Emergency Power for Cardio-Vascular Imaging Systems

This application note addresses the use of hospital emergency power for medical imaging equipment. Emergency power within medical facilities is very common for loads such as lighting, life safety equipment, elevators, and HVAC equipment. The use of this emergency power for medical imaging loads is less common, but is becoming more widespread. This document discusses the regulatory, technical, and practical requirements for powering medical imaging (specifically cardio-vascular) equipment from emergency power within health care facilities.

The document is primarily intended for the use of the following individuals:

- **Field Service Engineers** installing or servicing Medical Imaging equipment
- **Architects** and **Engineers** doing site design for Medical Imaging equipment
- **Facility Managers** who are considering emergency power for Medical Imaging equipment

In the past, the use of emergency power has been limited in radiology departments. X-Ray equipment is generally less critical to life safety than items such as life-support, oxygen, lights, etc. X-Rays that were required during emergency power situations were obtained using small battery powered portable units.

In recent times, however, full powered X-Ray and CT systems have been powered from emergency electrical systems in trauma centers, where major disasters such as earthquakes or hurricanes may produce a combination of loss of power and injuries requiring more extensive diagnostic imaging. An additional application for emergency power has also become more common: *Cardio-Vascular* and other *Invasive Procedure* medical imaging systems.

Emergency Power for Cardio-Vascular Imaging Systems

Emergency power for Cardio-Vascular imaging systems may be required by the facility for several reasons related to patient safety in the event of a loss of utility power:

1. A patient undergoing this type of procedure is often in a weakened condition, and the catheterization process additionally stresses the patient's cardio-vascular system. Some patients may not be strong enough to undergo a second procedure if the first is interrupted due to a power failure.

2. The contrast media used is a toxic substance, and every effort is made to reduce the use of this substance to the minimum required to obtain diagnostic images. Having to repeat a procedure due to power loss increases the amount of contrast media used.

3. Some techniques cannot be easily or safely terminated (withdrawal of the catheter) without at least limited imaging capabilities (Fluoroscopy).

4. If power is lost and a patient goes into cardiac arrest, lack of power may increase the time required to reposition the geometry so that the medical team can resuscitate the patient.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

National Regulations and Standards

The National Fire Protection Association (NFPA) documents NFPA-70 (National Electric Code) and NFPA-99 (Health Care Facilities Code) are the primary regulations regarding the application and technical specifications for emergency power in health care facilities. A thorough review of these documents is beyond the scope of this document. However, a listing of the major sections related to emergency power, and some of the fundamental concepts, are included for reference.

NFPA-70 "National Electric Code"

Article 517 (Health Care Facilities), Section C. (Essential Electrical System)

517-25 through 517-50, inclusive.

Article 700 (Emergency Systems)

NFPA-99 "Health Care Facilities Code"

Chapter 3 (Electrical Systems) , Section 4.2 (Essential System)

Each of these standards requires that the critical branch of a health care facility supply power to *"...special (selected) power circuits for...Angiographic labs and Cardiac Catheterizations labs..."* [NEC 517- 33(a)(8) and NFPA-99 3-4.2.2.2(c)(8)] Note that neither of these documents specifically and clearly requires that medical imaging systems be powered from the critical branch. However, in many cases the equipment users demand some level of emergency power for these systems, due to the patient safety issues listed above.

In addition to these regulatory standards, the following IEEE/ANSI Standards provide additional design guidelines for Emergency Power systems:

IEEE Std 602-1986 "IEEE Recommended Practice for Electric Systems in Health Care Facilities" *(The White Book)*

Chapter 5 "Emergency Power Systems"

IEEE Std 446-1987 "IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications" *(The Orange Book)*

The NFPA and IEEE documents detail several classes of backup power:

- ☐ Essential Electrical System
- ☐ Equipment System
- ☐ Emergency System
- ☐ Critical Branch
- ☐ Life Safety Branch.

These are described in block diagram form for a power distribution system in a typical medium to large health care facility in Figure 1.

