


Electrical design of healthcare facilities (essential system requirements)

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Healthcare Facilities

Due to the critical nature of the care being provided at healthcare facilities and their increasing dependence on electrical equipment for preservation of life, they have special requirements for the design of their electrical distribution systems.



Electrical design of healthcare facilities (essential system requirements) - on photo: Power substation in St. Paul's Hospital; source: Status Electrical Corporation

Healthcare facilities are defined by NFPA (National Fire Protection Agency) as “Buildings or portions of buildings in which medical, dental, psychiatric, nursing, obstetrical, or surgical care are provided”.

These requirements are typically much more stringent than commercial or industrial facilities.

This technical article summarizes some of the **unique electrical requirements of healthcare facility design**.

There are several agencies and organizations that develop requirements for healthcare electrical distribution system design. The following is a listing of some of the specific NFPA (National Fire Protection Agency) standards that affect healthcare facility design and implementation:

- **NFPA 37-2015** – Standard for Stationary Combustion Engines and Gas Turbines
- **NFPA 70-2014** – National Electrical Code
- **NFPA 99-2015** – Healthcare Facilities
- **NFPA 101-2015** – Life Safety Code
- **NFPA 110-2016** – Standard for Emergency and Standby Power Systems
- **NFPA 111-2016** – Standard on Stored Electrical Energy Emergency and Standby Power Systems

These standards and guidelines represent the most industry recognized requirements for healthcare electrical design.

*However, the electrical design engineer should consult with the authorities having jurisdiction over the local region for **specific electrical distribution requirements**.*

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1. Healthcare Electrical System Requirements

Healthcare electrical systems usually consist of two parts:

1. Non-essential (or normal) electrical system.
2. Essential electrical system.

All electrical power in a healthcare facility is important, though some loads are not critical to the safe operation of the facility.

These “non-essential” or “normal” loads include things such as: general lighting, general lab equipment, non-critical service equipment, patient care areas, etc. These loads are not required to be fed from an alternate source of power.

The electrical system requirements for the essential electrical system (EES) vary according to the associated risk to the patients, visitors and staff that might occupy that space. NFPA 99 assigns a risk category to each space within the healthcare facility based on the risk associated with a failure of the power distribution system serving that space.

These risk categories are summarized in Table 1 below.

Table 1 – Essential Electrical System (EES) Risk Categories

Risk Category	Failure of Such Equipment or System is Likely to Cause:
Category 1	...major injury or death of patients or caregivers...
Category 2	...minor injury to patients or caregivers...
Category 3	...patient discomfort...
Category 4	...no impact on patient care...

The risk category of the space within the healthcare facility determines whether or not that space is required to be served by an Essential Electrical System (EES). If an EES is required to serve the space, the risk category also dictates whether the EES must meet Type 1 or Type 2 requirements.

Table 2 lists the associated EES Type requirements for each risk category.

Table 2 – Essential Electrical System (EES) Risk Category by Type

Risk Category	Essential Electrical System (EES) Type	Example
Category 1	Type 1	Critical Care Space
Category 1	Type 2	General Care Space
Category 1	EES not required	Basic Examination Space
Category 1	EES not required	Waiting Room

2. Type 1 Essential Electrical Systems (EES)

Type 1 essential electrical systems (EES) have the most stringent requirements for providing continuity of electrical service and will, therefore, be the focus of this section.

Type 1 EES requirements meet or exceed the requirements for Type 2 facilities.

