Assessing the Health of Your Healthcare Facility's Electrical Power Distribution System

Executive summary

A vital concern in any healthcare environment is the "health" of the electrical power distribution systems. This paper discusses considerations that should be taken into account when assessing healthcare electrical power distribution systems, including code compliance, bonding and grounding issues, ground fault protection requirements, and surge protection needs. The procedures for carrying out assessments are also outlined, as well as the concerns and issues to be aware of that could compromise performance and/or safety of a healthcare facility.

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Schneider Electric

Summary

Introduction

An issue of vital concern in any healthcare environment is the "health" of the system infrastructures that works behind the scenes. Like any engineered system, electrical power distribution systems cannot be designed and constructed to indefinitely operate 100% of the time. Whether for a relatively new power system, or for an older existing installation, an assessment of the condition of the electrical power systems can mean the difference between an electrical system which operates as designed and intended as well as meets current electrical codes and standards and one that does not.

This paper provides basic considerations that should be taken into account for assessments of the electrical power distribution systems within health-care facilities, including code compliances, bonding and grounding issues, ground fault protection requirements and surge protection needs. The procedures for carrying out assessments are also outlined, as well as the concerns and issues to be aware of that could compromise performance and/or safety of a healthcare facility. Charts are presented to show losses resulting from electrical equipment.

References

- Power distribution systems or PDS is specifically referring to the electrical power system.
- ANSI refers to the American National Standards Institute.
- IEEE refers to the Institute for Electrical and Electronic Engineers, Inc.
- NEMA refers to the National Electrical Equipment Manufacturers Association.
- NFPA refers to the National Fire Protection Association.
- NFPA 70 – 2008 Edition is commonly referred to as the National Electrical Code (NEC).
- NFPA 70B – 2010 Edition: Recommended Practice for Electrical Equipment Maintenance.
- NFPA 70E – 2009 Edition: Standard for Electrical Safety in the Workplaces
- NFPA 99HB – 2005 Edition: Health Care Facilities Handbook This is the handbook edition of NFPA 99. NFPA 99 is the installation and performance requirements document for health care facilities and is the reference for The Joint Commission requirements. Most inspections by The Joint Commission will focus around the requirements of this document.
- NFPA 110 – 2010 Edition: Standard for Emergency and Standby Power Systems
- NFPA 111 – 2010 Edition: Standard on Stored Electrical Energy, Emergency and Standby Power Systems
- NFPA 780 – 2008 Edition: Standard for the Installation of Lightning Protection Systems
- IEEE Std C62.72™ – 2007: IEEE Guide for the Application of Surge-Protective Devices for Low-Voltage (1000 V or Less) AC Power Circuits

Why Perform an Assessment?

There are numerous reasons why it may become necessary to perform an assessment of the Power Distribution System (PDS) of a specific healthcare facility or hospital. The most common reasons that PDS assessments are solicited and commissioned are usually associated with some event or events that occurred that caused the facility's engineering or operations staff concerns, problems or stress.

Some typical examples might be:

- Tripping of protective devices.
- Evaluation of devices or equipment as protective relays or circuit breakers to determine functionality and reliability.
- Unexplainable dysfunction or unexpected operations of electrical equipment or controls relative to what has been usual and customary.
- An electrical shock incident of a patient, visitor or staff member.
- Abnormalities with the emergency power systems.

However, these assessments are commissioned after the fact, are usually very limited in scope, and are principally focused only in ameliorating the specific concerns or conditions at hand.

Another reason assessments are performed is that management may desire to have an independent review or second opinion of work performed by others. An independent assessment or inspection is often employed as a quality assurance method to review the contracted scope-of-work performed by a specific contractor. Assessments are often employed to determine if an existing or new electrical installation is in compliance with local electrical codes, the NEC, applicable IEEE® Standards, the equipment manufacturer's installation and operational specifications, or best engineering and construction practices.