Figure 2, taken from NFPA-70, illustrates the various facility sources, power distribution, and transfer switches in a health care facility.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

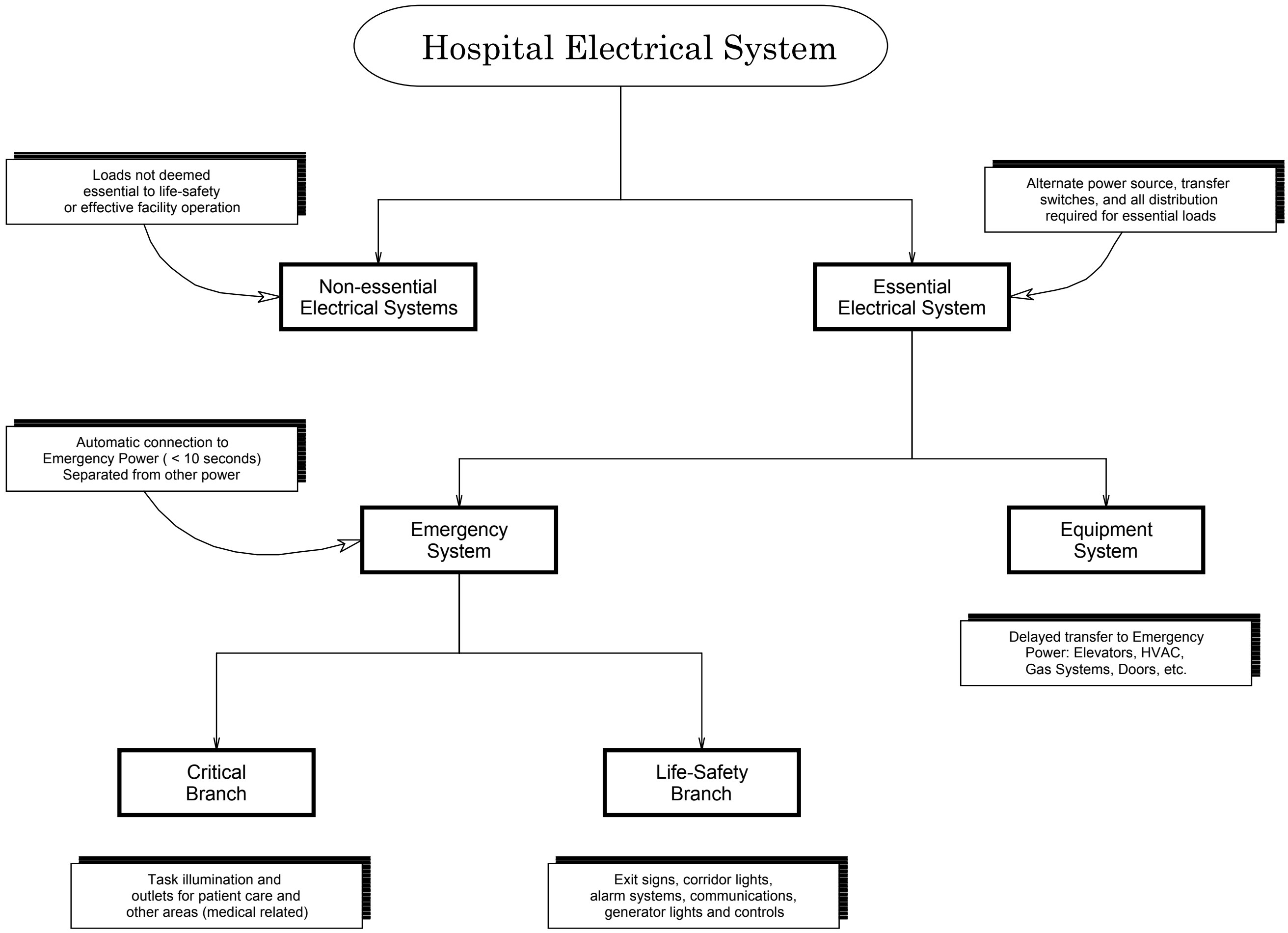

Figure 1: Medium-to-Large Hospital electrical system as described by NFPA-70 and NFPA-99