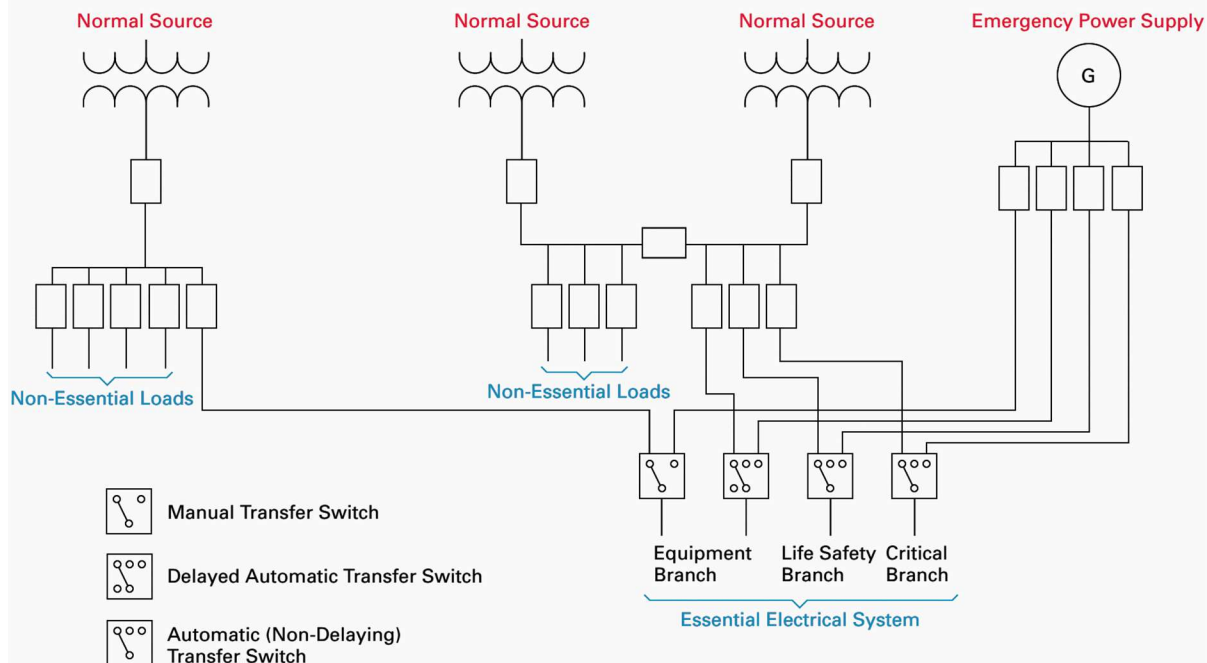


Figure 1 – Typical Large Hospital Electrical System – Type 1 Essential Electrical System

2.1 Sources of electrical power

Type 1 systems are required to have a minimum of two independent sources of electrical power – a normal source that generally supplies the entire facility and one or more alternate sources that supply power when the normal source is interrupted.

The alternate source(s) must be an **on-site generator driven by a prime mover** unless a generator(s) exists as the normal power source. In the case where a generator(s) is used as the normal source, it is permissible for the alternate source to be a utility feed.

Alternate source generators must be classified as **Type 10, Class X, Level 1 gensets** per NFPA 110 Tables 4.1(a) and 4.2(b) that are capable of providing power to the load in a maximum of 10 seconds.

Typically, the alternate sources of power are supplied to the loads through a **series of automatic and/or manual transfer switches**. The transfer switches can be non-delayed automatic, delayed automatic or manual transfer depending on the requirements of the specific branch of the EES that they are feeding.

It is permissible to feed multiple branches or systems of the EES from a [single automatic transfer switch](#) provided that the maximum demand on the EES does not exceed 150 kVA.

This configuration is typically seen in **smaller healthcare facilities that must meet Type 1 EES requirements** (see Figure 2).

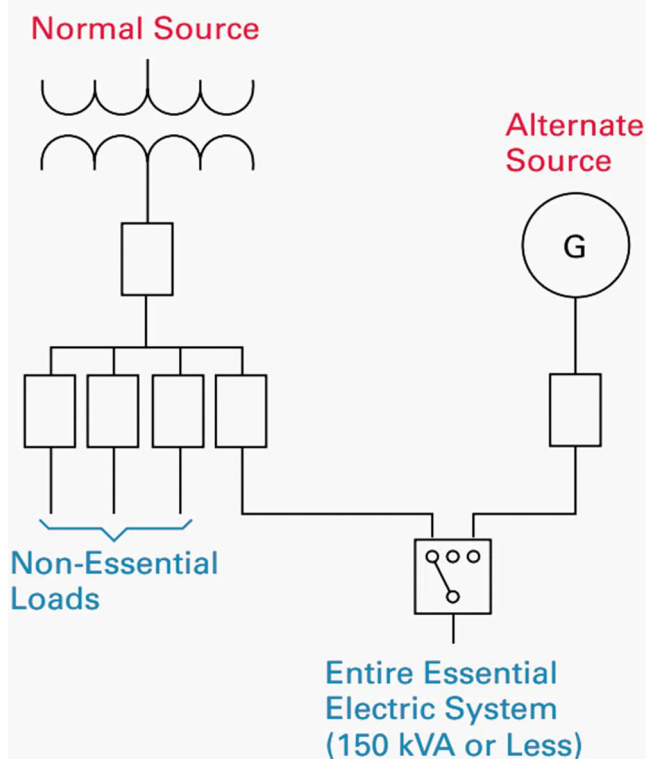


Figure 2 – Small Healthcare Facility
Electrical System – Single EES Transfer Switch

2.2 Essential Electrical System Branches

The Type 1 EES consists of three separate branches capable of supplying power considered essential for life safety and effective facility operation during an interruption of the normal power source.