To provide a broader and much more important perspective, comprehensive assessments by an experienced professional electrical engineer are best employed to provide information to management on the "present state" of specific PDS. The results of such assessments are extremely valuable in determining the remaining usefulness or reliability of electrical equipment as well as the compatibility of existing equipment with newly installed or planned electrical equipment expansions. An understanding of the remaining usefulness or reliability of electrical equipment can provide management with an opportunity to adequately and proactively budget for a systematic replacement or retrofit of existing electrical equipment that might be aged, dysfunctional, outdated, under rated, unreliable or worn out. Interconnecting dissimilar electric equipment or circuit breakers provided by different electrical manufacturers can often result in poorly coordinated overcurrent protection or unwanted tripping conditions.

Comprehensive assessments can be employed to construct a framework or guide for preventive maintenance programs and planned equipment enhancements or replacements.

Occasionally PDS assessments are contracted and performed in order to fully understand the liability the system may present for a reliable hospital operation. As such PDS assessments can also provide for the following:

- A means to determine the power distribution systems' risk to future fdysfunctions.
- A means to determine if there are any violations of electrical codes, electrical standards, or best practices.
- A means to determine the cost of the necessary corrections or improvements.
- A means to determine the necessary requirements to improve the present states of a PDS in order to extend the life and reliability of the equipment.

Since September 11, 2001 some electrical codes have been revised to mandate assessments. For example, NEC 708.5(A), mandated that risk assessments be perform in all facilities classified as "Critical Operations Power Systems".

Assessment Process

Who Should Perform PDS Assessments?

The specific health care facilities, hospital or their assigned agent should interview and select professional electrical engineers and engineering services companies who are experienced in the design and installation of a wide variety of power distribution equipment. The selected electrical engineer should also be very familiar and well versed on all applicable electrical codes and standards specifically pertaining to electrical installations in health care facilities and hospitals. The selected electrical engineer or engineering service company should be able to produce a resume the reference prior assessment experiences. The selected professional electrical engineer(s) should be able to produce a report with a P.E. stamp from a licensed professional engineer in the state where the assessments will be performed.

Before Beginning the Assessment Process

Several things need to be considered before beginning any assessment process. These include workplace safety, scope of work and the items and tools necessary to perform the assessment.

Workplace Safety

Before starting the PDS assessments it is extremely importation to remember that safety is always of paramount concern and focus. Although it is the responsibility of facility management to assure the security at the facilities and to maintain a safe work environment, the electrical engineer performing the on-site assessments should be trained in accordance with NFPA 70E®, Standard for Electrical Safety in the Workplaces. Any electrical engineer performing the on-site assessments should reserve the right to discontinue any on-site activity if conditions are deemed to be unsafe. Safety procedures should be reviewed and understood by both the assessment party and the facility maintenance team.

In addition, the electrical engineer performing the on-site assessments should be informed and made aware of any biological or other hazards that may be present during the course of his movements through and around the facilities.

Security is also of importance. The facility management should arrange for security cards, identification badges and access to entry cards or security keys. The assessment engineering team also needs to be made aware of restricted areas or areas that may require staff personnel to provide an escort.

Clarify "Scope of Work"

Clarify and document the "scope of work" before the assessment process begins. Before beginning any on-site assessments, there should be a clear and documented understanding as to which equipment or portions of the PDS will be incorporated into an assessment program or study. The understanding takes the form of a scope of work document that is drafted with the input of the assessment engineer and management of the healthcare facilities. The scope of work needs to include all the equipment that is contracted and agrees to be incorporated into the assessment.

Examples of such engineering functions that might also be included into an assessment could include, taking a wide assortment of different measurements, performing electrical or functional tests, installing metering or monitoring equipment, or operating a facility's equipment. Diligence in the beginning of any intended process is intended to prevent misunderstanding, distractions or expectations of tasks not clearly covered in the scope of work.

It is also important for the electrical engineer performing any assessments to clearly identify any specific assistance from a facility's operations and maintenance staff that may be need while on site. It is important to clearly inform the management of the healthcare facilities of any supportive roles that may be necessary by them, their associated staff, or their designated agents or contractors.

