

IEEE Std 3006.9™-2013

IEEE Recommended Practice for
Collecting Data for Use in Reliability,
Availability, and Maintainability
Assessments of Industrial and
Commercial Power Systems



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IEEE Recommended Practice for Collecting Data for Use in Reliability, Availability, and Maintainability Assessments of Industrial and Commercial Power Systems

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Abstract: Collection of data for use in reliability, availability, and maintainability assessments of industrial and commercial power systems is described in this recommended practice. It is likely to be of greatest value to the power-oriented engineer with limited experience in the area of reliability. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems.

Keywords: data collection forms, database analysis, database development, design reliable industrial and commercial power systems, equipment reliability, IEEE 3006.9TM, maintainability, reliability analysis

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Introduction

This introduction is not part of IEEE Std 3006.9-2013, IEEE Recommended Practice for Collecting Data for Use in Reliability, Availability, and Maintainability Assessments of Industrial and Commercial Power Systems.

IEEE 3000 Standards Collection™

This recommended practice was developed by the Technical Books Coordinating Committee of the Industrial and Commercial Power Systems Department of the Industry Applications Society as part of a project to repackage the popular IEEE Color Books®. The goal of this project is to speed up the revision process, eliminate duplicate material, and facilitate use of modern publishing and distribution technologies.

When this project is completed, the technical material in the thirteen IEEE Color Books will be included in a series of new standards—the most significant of which will be a new standard, IEEE Std 3000™, IEEE Recommended Practice for the Engineering of Industrial and Commercial Power Systems. The new standard will cover the fundamentals of planning, design, analysis, construction, installation, startup, operation, and maintenance of electrical systems in industrial and commercial facilities. Approximately 60 additional dot standards, organized into the following categories, will provide in-depth treatment of many of the topics introduced by IEEE Std 3000™:

- Power Systems Design (3001 series)
- Power Systems Analysis (3002 series)
- Power Systems Grounding (3003 series)
- Protection and Coordination (3004 series)
- Emergency, Standby Power, and Energy Management Systems (3005 series)
- Power Systems Reliability (3006 series)
- Power Systems Maintenance, Operations, and Safety (3007 series)

In many cases, the material in a dot standard comes from a particular chapter of a particular IEEE Color Book. In other cases, material from several IEEE Color Books has been combined into a new dot standard.

The material in this recommended practice largely comes from Chapter 11 of IEEE Std 493™ (*IEEE Gold Book™*).

IEEE Std 3006.9™

Five categories of information contain the necessary data for reliability modeling: site identification, site one line drawings, nameplate information, critical equipment designation and sparing, and maintenance data. When combined, this information gives the analyst all the necessary data to populate a reliability model. Data collection for facilities is not intended to be done in a single setting nor in a single month. This is an ongoing activity that should be completed in as timely a manner as possible without impacting the readiness of the facility. Once completed, updates to the information are only necessary as maintenance is performed on the equipment.

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1. Overview

1.1 Scope

This recommended practice describes how to collect data for use in reliability, availability, and maintainability assessments of industrial and commercial power systems. It is likely to be of greatest value to the power-oriented engineer with limited experience in the area of reliability. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 493TM (*IEEE Gold Book*TM), Design of Reliable Industrial and Commercial Power Systems.

3. Definitions and acronyms

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹

Some commonly used terms in system reliability analyses are defined here. These terms are also used in the wider context of system reliability activities. These definitions are referenced in several reliability publications, and the formulas can be verified in the Reliability Analysis Center (RAC) Toolkit for commercial practices, page 12, or MIL-STD-339. Definitions include the following:

availability: (A) (general) The ability of an item—under combined aspects of its reliability, maintainability, and maintenance support—to perform its required function at a stated instant of time or over a stated period of time. (B) (As a performance metric for individual components or a system) The long-term average fraction of time that a component or system is in service and satisfactorily performing its intended function. (C) (As a future prediction) The instantaneous probability that a component or system will be in operation at time t .

component: A piece of electrical or mechanical equipment viewed as an entity for the purpose of reliability evaluation.

failure (f): The termination of the ability of a component or system to perform a required function.

failure rate (λ): The mean (arithmetic average, also known as the forced outage rate) is the number of failures of a component and/or system per unit exposure time. The most common unit in reliability analyses is hours (h) or years (y). Therefore, the failure rate is expressed in failures per hour (f/h) or failures per year (f/y).