They are the **life safety branch, critical branch and equipment branch.**

2.2.1 Life Safety Branch

Life Safety Branch supplies **power for lighting, receptacles and equipment** to perform the following functions:

1. Illumination of means of egress.
2. Exit signs and exit direction signs.
3. Alarms and alerting systems.
4. Emergency communications systems.
5. Task illumination, battery chargers for battery powered lighting, and select receptacles at the generator.
6. Elevator lighting control, communication and signal systems.
7. Automatic doors used for egress.

These are the only functions **permitted to be on the life safety branch.** Life safety branch equipment and wiring must be entirely independent of all other loads and branches of service. This includes separation of raceways, boxes or cabinets.

Power must be supplied to the life safety branch **from a non-delayed automatic transfer switch.**

2.2.2 Critical Branch

Critical Branch supplies power for task illumination, fixed equipment, selected receptacles and selected power circuits for areas related to patient care.

The purpose of the critical branch is to provide power to a limited number of receptacles and locations to reduce load and minimize the [chances of fault conditions](#).

The transfer switch(es) feeding the critical branch **must be automatic type.** They are permitted to have appropriate time delays that will follow the restoration of the life safety branch, but should have power restored within 10 seconds of normal source power loss.

The critical branch provides power to circuits serving the following areas and functions:

1. Critical care areas.
2. Isolated power systems in special environments.
3. Task illumination and selected receptacles in the following patient care areas: infant nurseries, medication prep areas, pharmacy, selected acute nursing areas, psychiatric bed areas, ward treatment rooms, nurses' stations.
4. Specialized patient care task illumination, where needed.
5. Nurse call systems.
6. Blood, bone and tissue banks.
7. Telephone equipment rooms and closets.
8. Task illumination, selected receptacles and selected power circuits for the following: general care beds (at least one duplex receptacle), angiographic labs, cardiac catheterization labs, coronary care units, hemodialysis rooms, selected emergency room treatment areas, human physiology labs, intensive care units, selected postoperative recovery rooms.
9. Additional circuits and single-phase fraction motors as needed for effective facility operation.

2.2.3 Equipment Branch

Equipment Branch consists of [major electrical equipment](#) necessary for patient care and Type 1 operation. The equipment branch of the EES that consists of large electrical equipment loads needed for patient care and basic healthcare facility operation.

Loads on the equipment system that are essential to generator operation are required **to be fed by a non-delayed automatic transfer switch.**

The following equipment must be arranged for delayed automatic transfer to the emergency power supply:

1. Central suction systems for medical and surgical functions.
2. Sump pumps and other equipment required for the safe operation of a major apparatus.
3. Compressed air systems for medical and surgical functions.
4. Smoke control and stair pressurization systems.
5. Kitchen hood supply and exhaust systems, if required to operate during a fire.

The following equipment must be arranged for delayed automatic or manual transfer to the emergency power supply:

1. Select heating equipment.

2. Select elevators.
3. Supply, return and exhaust ventilating systems for surgical, obstetrical, intensive care, coronary care, nurseries and emergency treatment areas.
4. Supply, return and exhaust ventilating systems for airborne infectious/isolation rooms, labs and medical areas where hazardous materials are used.
5. Hyperbaric facilities.
6. Hypobaric facilities.
7. Autoclaving equipment.
8. Controls for equipment listed above.
9. Other selected equipment in kitchens, laundries, radiology rooms and central refrigeration as selected.

Any loads served by the generator that are not approved as outlined above as part of the essential electrical system must be connected through a separate transfer switch.

*These transfer switches must be configured **such that the loads will not cause the generator to overload and must be shed in the event the generator enters an overload condition.***

2.3 Ground fault protection

Per NFPA 70 NEC Article 230.95, ground fault protection is required on any feeder or service disconnect 1000 A or larger on systems with line to ground voltages of 150 V or greater and phase-to-phase voltages of 600 V or less.

For healthcare facilities (of any type), a second level of ground fault protection is required **to be on the next level of feeder downstream.**

This second level of ground fault is only required **for feeders that serve patient care areas and equipment intended to support life.** 100% [selective coordination](#) of the two levels of ground fault protection must be achieved with a minimum six-cycle separation between the upstream and downstream device.

As of the NEC, ground fault protection is allowed between the generator(s) and the EES transfer switch(es). However, NEC 517.17(B) prohibits the installation of ground fault protection on the load side of a transfer switch feeding EES circuits (see Figure 1 1-76—additional level of ground fault).