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

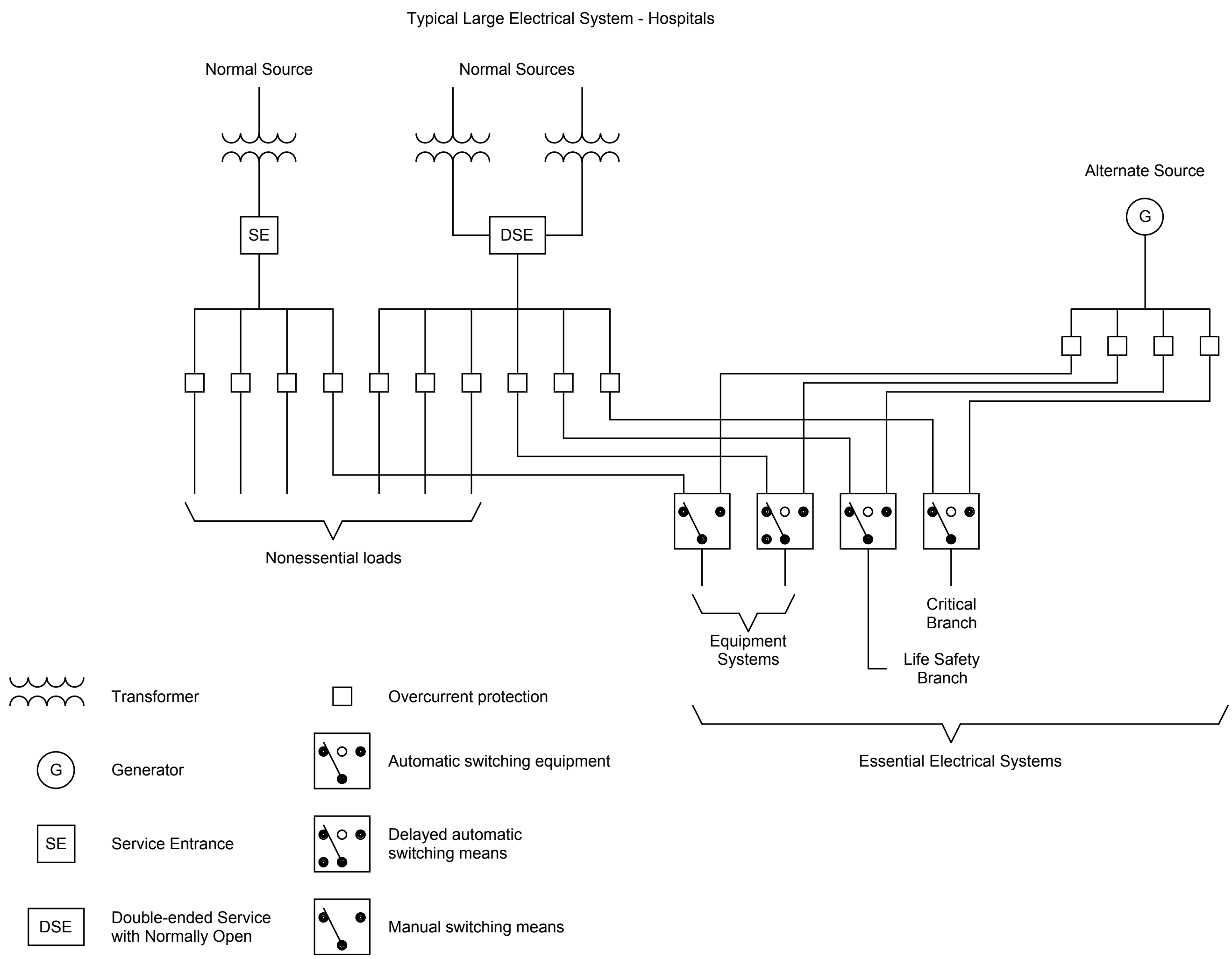

Figure 2: Medium-to-Large Hospital electrical system schematic from NFPA-70 Figure 517-30 (2)

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

Responsibility and Involvement

The requirement for, and the implementation of, emergency power for medical imaging systems involves several individuals or entities.

First, the **Equipment Users** (doctors, technicians) must determine what level of operation is desired during loss of utility power. Most users initially demand a high level of emergency power protection; this level may then be reduced due to cost or technical constraints imposed by other parties.

Highest	✓✓✓	Uninterruptible Power (no delay or equipment reset)
⇧	✓✓	Full power operation during utility power outage (within 10 seconds)
	✓✓	Full power operation during utility power outage (delayed / manually switched)
	✓	Reduced power operation during utility outage (within 10 seconds)
⇩	✓	Reduced power operation during utility outage (delayed / manually switched)
Lowest	⌦	No operation during utility outage

The **Equipment Manufacturer** or its representative must provide details on the power requirements for the particular piece of equipment, as well as any possible interfaces to the facility essential power system. In addition, the manufacturer must work with the end user to discuss the impact of a power outage on the equipment and any procedures underway.