Some support activities that may be necessary for the healthcare management to provide are listed below:

- Provide an individual authorized to resolve questions and coordinate customer activities, as required.
- Provide an experienced electrical engineer or supervisor that is familiar with design documents and records to direct and assist Engineering Services personnel in any necessary equipment inspections.
- Provide and expedite any badge processes necessary to required entry and escorts as necessary.
- Inform the assessment engineer of any particular or specific safety requirements necessary to perform any activities on the customer's site.
- Provide maintenance or operations staff personnel that are familiar with the existing power distribution systems who will accompany assessment engineer through the facilities and arrange for access to the applicable electrical equipment for inspections.
- Assist the assessment engineer in the collection of applicable manufacturing and construction record data that accompanied the equipment.
- Provide a timely response for all questions and submissions.
- Assist the assessment engineer by providing keys access to the facility's electrical panels and equipment rooms, and the assistance of an electrician or facilities technician familiar with the physical location of electrical equipment, electrical circuits and specific loads.
- Be responsible for collecting and provide all requested information concerning any or all specific 'as-built' electrical distribution system drawings and records.

What is Needed to Perform Assessments?

It is important that the electrical engineer performing the on-site assessments be effectively prepared before all work begins. This includes knowing what is needed to perform the on-site assessment.

Below is a partial list of items or support that is often involved with or required to perform the on-site assessments:

- Is special equipment required?
- What personal protective equipment is required?
- Are safety procedures required?
- Is test equipment or diagnostic equipment required?
- Is support personnel required?
- Are outside contractors required?
- Are power outages required?
- Is special monitoring equipment required?
- Are special tools required?
- Are cameras allowed?

After an Event — "The 20 Questions or Interview Period"

If the on-site assessments are associated with a specific event, the selected engineer should start the process by interviewing the facility staff and all applicable or associated parties in order to gather as much historical data and information on the sequence of event as possible. Recollections and memories of different staff members or contractors often reveal different or conflicting descriptions of occurrences or sequences of events.

Begin to quantify as many variables as possible for your assessments and analyses. Below are some examples:

- What events occurred or did not occur? What equipment was involved?
- When did the events occur? What date(s)? At what times and on which days did the event(s) occur?
- What were the conditions and states of internal and external environmental condition? Were the internal spaces hot and humid? Were there any internal water or drain leaks? Were there thunder storms passing over head outside of the building at the time of the reported event? Was it raining outside?
- What conditions or combination of conditions could have caused or contributed to the conditions reported? Begin to formulate conditions, pictures and scenarios in your mind.
- Ask for and review all available and applicable documentation (one-line diagrams, inspection reports, test reports, original specifications, etc.)
- What is the type and sequence of operation?
- What is the history of construction? What is the history of facility operations? How long have the systems been in place? Were there any previous issues, incidents or concerns?
- Determine and select the point to begin the inspections/assessments. Coordinate action plans with the customer.

General On-Site Assessments and Data Collection

All power distribution systems are different and dynamic. The electrical engineer performing the on-site assessments should have a one-line diagram to study, become familiar with the normal electrical operations characteristics, building construction and layout, and limits of the equipment to be assessed. It is important to know what electrical codes were in place when the equipment or system was originally constructed or set in place. Not all municipalities and states employ exactly the same electrical codes and standards. Any special electrical code requirements in the specific location need to be taken into consideration.

The dimensions of the facilities under assessment are also an important consideration. Are there any outside influences and conditions to consider such as switching operations by the local electrical utility, atmospheric disturbances or recent changes in configuration or operation of the facility's internal electrical distribution systems? It is important to quantify as many variables as possible as part of any assessment program.

A Starting Point

The system configuration is based strictly on the specific secondary winding configuration of the power class or distribution class transformer supplying the service and exactly how it may or may not be referenced to earth. The system configuration is NOT based on the connection of any specific load or loads. Much of the data collected during the inspection processes are similar or identical to the data collection for short circuit study, time/current coordination study, or an arc flash study. The only difference is that the electrical engineer might be principally focusing on the installation and state of the equipment.

For example:

- How many sources of power (transformers, generators, UPS units, back up batteries, MG sets, solar panel arrays, wind generators, transfer switches)?
- Who is the local electrical utility or electrical service provider?
- Who owns the service transformers?
- How are the service transformers, generators, UPSs or MGs configured or referenced to earth?