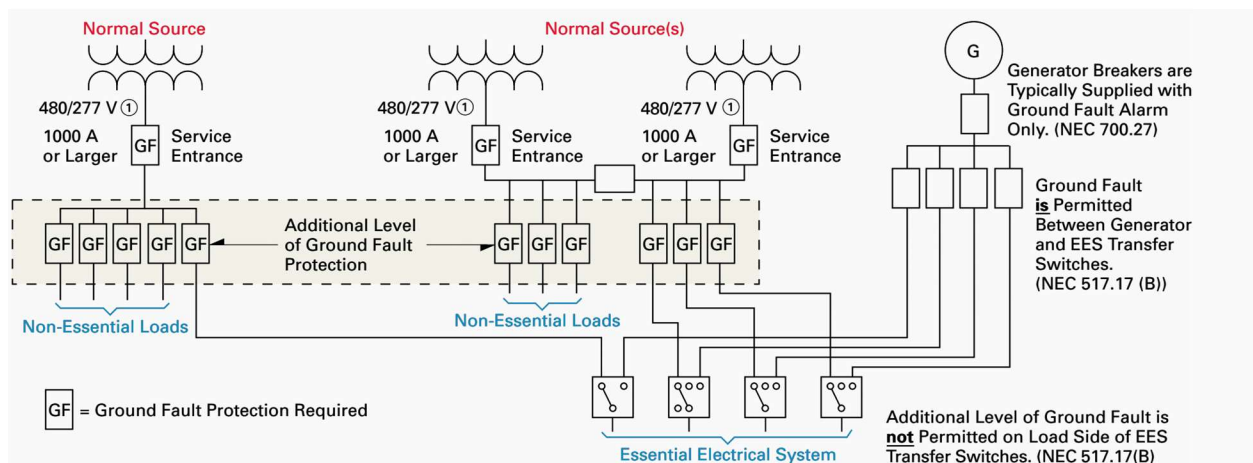


Figure 3 – Additional Level of Ground Fault Protection

NOTE // – Ground fault protection is required for service disconnects 1000 A and larger or systems with less than 600 V phase-to-phase and greater than 150 V to ground per NEC 230.95.

Careful consideration should be used in [applying ground fault protection](#) on the essential electrical system to prevent a ground fault that causes a trip of the normal source to also cause a trip on the emergency source.

Such an event could result in complete power loss of both normal and emergency power sources and could not be recovered until the source of the ground fault was located and isolated from the system. To prevent this condition, NEC 700.27 removes the ground fault protection requirement for the emergency system source.

*Typically, the emergency system generator(s) are equipped with **ground fault alarms that do not automatically disconnect power during a ground fault.***

Table 3 – Ground Fault Protection Applicable Codes

Description	Standard	Section
Services	NEC	230.95
Branch-Circuits	NEC (see Article 100 definition for applicability)	210.13
Feeders	NEC	215.10
Additional level	NFPA 99	6.3.2.5
	NEC	517.17
Alternate Source	NEC	700.27
	NEC	701.26

2.4 Wet procedure locations

A wet procedure location in a healthcare facility is any patient care area **that is normally subject to wet conditions while patients are present**. By default, operating rooms are considered wet procedure locations unless a risk assessment is performed to show otherwise.

Other examples of wet procedure locations might include anesthetizing locations, dialysis locations, etc. (patient beds, toilets and sinks are not considered wet locations).

These wet procedure locations require **special protection to guard against electric shock**. The ground fault current in these areas must be limited to not exceed **5 mA**.

2.4.1 GFCI outlets

Protection to patient and staff in wet procedure locations can be provided through the use of GFCI outlets, GFCI breakers or isolated power systems. If GFCI protection is utilized, each circuit must have a dedicated GFCI outlet or GFCI breaker.

It is not permissible to use a single GFCI device to protect multiple outlets. This limits interruption resulting from a ground fault to a single outlet.



Figure 4 – The electrical GFCI outlets can have either the standard three-prong or twist-lock type connectors. Virtually all hospital electrical equipment comes with three-prong plugs. Twist-lock plugs were an older replacement for explosion-proof connectors that were required in the days of flammable anesthetics. Twist-lock plugs provide some protection against accidental disconnection.

2.4.2 Isolated power systems

Isolated power systems provide power to an area that is isolated from ground (or ungrounded). This type of system **limits the amount of current that flows to ground** in the event of a single line-to-ground fault and maintains circuit continuity.