The **Facility Engineer** or **Architect** does the actual design work for the essential electrical system, and coordinates the interface of this system to the medical imaging system. Many parameters that may affect the decision to install emergency power for a given piece of equipment are provided by this individual. These include issues such as: local and federal regulations, floor space, HVAC requirements, installation and component costs, and the existing facility electrical system capacity.

Finally, the **Facility Owner** or **Management** must determine what level of optional emergency power (not required by code) is cost-effective or possible based on financial and risk concerns.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

Emergency vs. Uninterruptible Power

A distinction must be made between **Emergency** or **Backup Power**, and **Uninterruptible Power**. Uninterruptible Power is as described by its name. This type of power is truly continuous, with an "Off" time that is either zero or some very small value (10 msecs. maximum). Uninterruptible Power is most commonly found in computer and other electronics systems where the loss of power can cause data loss, corruption, or costly downtime.

Emergency or Backup Power is generally not "Uninterruptible". Emergency Power is derived from a diesel or other type of generator and is switched using mechanical transfer switches. As a result, transition from normal utility power to emergency power results is an "Off" time, or dead time, of anywhere from 50 msecs. to 10 seconds. (for the Emergency System) or several minutes (for the Equipment System). Most electronic loads (including medical imaging systems) view this length of outage as long term, and will turn off during the outage. These will have to be manually reset by the operator after the transfer to emergency power, and again when power is transferred back to the normal utility source.

If a facility has unlimited space, funds, and technology, the optimum emergency power source for a medical imaging system would be a large Uninterruptible Power Supply (UPS) that could provide continuous power during all utility conditions. However, practical considerations preclude this in almost all situations. The following problems are encountered:

1. The high power usage during radiographic imaging requires 100-200 kVA of power, though only for short periods. This would require a UPS system capable of handling this amount of power. This would be extremely costly in terms of floor space required, HVAC loading, purchase cost, and cost to operate (efficiency and maintenance).

2. The severe step load required during radiographic imaging would require oversizing of most UPS systems to reduce the voltage fluctuations that such step loading would produce. Medical imaging systems require a voltage drop during imaging not to exceed 5-10% of nominal.

Emergency Power for Cardio-Vascular Imaging Systems

In practice, emergency power for a medical imaging system is most likely to be provided by the existing facility emergency generator, via the Critical Branch of the Essential Electrical System.

In a large facility, the Critical Branch may have sufficient capacity to supply the full medical imaging system load. Use of emergency power in this case is relatively straightforward. The imaging system is simply powered from the existing facility critical branch. In medium and small facilities, there may not be sufficient capacity to run the medical imaging system from the critical branch. In these cases alternate solutions are possible requiring load-shedding (disabling the high power radiographic load) and using dedicated transfer switches to switch from normal to emergency power.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

Case A: Critical Branch is Capable of Supplying Full Power to C/V Imaging System

If the Critical Branch is capable of supplying full power to the medical imaging system, a design similar to Figure 3 can be used. The branch circuit must be rated for at least 50% of the Momentary rating of the medical imaging system (NEC 517-73). Since power will be interrupted during both testing and actual outages, any imaging system component that has a long boot-up time, or may lose images or other data, may require a small UPS. Using this scheme, a procedure could theoretically be continued while on emergency power. However, knowing that a second interruption is likely when the normal power is returned, a doctor may elect to terminate the procedure until the utility power has stabilized, or a long term emergency power situation is confirmed.