Assessing Power Class Transformers

Following is a list of specific things to look for when assessing power class transformers (greater than 500 KVA):

- What is the size of the transformer in KVA?
- What are the primary and secondary winding configurations?
- What are the primary and secondary voltages?
- What is the present tap setting?
- Does the transformer have a "no load" tap changer or a "load" tap changer?
- What is the percent impedance (%Z) of the transformer?
- What is the condition of transformer?
- What is the cooling means for the transformer?
- What is the temperature gauge reading (present temperature and the maximum temperature indicated)?
- What is the liquid level indication?
- Nitrogen gas blanket?
- Is there a nitrogen gauge or regulator present?
- Are there fluid leaks present? Were there previous fluid leaks?
- What are the types of primary and secondary protection?
- What is the type of bonding and grounding method employed?

Power class transformers located outside of the facility must have enclosure types that are rated for the specific application, environment and location. The transformer must be accessible to qualified personnel and protected from unauthorized persons. Because of local ordinances the transformer might require security fencing or camouflage. Such transformers require appropriate safety labels or signs.

Power class transformers located inside of the facility must be dry types or filled with non-flammable liquid. Such transformers located indoors may be required to be located in a sealed and secured vault or placed in a room with a specific fire rating. Environmental considerations are very important to the place of indoor transformers. Since such transformers must be in specific rooms or locations accessibility to the transformer, heat dissipation and cooling for the transformer and security for the transformer are always an issue or concern and consideration. The importance of a large volume of open space around indoor power class transformers is for heat dissipation for the transformer windings. Because of the required open space around large indoor transformers, such areas are routinely employed after the initial construction as a storage area for excess materials or records.

General On-Site Assessments and Data Collection (continued)

Assessing Distribution Class Transformers

The following is a list of specific things to look for when assessing distribution class transformers (500 KVA or less):

- Size in KVA.
- Primary and secondary winding configurations.
- Primary and secondary voltages.
- Percent impedance (%Z).
- Is the transformer readily accessible? [Refer to NEC 450.13]
- Is there sufficient space around dry type transformer to allow for adequate cooling? [Refer to NEC 450.9 and 450.21]
- What is the physical condition of the transformer?
- Is the transformer ventilation adequate to prevent overheating and a risk of fire? [Refer to NEC 450.9]
- Is the transformer audible? As dry type transformers age or become overloaded over a long period of time, thermal stresses can cause the laminations to begin to separate. Consequently, the normal 60 Hz hum sounds more like a continuous high frequency scream.
- Types of primary and secondary protection?
- Size and type of primary and secondary conductors? Are they underrated? [Refer to NEC 210.20 and 240.21]
- Type of bonding and grounding method employed? [Refer to NEC 250.4]
- How and where is the Xo terminal connected to the building steel?

"The ventilation shall be adequate to dispose of the transformer full-load losses without creating a temperature rise that is in excess of the transformer rating. Transformers with ventilating openings shall be installed so that the ventilating openings are not blocked by walls or other obstructions. The required clearances shall be clearly marked on the transformer."

- Is there accessibility to each transformer? [Refer to NEC 450.13 — "All transformers and transformer vaults shall be readily accessible to qualified personnel for inspection and maintenance."]
- Is there dry type transformer installed indoors? [Refer to NEC 450.21 — "Dry-type transformers installed indoors and rated 112.5 KVA or less shall have a separation of at least 305 mm (12 in.) from combustible material unless separated from the combustible material by a fire-resistant, heat-insulated barrier."]

["Individual dry-type transformers of more than 112.5 KVA rating shall be installed in a transformer room of fire-resistant construction. Unless specified otherwise in this article, the term fire resistant means a construction having a minimum fire rating of one hour."]

Assessing Service Equipment

The following is a list of specific things to look for when assessing the service equipment:

- The types of primary and secondary protection.
- The type of equipment — is it a switchboard or is it switchgear?
- The type of main and feeder overcurrent protective devices.
- What is the NEMA rating and type of equipment relative to the surrounding environment?
- The manufacturer, brand and nameplate data.
- What are the settings of the circuit breaker's protective functions? Is there apparent coordination? [Refer to NEC 110.9]
- What are the dates of installation? This will determines the which electrical codes are applicable at the time of installation.
- Is there a ground-fault protection system? If so, exactly where? What equipment is affected? How many levels of ground fault protection exist?

