporting period time.

7.3.2 Unavailability

Unavailability = outage time/reporting period time.

NOTE — Some examples are:

1) Forced unavailability = forced outage time/reporting period time.
2) Scheduled unavailability = scheduled outage time/reporting period time.

7.4 Probability of Failure Indices

The probability of a component failing to respond to a command, or responding when it should not = number of failures to respond as intended/exposure operations.

7.4.1 Probability of Failure to Open on Command

Probability of failure to open on command = number of failures to open/number of commands to open.

NOTE — This index can be calculated separately for commands to open under fault and without fault.

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7.4.2 Probability of Failure to Close on Command

Probability of failure to close on command = number of failures to close/number of commands to close.

7.4.3 Probability of Failure to Operate on Command

Probability of failure to operate on command = number of failures to operate/number of commands to operate.

7.4.4 False Operation Probability

False operation probability = number of unintended operations/exposure operations for which component should not respond.

NOTE — 7.4.1 and 7.4.2 are applicable to circuit breakers. 7.4.3 and 7.4.4 are applicable to relays.

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