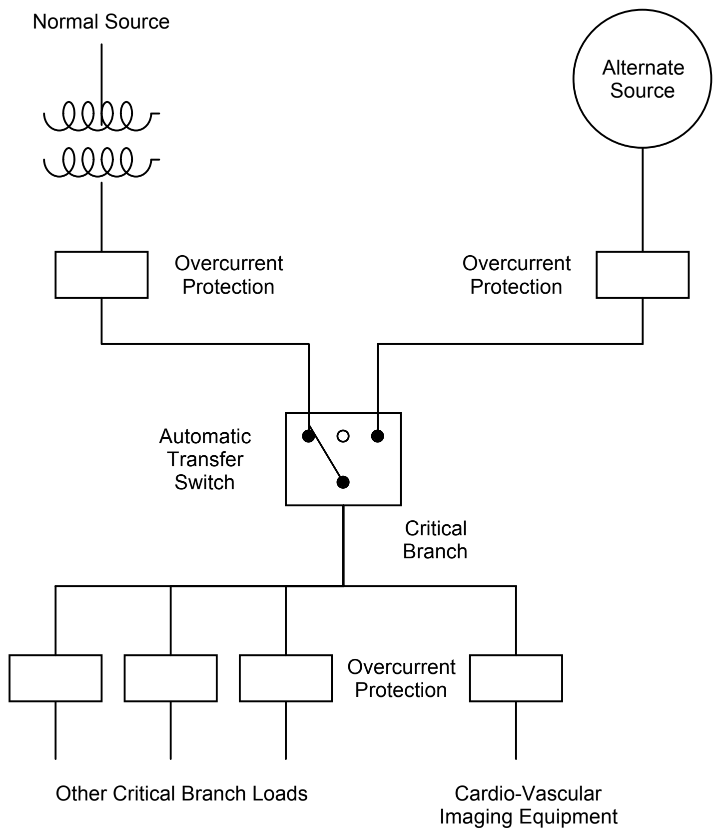

Figure 3

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

Case B: Critical Branch is Capable of Supplying Full Power, But Emergency Generator is Not

If the normal, utility power capacity of the Critical Branch is adequate to supply the full power required by the medical imaging system, but the Alternate Source (Generator) is not, then a second approach must be used. Some medical imaging systems have provision to disable or reduce the full power radiographic functions. If this is the case, an isolated contact, which changes state during operation from the Alternate Source, can be supplied to the imaging system. In this case, the medical personnel cannot complete the procedure, but low power Fluoroscopy and system control power is available so that the procedure can be safely terminated. Figure 4 illustrates the electrical system for this case.