- Is the ground-fault protection system for each level functional?
- If there are multiple interconnected source of electrical powers, has the necessary modified differential ground-fault protection system been designed, installed and functionally tested?
- Was the ground-fault protection system tested when first installed? If so, where are the records? [Refer to NEC 230.95]
- Is there a main bonding jumper? Has the main bonding jumper been properly installed and labeled? [Refer to NEC 250.24]
- The neutral disconnect link properly installed and labeled?
- Where all of the shipping split ground busses and interconnecting terminals made up after initial installation?
- The type and size of service and feeder conductors.
- Is there a neutral with the service entrance cables? [Refer to NEC 250.24(C)]
- How are they terminated? What types of lugs were utilized? Compression type or lug with set screw type? Are the terminals made of copper, aluminum, brass or some type of alloy? Are there any possibilities for galvanic reactions from the connection of dissimilar metals?
- Are all terminal lugs effectively torqued? Was the correct Grade 5 or higher rated hardware utilized?
- Are service and feeder cables effectively braced, laced, and secured? [Refer to NEC 300.20, 408.3(A)(1), and 408.3(B)].
- What is the exact type of bonding and grounding method employed?
- Are there any surge protective devices installed? If so, are they properly rated, labeled, installed and effectively connected? [Refer to NEC 285 and IEEE Std C62.72™]

Assessing New Electrical Equipment Installations

Note: Short circuit and time/current coordination studies are necessary to insure that all overcurrent protective devices are effectively coordinated and properly set.

The following list includes some typical reasons for assessing new electrical equipment installations:

- To help insure and verify that the electrical equipment is in compliance with the purchase specifications and intended power distribution system design by the Engineer of Record.
- To help insure and verify that the electrical equipment has been installed as designed and intended and in accordance with applicable codes, standards or best practices.
- To document initial assessments to serve as a benchmarks or references for future inspections.
- To help insure that new electrical distribution equipment is effectively coordinated with any existing electrical and power distribution equipment.

General On-Site Assessments and Data Collection (continued)

Assessing Downstream Equipment

The following is a list of specific things to look for when assessing downstream panelboards, load centers, power panels and fused disconnects:

- The neutral disconnect link.
- What are the models, types and ages of the equipment?
- What are the types, sizes and ratings of all Overcurrent Protective Devices (OCPDs)?
- Is the equipment listed for the environment?
- Are there environmental concerns?
- Is there an effective ground fault return path? [Refer to NEC 250.4(A)(5)]
- What is the intended ground fault return path during any phase-to-ground fault at any point in the power distribution system?
- What is the condition of the interior?
- Are there any obvious objectionable neutral-to-ground bonds?
- Is there sufficient clearance around the equipment to avoid a fire hazard? [Refer to NEC 110.26]
- Is there any corrosive conditions? [Refer to NEC 310.9]
- Has the limiting temperature of the equipment been exceeded? [Refer to NEC 310.10]
- Are there any corrosive conditions? [Refer to NEC 310.9]
- Are switchboards properly installed and protected from damp or wet locations? [Refer to NEC 312.2 and 408.16]
- Are the panelboards and sub-panels installed and properly protected from damp or wet locations? [Refer to NEC 312.2 and 408.37]
- Are there any tap rule violations? [Refer to NEC 240.21(B) — tap rule section]
- Are the cables sized correctly? Are the OCPD sized correctly?
- Proper temperature rise rating of cable relative to OCPD and environment. [Refer to NEC 310.15]
- Six cycle separation for ground fault protection. [Refer to NEC 517.17(C)]
- Do isolated power systems function and operate as designed and intended? When was the last time they were tested? Were the test results documented, recorded and available for retrieval and review?
- Are there any surge protective devices installed? If so, are they properly rated, properly labeled, properly installed and effectively connected? [Refer to NEC 285 and IEEE Std C62.72™]

Assessing Electrical Room Construction

- What are the cooling and humidity requirements for equipment?
- Are there ventilation requirements for specific equipment rooms?
- What are the minimal spaces between physical structures and other electrical equipment?
- Is the equipment adequately accessible for maintenance and servicing personnel?
- What are the security accessibility and requirements?
- Where are the Emergency Power-Off (EPO) installations and their locations?
- Is the equipment NEMA 1 or NEMA 3R?
- Are service and load conductors rated for application and environmental conditions?
- Are dissimilar circuit breakers being employed in multiple-ended power distribution equipment (multiple sources)?
- Review and understand the GFPE system as meeting the NEC.
- Storage must remain outside the electrical equipment area.
- Are there adequate fire alarms?