inherent availability (Ai): Long-term average fraction of time that a component or system is in service and satisfactorily performing its intended function. Ai considers only downtime for repair of failures. No logistics time, preventative maintenance, etc., is included.

maintenance down time (MDT): The total down time for scheduled maintenance (including logistics time, including spare parts availability, crew availability, etc) for a given total period (TP) in hours.

mean down time (MDT): The average downtime caused by scheduled and unscheduled maintenance, including any logistics time. This is synonymous with mean time to restore system (MTTRS) as found in some publications.

mean time between failures (MTBF): The arithmetic mean of the times (observed or calculated) between random failures of a component or system.

mean time between maintenance (MTBM): The average time between all maintenance events, scheduled and unscheduled, and includes any associated logistics time.

mean time to failure (MTTF): The mean exposure time between consecutive repairs (or installations) of a component and the next failure of that component. MTTF is commonly found for non-repairable items such as bulbs, etc.

¹IEEE Standards Dictionary Online subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

mean time to maintain (MTTM): The average time it takes to maintain a component, including logistics time. MTTM is primarily a measure of the preventive maintenance frequency and durations.

mean time to repair (MTTR or simply 'r'): The mean time to replace or repair a failed component. Logistics time associated with the repair, such as parts acquisitions and crew mobilization, are not included. It can be estimated by dividing the summation of repair times by the number of repairs and, therefore, is practically the average repair time. The most common unit in reliability analyses is hours (h/f).

operational availability (Ao): Long-term average fraction of time that a component or system is in service and satisfactorily performing its intended function. Ao differs from Ai in that it includes all downtime. Included are downtime for the repair of failures, scheduled maintenance, and any logistics time required (such as obtaining the necessary parts and scheduling the technician to perform the repair).

reliability: The probability that a component or system will perform required functions under stated conditions for a stated period of time $R(t)$, or (for discrete missions) a stated number of demands.

NOTE—The term reliability is also used as a reliability characteristic (metric) denoting a probability of success, or a success ratio. And in general usage, reliability refers to system performance over time.

repair downtime (RDT): The total downtime for unscheduled maintenance (excluding logistics time) for a given total period (TP) in hours.

repair logistics time (RLT): The total logistics time for unscheduled maintenance for a given total period (TP) in hours.

system: A group of components connected or associated in a fixed configuration to perform a specified function.

total downtime events (TDE): The total number of downtime events (including scheduled maintenance and failures) during the total period (TP). (Formerly All Actions, Maintenance and Repair)

total failures (TF): The total number failures during the total period (TP).

total maintenance actions (TMA): The total number of scheduled maintenance actions during the total period (TP).

total period (TP): The calendar time over which data for the item was collected (hours).

year (y): The unit of time measurement approximately equal to 8765.81277 hours (h). Any rounding of this value will have adverse effects on analyses depending on the magnitude of that rounding. 8766 is used commonly as it is the result of rounding to 365.25×24 (which accounts for a leap year every 4th year). 8760, which is 365×24 , is the most commonly used value in the power reliability field. By convention, 8760 will be used throughout this document.

3.2 Acronyms

RBD	reliability block diagram
DoD	Department of Defense
HVAC	heating, ventilating, and air conditioning
SCADA	supervisory control and data acquisition

UPS	uninterruptable power supply
MTBF	mean time between failures
MTTR	mean time to repair
MTBM	mean time between maintenance actions
MTTM	mean time to maintain

4. Data collection

Five categories of information identify the basic data parameters necessary for reliability modeling: site identification, site one-line drawings, nameplate information, critical equipment designation and sparing, and maintenance data. When combined, this information gives the analyst the necessary data to populate a reliability model. Additional information gathered at the time of the data collection process will enhance any analysis performed on the data set. Additional information such as construction type and condition enhances the results of the analysis in providing additional descriptors to the component. Data collection for facilities is not intended to be done in a single setting nor in a single month. This is an ongoing activity that should be completed in as timely a manner as possible without impacting the readiness of the facility. Once completed, updates to the information are only necessary as maintenance is performed on the equipment.