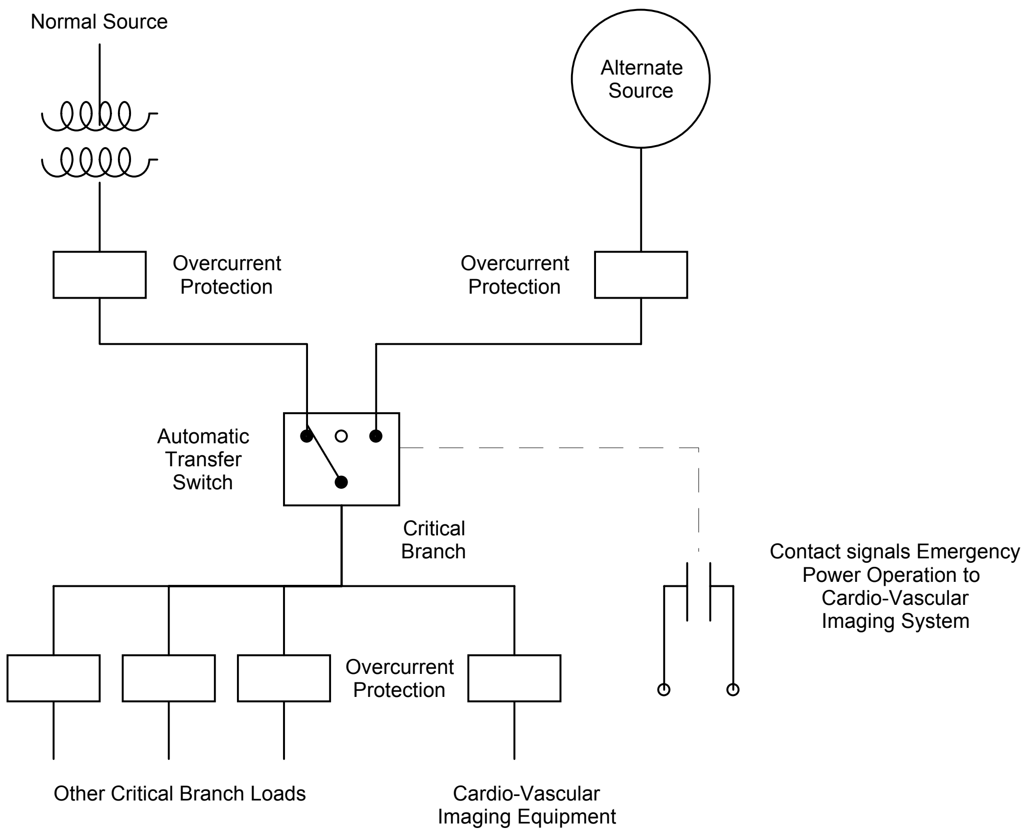

Figure 4

In this case, the capacity of the emergency power required depends upon which components are switched on, the fluoroscopy load, and the geometry movements. Load current is typically 30 Amps @ 480 VAC (25 kVA) for a complex medical imaging system.

Since a procedure would not normally be continued using only fluoroscopy during limited emergency power, a UPS for the controls or digital imaging computer is less likely to be required. However, a UPS may be of benefit so that the computer(s) can be powered down in a controlled fashion. A UPS would also permit a procedure to be quickly resumed following a brief outage or drop-out that might not cause the emergency system to activate, but would reset the medical imaging system.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

Case C: Critical Branch is Not Capable of Supplying Full Power for C/V Imaging System

If the Critical Branch is not capable of supplying the full power operation of the medical imaging system from either the normal or alternate source, it cannot be used to supply the medical imaging system during normal operation. However, the medical imaging system can be supplied by two feeds: the normal feed from the non-essential branch rated for full power, and a lower rated feed from the critical branch. These must be connected through a transfer switch dedicated to the medical imaging system. See Figure 5.