- Is all electrical equipment effectively bonded and grounded?
- Is there effective lighting within electrical rooms or closets?
- Have equipment installation requirements and guidelines been provided by the electrical equipment manufacturer?
- Have operations and maintenance manuals been provided by the electrical equipment manufacturer?
- What are the existing startup and testing requirements?
- What are the proper lock-out/tag-out requirements?
- Are the appropriate danger and warning labels properly affixed? Have all of the "inform and warn" requirements been satisfied?
- Is there a need for a house keeping pad under the electrical equipment?
- Have the proper locations within a specific building or facilities for the placement of service equipment, distribution equipment, power panels, motor control centers, ATS units, battery banks, UPS units, on-site generators, etc., been appropriately selected?
- Are there flooding concerns from either external or internal sources?
- Are there any structural/seismic requirements for the electrical room?
- Are there any structural and bracing requirements for the electrical equipment enclosures?
- What are the structural and bracing requirements for overhead busways, busducts and conduits?
- Is there a need for floor drains or sump pumps in electrical rooms?
- Are there temperature and humidity requirements necessary for the electrical rooms?
- Is the appropriate protection installed to protect the electrical equipment from or vermin infestations?

Assessing Emergency Generators

The following is a list of specific things to look for when assessing emergency generators:

- Is there any paralleling of transformer with other transformers or emergency generators?
- What is the kW and KVA rating of the emergency generators?
- How are the Xo terminals of the transformer and generators bonded to ground?
- Is the frame of the transformer and the emergency generators effectively bonded to earth and to each other via a permanently connected low impedance path?
- What is the maximum power factor? (80%?)
- What is the winding configuration?
- What is the output voltage?
- Is there other applicable nameplate information?
- What is the type of bonding and grounding method employed?
- Paralleling?
- What is the percent (%) pitch?
- Are there any protective relaying issues?
- What is the fuel source for the prime mover?
- What is the state of the generator's start batteries?
- What is the capacity and condition of the generator's day tank?
- How is the generator controlled and regulated?

Assessments May Involve Some Testing

- What is the proper temperature rise ratings of the cables relative to the OCPDs and the environment?
- What is the present state of all insulation levels relative to manufacturer's specifications or previous test results (i.e. deterioration or shorted windings, excessive leakage current, corona damage)?
- Are the torque values as designed and intended?
- What is the present state of contact resistances of all fused power switched and power circuit breakers?
- Do movable parts operate as designed and intended?
- Do protective devices operate as designed and intended (i.e. long time overloads, short circuit protection, instantaneous overload and ground fault protection)?
- Are the setting of all protective devices correctly placed on the proper pickup and time delay settings?
- Is there any deterioration of insulating fluids? If so, why? What is the root cause of any deterioration?
- Is the equipment effectively bonded and grounded via a low impedance path?
- Is there an effective grounding system?
- Is the electrical equipment functioning as designed and intended?
- Are there any deteriorated components, parts or equipment that need to be replaced or repaired?
- Documented findings serve as benchmarks and reference for future testing.

Loss Experience for Electrical Equipment

The information in Table 1 and Figure 1 is data collected from a single insurance company, Factory Mutual Global. The charts below present Factory Mutual Global's loss data showing losses caused by electrical equipment within the United States during specific time periods. It is extremely important to note that the data is just from one insurance company. If one considers the number of other large insurance companies within the United States, one can gain an appreciation for the magnitude of losses annually just from electrical equipment.