5. Facility identification data

Facility identification data provides basic information about the equipment and the particular facility. Facility identification data consists of the following:

- a) Date of the survey establishes the site configuration baseline date
- b) Facility name/ID number/location identifies the facility
- c) Equipment facility name/ID identifies the equipment with a site-specific ID number, name, or location
- d) In-service date provides the date the equipment was installed, which gives the analyst a starting point to calculate time to failure metrics
- e) Parent system allows the equipment to be assigned to the proper site subsystem

6. Facility one-line drawings

One-line drawings are used to develop the reliability block diagrams (RBDs) and can indicate reliability borders for the electrical distribution, pneumatic, or plumbing systems. The one-line also indicates critical and redundant equipment, systems, and circuits. These drawings may also provide length of wires and pipe, which are needed for the reliability models.

7. Nameplate information

Nameplate data identifies the equipment and its specifications that allow the analyst to obtain time to failure data from the equipment manufacturer or to utilize commercial or military failure databases such as

the IEEE's or Department of Defense's (DoD) Reliability Analysis Center. Nameplate data consists of the following:

- a) Equipment manufacturer
- b) Equipment model
- c) Equipment type
- d) Equipment ratings
- e) Serial number

8. Critical equipment designation and sparing

Critical equipment designation and sparing data identifies equipment that is critical to the mission of the particular facilities. Critical equipment must be highly reliable—generally more reliable than is practical in a single piece of equipment. In general, this equipment has an automatically switched spare or a quickly replaceable spare on-site. Critical equipment designation and sparing data consists of the following:

- a) Critical equipment designation identifies mission critical equipment
- b) Redundant equipment identifies the presence or lack of redundant equipment for critical equipment
- c) Spares identifies on-site critical equipment spares

9. Maintenance data

Maintenance data provides the reliability analyst with time to failure data as well as insight into the level of periodic maintenance performed on a piece of equipment. Time to failure data provides data for calculation of time to failure metrics while periodic maintenance data allows a validation of manufacturer supplied failure data. This data contains both scheduled and unscheduled maintenance actions. Scheduled maintenance lists periodic maintenance while unscheduled maintenance lists equipment failures and repairs. Maintenance data consists of the following:

- a) Handwritten log books or records
- b) Computerized maintenance records

10. Data forms

The manual data forms in Annex A have been developed for the facility engineer's use. These forms contain the necessary data to be collected on the equipment. In order to keep the forms to a minimum, there is a single form for each class of equipment. For example, on form A.2.5 there are three types of boilers: hot water, low-pressure steam, and high- pressure steam. This single form will be used to gather data on all three types of boilers. Facility equipment has been divided into two categories: power generation and distribution equipment, and HVAC equipment. Table 1 lists power generation and distribution equipment; Table 2 lists HVAC equipment.

Table 1—Power generation and distribution equipment

Form number	Equipment class
A.1.1	Battery
A.1.2	Battery charger
A.1.3	Cable/conductor
A.1.4	Capacitor/harmonic filter bank
A.1.5	Circuit breaker
A.1.6	Industrial control panel
A.1.7	Engine
A.1.8	Fuel distribution system
A.1.9	Tank
A.1.10	Fuse
A.1.11	Gauge
A.1.12	Generator assembly
A.1.13	Inverter
A.1.14	Lightning arrestor
A.1.15	Meter
A.1.16	Poles and cross members
A.1.17	Transformer
A.1.18	Relay
A.1.19	Rectifier
A.1.20	SCADA system
A.1.21	Switchboxes/panels enclosures
A.1.22	UPS, uninterruptible power supply
A.1.23	Voltage regulator

Table 2—HVAC equipment

Form number	Equipment name
A.2.1	Accumulator
A.2.2	Air dryer
A.2.3	Air-handling unit
A.2.4	Blower
A.2.5	Boilers
A.2.6	Cabinet heater (radiator)
A.2.7	Chiller
A.2.8	Compressor

A.2.9	Condenser
A.2.10	HVAC control panel
A.2.11	Convactor
A.2.12	Cooling tower
A.2.13	Damper
A.1.14	Direct-fired furnace
A.2.15	Evaporator
A.1.16	Fan
A.2.17	Filter
A.2.18	Heat exchanger
A.2.19	Humidistat
A.2.20	Motor, electrical
A.2.21	Piping
A.2.22	Pressure control
A.2.23	Pump
A.2.24	Strainer
A.2.25	Thermostat
A.2.26	Transducer
A.2.27	Valve