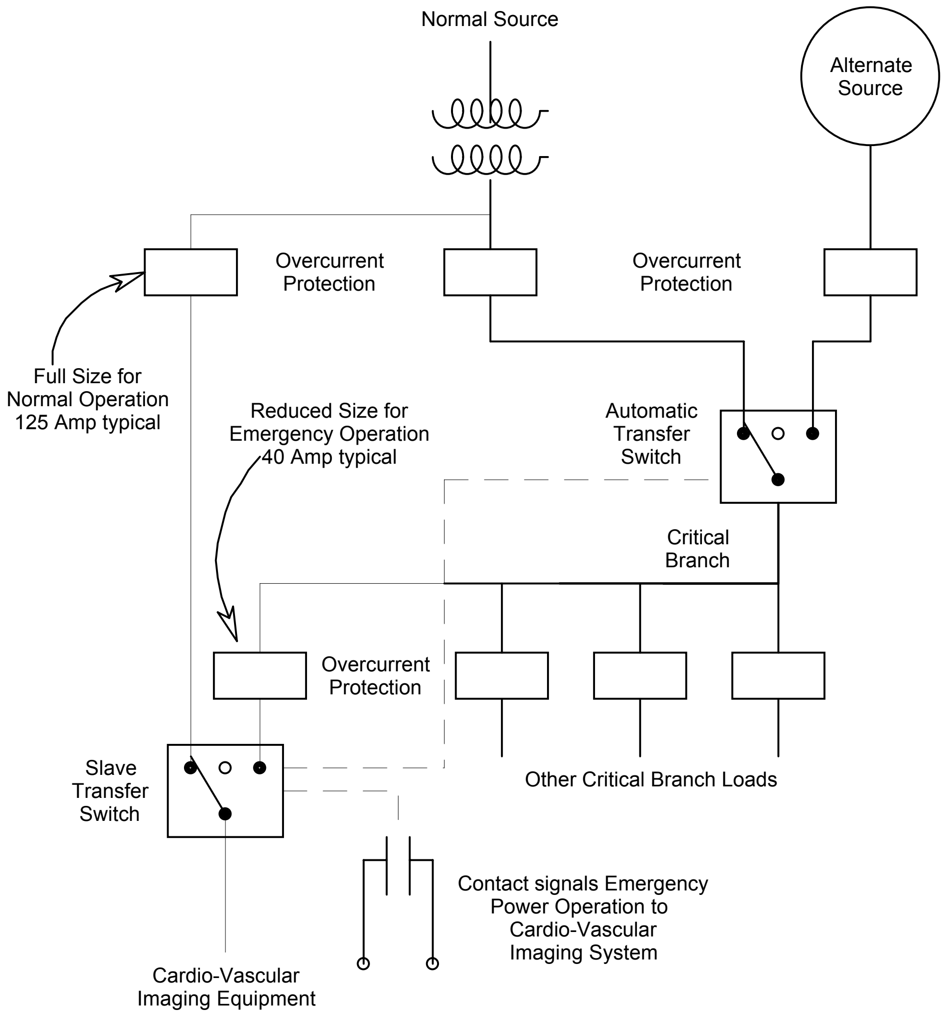

Figure 5

As in Case B, the emergency power required will vary based on system application and use, but the maximum emergency power required for a Medical Imaging system will be 30 Amps @ 480 VAC (25 kVA). The separate circuit breaker for the emergency power feed should be rated at 40 Amps to accommodate system inrush currents.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

The transfer switch must be rated for full radiographic power, since it supplies this power during normal source operation. It may be remotely controlled (slave) from the critical branch transfer switch. In addition, similar contacts as in Case B must be supplied to the imaging system to disable full power radiographic techniques. Finally, since the transfer switch is dedicated to the medical imaging system, care must be taken in selecting the type of transfer switch.

As in Case B, a UPS for the digital imaging computer is less likely to be required, since procedures would normally be terminated, not continued.

Transfer Switches

Case C (Figure 5) requires the use of a transfer switch dedicated to the medical imaging system. Some medical imaging system manufacturers have transformer-based power conditioning equipment integrated into their systems as either a standard or as an option. Care must be taken when specifying a transfer switch dedicated to a large, transformer-based load.

Mechanical transfer switches with a single mechanical operator function in a break before make mode. The timing between break and make is specified not to exceed a value, typically 100 msec. However, in reality the time delay can be as short as 30-50 msec. In most single operator transfer switches, this time is not adjustable.

A transformer based power conditioner may contain energy storage devices (inductive and capacitive) that are relatively large in comparison to the stand-by load of the imaging system. If such a device is powered from a mechanical transfer switch, these storage devices must discharge during the delay time between break and make. If complete discharge does not occur, large inrush currents can occur when the second source is connected, resulting in spurious tripping of overcurrent protection devices.

To prevent this inrush from occurring, a transfer switch with a longer (>100 msec.), or adjustable delay time between break and make may be required. One manufacturer, *Russelectric*, makes a dual operator transfer switch (Type RMTD) that has been found to be suitable for this application. Other manufacturers may also make suitable devices.

Interface to C/V Imaging System for Reduced Power

Cases B and C above require an interface between the facility essential electrical system and the medical imaging system in order to inhibit high power operation when the system is powered from the auxiliary power source. In many cases, this interface is in the form of an isolated contact supplied from the transfer switch to a specific rack cabinet in the medical imaging system.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197

Uninterruptible Power Supplies

If the facility requires that the medical imaging system be powered continuously throughout the transfers between the normal utility power and the alternate source, the only possibility is use of an Uninterruptible Power Supply rated for the entire medical imaging load. For a 80-100 kW X-Ray Generator, the UPS would need to be rated for 150-250 kVA. With an installed cost of around $1 per VA, and a footprint of 100-200 sq. feet, the full size UPS is a very costly alternative. Please consult with the Medical Imaging manufacturer or service organization if a full power UPS system is a requirement or is being considered.

In many cases, the X-Ray system and imaging system will require less than a minute to re-boot after an outage, and are quickly available for use. However, the digital imaging computer and other digital components may require many minutes, due to the need to check memory and load software. As a result, the digital portion of the system may not be available for use until many minutes after a switchover to emergency power. A UPS system (typically 3-15 kVA) dedicated to the digital imaging computer or other system components may be necessary if the function of this device is required immediately following a transfer to emergency power. Such a UPS can also prevent the loss of any images that have not been stored to a permanent disk or output device.

The benefits of this approach vary from system to system:

- Faster system recovery after transfer to emergency power
- No loss of digital images from RAM or disk based Digital Imaging Computer
- Computer system ride-through of short outages or sags

Contact the Medical Imaging manufacturer for additional information on UPS systems that have been approved for use with a particular system.

P.O. Box 1164 Waterbury CT 06721 Voice (203) 757-0790 FAX (203) 754-6197