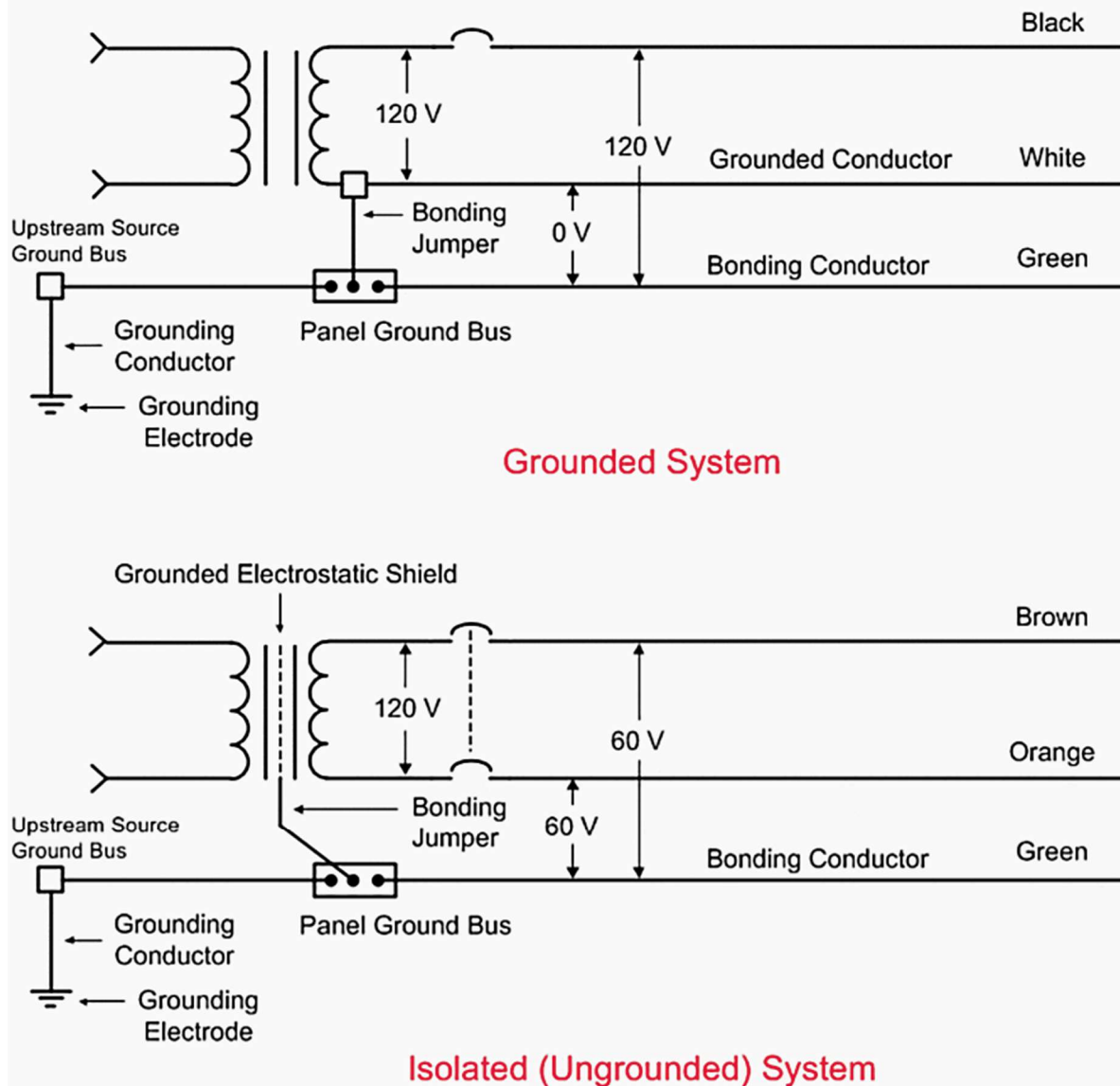


Figure 5 – Grounded vs. Isolated (Ungrounded) System

2.4.3 Electronic line isolation monitors

Electronic line isolation monitors (LIM) are used **to monitor and display leakage currents to ground**. When leakage current thresholds are exceeded, visible and/or audible alarms are initiated to alert occupants of a possible hazardous condition.

This alarm occurs without interrupting power to allow for the safe conclusion of critical procedures.