Annex A

(normative)

Data collection forms

A.1 Power generation and distribution equipment

A.1.1 Battery

Today's date _____ Facility name/ID _____

Equipment facility ID/name _____

Manufacturer _____ Date of manufacture _____

In-service date _____

Battery installed in equipment _____

Parent system _____

Battery type:

Dry cell _____ Lithium ion _____ Nickel metal hydride _____

Nickel cadmium _____ Wet cell, lead acid _____ Gel cell _____

Ratings:

Voltage _____ V

Ampere hour _____ Ah

Battery purpose: Backup _____ Load _____ VA

Constant power _____ Load _____ VA

Does the battery supply power to a critical function? Yes _____ No _____ Charger in use? Yes _____ No _____

Charger: Manufacturer _____

Ratings:

Voltage _____ V

Current _____ A

Is this charger used for more than a single battery? No _____ How many? _____

What is the time to 80% discharge at operational load? _____ h

Is there a spare on-site for this battery? Yes _____ No _____

What periodic maintenance is performed on the battery and at what interval?

Item number	Maintenance performed	Interval	Date last performed	Comments
1				
2				
3				
4				

Is a maintenance log kept for this battery? Yes ___ No ___

Has this device or any components been replaced due to failure? Yes ___ No ___

At what interval is the battery replaced? _____

A.1.2 Battery charger

Today's date _____ Facility name/ID _____

Equipment facility ID/name _____

Manufacturer _____ Date of manufacture _____

In-service date _____

Battery installed in equipment _____

Serial number _____

Parent system _____

Input voltage _____ V

Output voltage _____ V

Output ampere _____ A

Is this device critical equipment? Yes ___ No ___

Is there a spare on-site for this device? Yes ___ How many? _____ No ___

What is the approximate time to replace this device? _____ h

Are records kept on maintenance and replacement? Yes ___ No ___

Written ___ Computerized ___

What periodic maintenance is performed and at what interval?

Item number	Maintenance performed	Interval	Date last performed	Comments
1				
2				
3				
4				

Has this device or any components been replaced due to failure?

Item number	In-service date	Date replaced	Comments
1			
2			

Today's date _____ Facility name/ID _____

Equipment facility ID/name _____

Manufacturer _____ Date of manufacture _____

In-service date _____

Battery installed in equipment _____

Parent system _____

Battery type:

Dry cell _____ Lithium ion _____ Nickel metal hydride _____

Nickel cadmium _____ Wet Cell, lead acid _____ Gel cell _____

Ratings:

Voltage _____ V

Ampere hour _____ Ah

Battery purpose: Backup _____ Load _____ VA

Constant power _____ Load _____ VA

Does the battery supply power to a critical function? Yes ___ No ___

Charger in use? Yes ___ No ___

Charger: _____ Manufacturer: _____

Ratings:

Voltage _____ V

Current _____ A

Is this charger used for more than a single battery? No ___ How many? _____

What is the time to 80% discharge at operational load? _____ h

Is there a spare on-site for this battery? Yes ___ No ___

What periodic maintenance is performed on the battery and at what interval?

Item number	Maintenance performed	Interval	Date last performed	Comments
1				
2				
3				
4				

Is a maintenance log kept for this battery? Yes ___ No ___

Has this device or any components been replaced due to failure? Yes ___ No ___

At what interval is the battery replaced? _____

A.1.3 Cable/conductor

Today's date _____ Facility name/ID _____

Equipment facility ID/name _____

Manufacturer _____ Date of manufacture _____

In-service date _____

Ratings:

_____ kVA

Operational load % kVA (if known)

_____ % kVA

Is the conductor:

Belowground ___ Aboveground ___ Aerial ___ In conduit ___

In tray ___ Insulated ___ Open wire ___ Armored ___

Type:

AC ___ DC ___

Voltage _____ V

Length _____ ft (m)

Is there a spare on-site for this device? Yes ___ How many? _____ No ___

What is the approximate time to replace this device? _____ h

Is there a redundant loop available for this circuit? Yes ___ No ___

Are records kept on maintenance and replacement? Yes ___ No ___

Written ___ Computerized ___

What periodic maintenance is performed and at what interval?

Item number	Maintenance performed	Interval	Date last performed	Comments
1				
2				
3				
4				

Has this device or any components been replaced due to failure?