Figure 1 presents Factory Mutual Global's loss data showing losses caused by electrical equipment per specific types of equipment. Many of these losses involved insulation breakdown. It is believed that some of these losses could have possibly been detected by preventive maintenance and testing. Consequently, the direct cost could have been greatly reduced. The losses also included fires caused by electrical ignition and electrical insulation breakdown.

Figure 2 equates to one large claim every two weeks from a phase-to-ground arcing fault.

Note: The NEC is a minimum construction and installation "requirement" document. The NEC is NOT a design or performance standard. "Minimum requirements" are often insufficient for the construction and installation of mission-critical facilities as large healthcare facilities and hospitals.

Electrical equipment should be installed, operated, serviced and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

Table 1: Electrical Losses Reported to Factory Mutual Global (1991-2000)

Equipment	Number	Gross US$ (Millions)
Transformers	1000	492
Cable/Wiring/Bus	893	362
Switchgear/Circuit Breakers	602	254
Generators	174	166
Motors	580	145
Misc. Electrical Apparatus	261	48
Total	**3510**	**1467**

Figure 1: Factory Mutual Global Customers Gross Electrical Losses

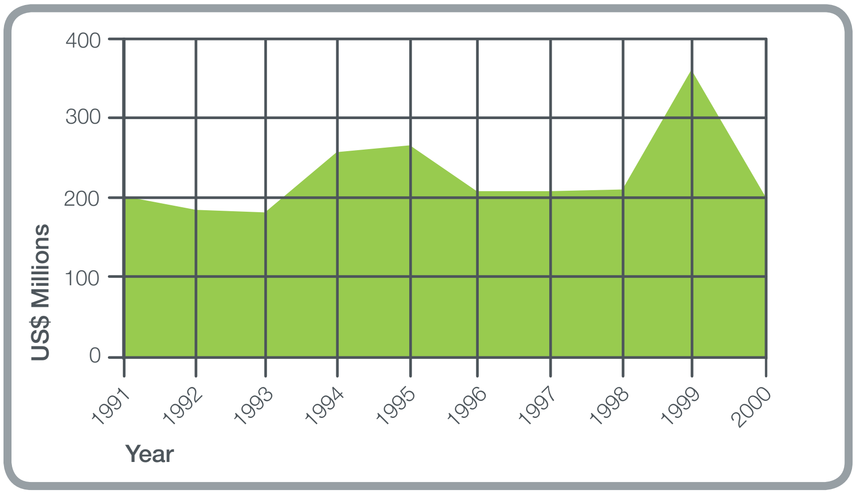
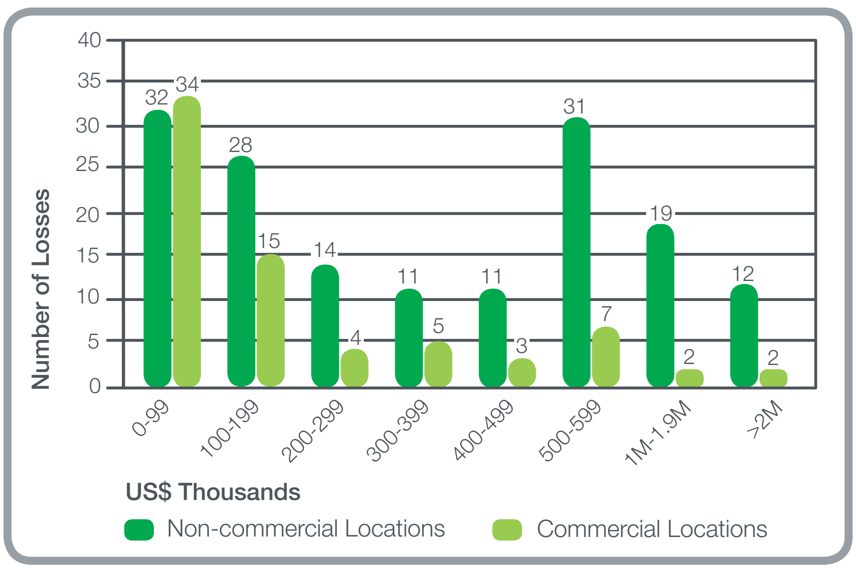


Figure 2: Ground Fault Losses Reported to Factory Mutual Global (1992-2001)



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