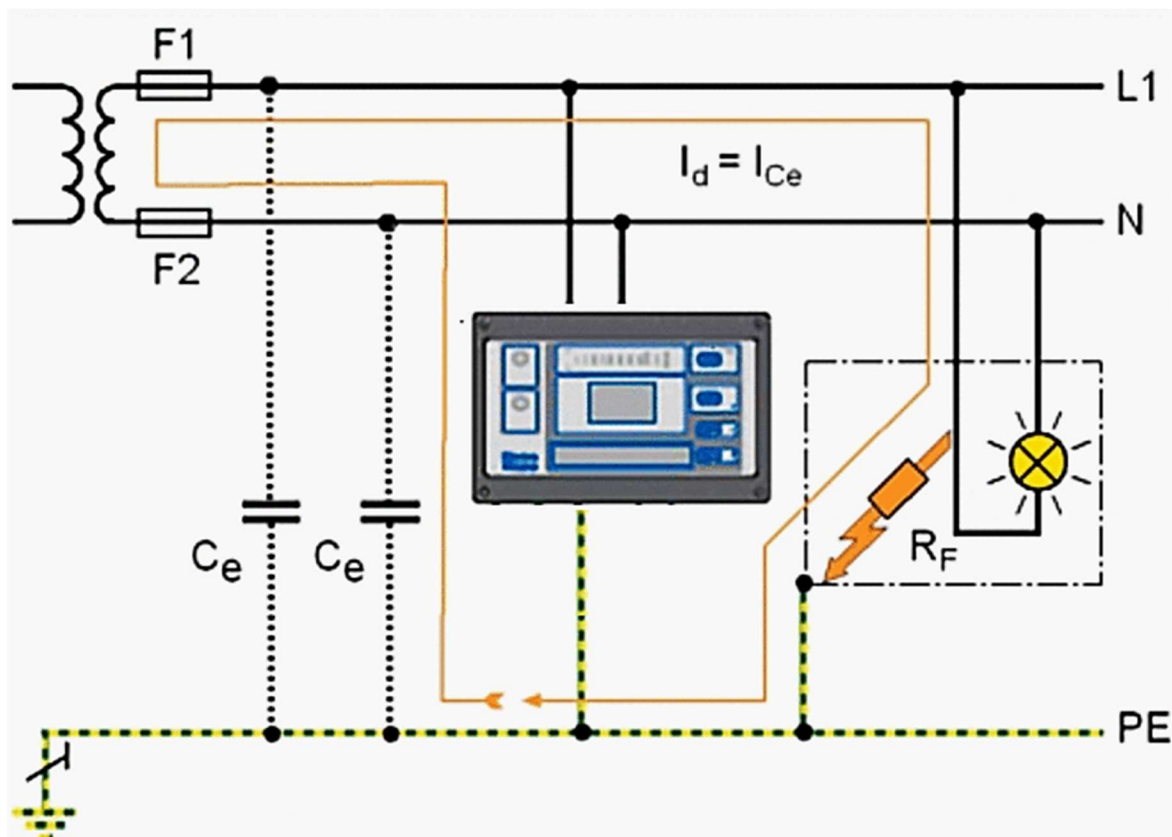


Figure 6 – Fault event in isolated power system

In the event of a **fault** R_F only a very low current I_{Ce} flows and:

- Overcurrent Protection Device does not trip.
- In the event of single conductor to ground fault, power is not interrupted.
- Alarm indicated by a Line Isolation Monitor.

2.5 Maintenance and Testing

Regular maintenance and testing of the electrical distribution system in a healthcare facility is necessary to ensure proper operation in an emergency and, in some cases, to maintain government accreditation.

Maintenance of healthcare facility includes the **regular testing of the emergency (alternate) power system(s)**. Diesel-powered EPS installations must be tested monthly in accordance with NFPA 110 Standard for Emergency and Standby Power Systems.

Generators must be tested for a minimum of **30 minutes** under the criteria defined in NFPA 110.

Routine maintenance should be performed on circuit breakers, transfer switches, switchgear, generator equipment, etc. by trained professionals to ensure the most reliable electrical system possible.

3. Paralleling Emergency Generators

3.1 Without Utility Paralleling

In many healthcare facilities (and other large facilities with critical loads), the demand for standby emergency power is large enough to require multiple generator sets to power all of the required essential electrical system (EES) loads.

In these cases, it becomes **more flexible and easier to operate the required multiple generators** from a single location using generator paralleling switchgear.

Figure 7 shows an example of a typical single-line diagram **for a paralleling switchgear lineup feeding the essential electrical system (EES)**. A typical abbreviated sequence of operation for a multiple emergency generator and ATS system follows.

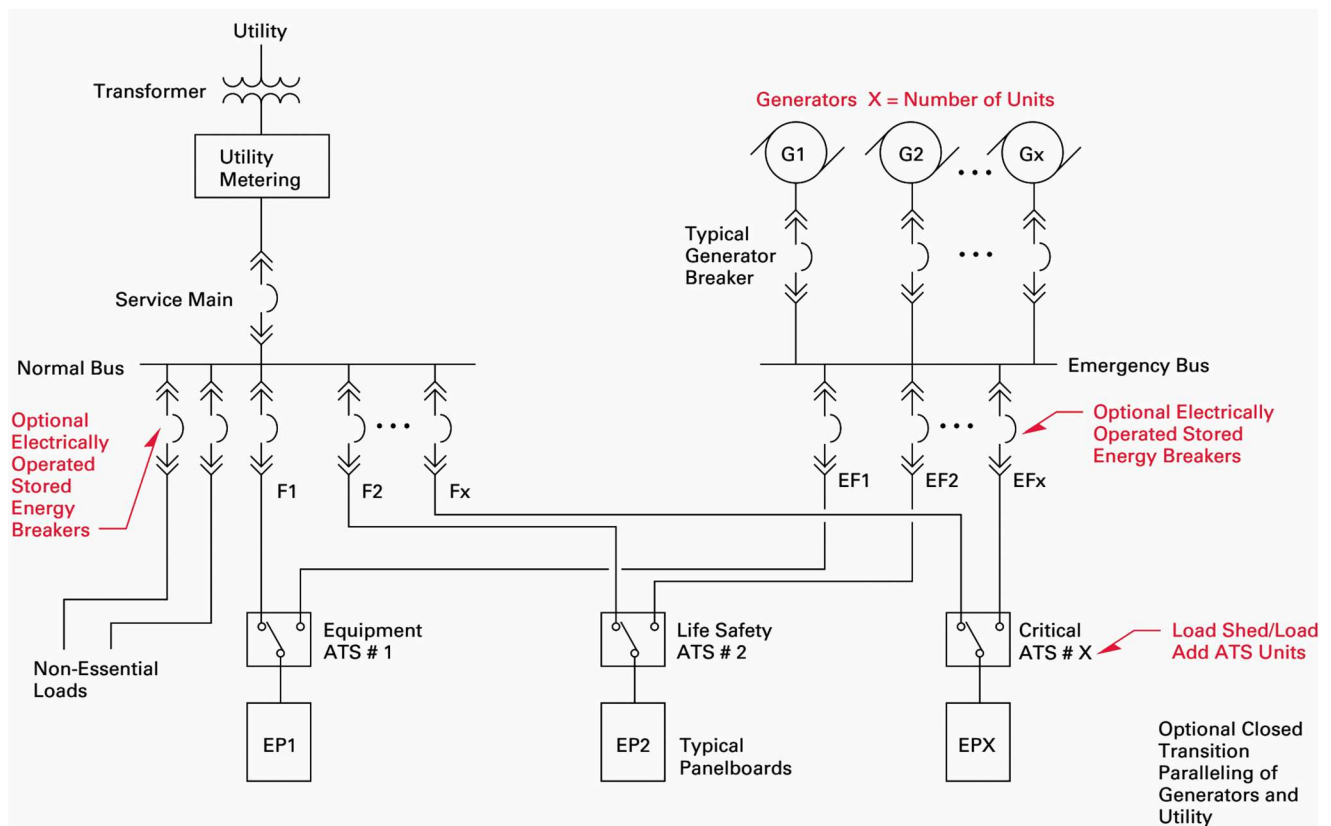


Figure 7 – Typical Single-Line Diagram for a Paralleling Switchgear Lineup Feeding the Essential Electrical System (EES)

Note that other modes of operation such as generator demand priority and automated testing modes are available but are not included below.

1. Entering emergency mode

- Upon loss of normal source, automatic transfer switches send generator control system a run request.
- All available generators are started. The first generator up to voltage and frequency is closed to the bus.
- Unsheddable loads and load shed Priority 1 loads are powered in less than 10 seconds.
- The remaining generators are [synchronized and paralleled to the bus](#) as they come up to voltage and frequency.
- As additional generators are paralleled to the emergency bus, load shed priority levels are added, powering their associated loads.
- The system is now in emergency mode.

2. Exit from emergency mode

- a. Automatic transfer switches [sense the utility source](#) is within acceptable operational tolerances for a time duration set at the automatic transfer switch.
- b. As each automatic transfer switch transfers back to utility power, it removes its run request from the generator plant.
- c. When the last automatic transfer switch has re-transferred to the utility and all run requests have been removed from the generator plant, all generator circuit breakers are opened.
- d. The generators are allowed to run for their programmed cool-down period.
- e. The system is now back in automatic/standby mode.

3.2 With Utility Paralleling

Today, many utilities are offering their customers excellent financial incentives to use their on-site generation capacity to remove load from the utility grid.

These incentives are sometimes referred to as **limited interruptible rates (LIP)**.

Under these incentives, utilities will **greatly reduce or eliminate kWhr or kW demand charges to their customers with on-site generation capabilities**. In exchange, during times of peak loading of the utility grid, the utility can ask their LIP rate customers to drop load from the grid by using their on-site generation capabilities.

Healthcare facilities are ideally suited to take advantage of these programs because they already have significant on-site generation capabilities due to the code requirements described.

Many healthcare facilities are taking advantage of these utility incentives by adding generator capacity over and above the NFPA requirements.

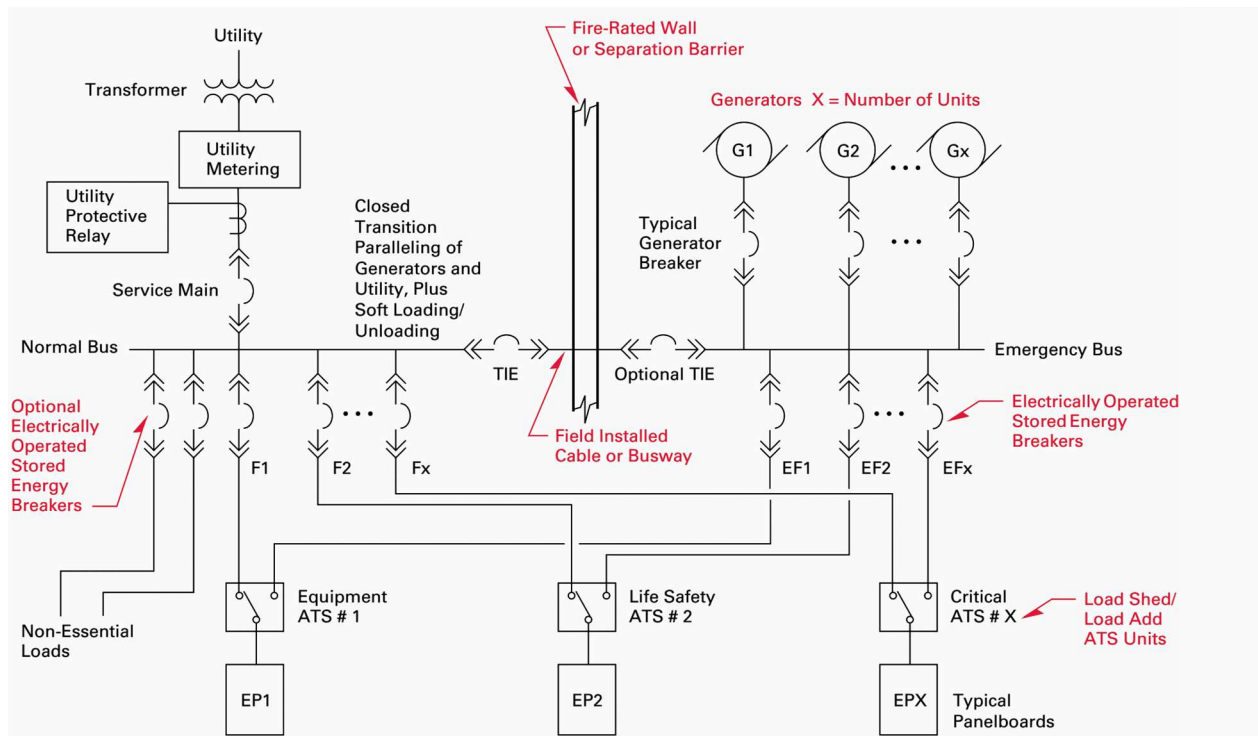


Figure 8 – Typical Single-Line Diagram of a Healthcare Facility with Complete Generator Backup and Utility Interconnect

Figure 8 shows an example single-line diagram of a healthcare facility with complete generator backup and utility interconnect.

NFPA 110 requirements state that the normal and emergency sources must be separated by a fire-rated wall. The intent of this requirement is so that a fire in one location cannot take out both sources of power.

To meet this requirement, the paralleling switchgear must be split into separate sections with a tie bus through a fire-rated wall.

Sources:

1. *Power Distribution Systems by Eaton*
2. *Healthcare Isolation Power Systems by David Knecht*
3. *2010 – 2011 Operating Room Manual / ELECTRICAL SERVICE by Lead Author: Steve Helfman, MD; Assistant Professor of Anesthesiology; Emory University Atlanta, GA*