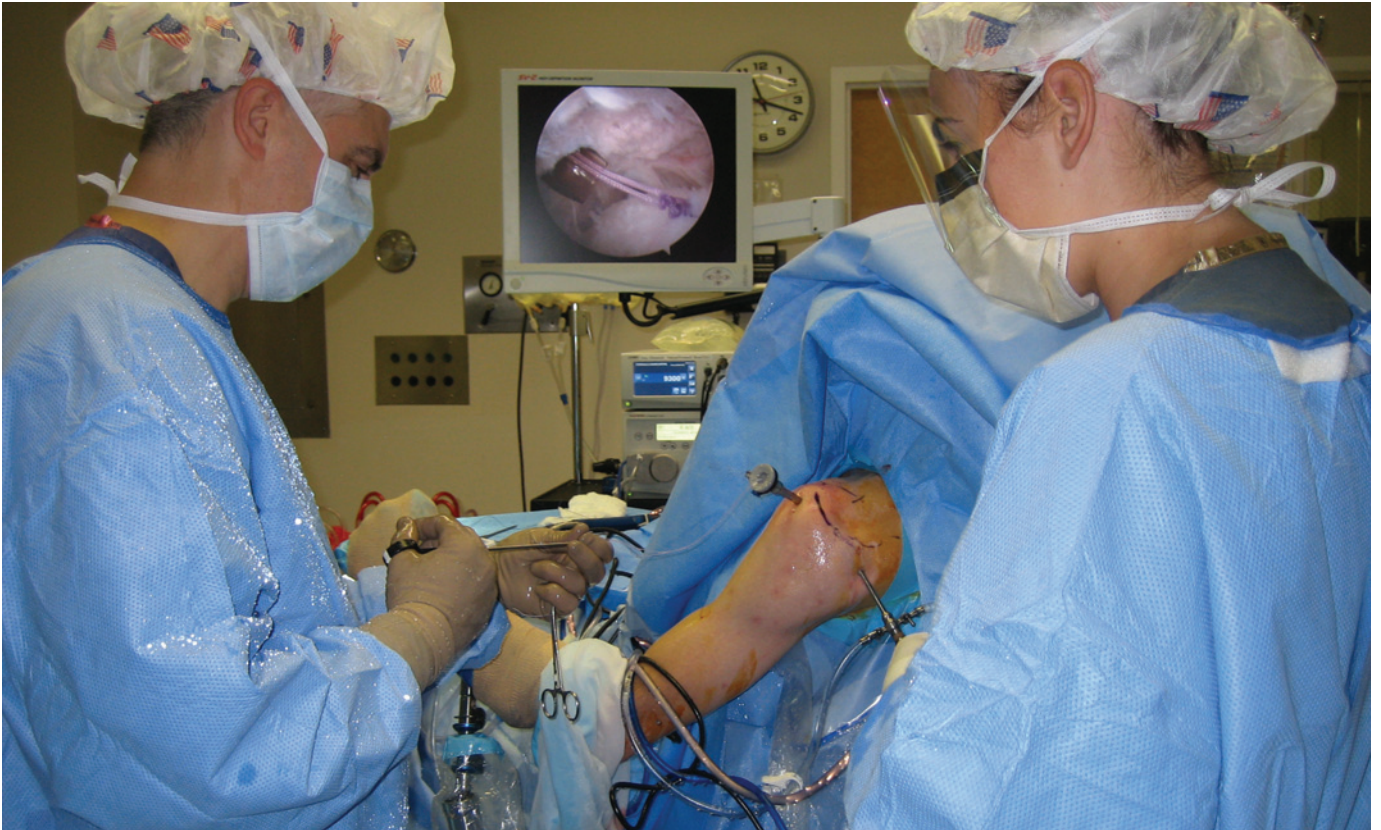


Understanding the Risk

Shock Resistant Systems Required in Patient Care Environments

By Keith Van Kerckhove, VP Engineering, PG LifeLink



Have you ever experienced the sensation of contacting a live 120V wire in your home or work place? If so, chances are, you felt moderate pain and involuntary muscle contractions caused you to pull away from the hazard. Luckily, the human body possesses a natural resistance to electric current, and under the right conditions, the risk of serious injury can be fairly low. However, there are many conditions where the risk is significantly higher. One such condition is the presence of moisture. Liquids in general are excellent conductors and they act to lower the body's resistance, multiplying the potential severity of electric shock by as much as 10 to 20 times. Contacting a live 120V con-

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ductor with wet skin will allow higher levels of current to flow through the body, potentially resulting in ventricular fibrillation and death. Anywhere that liquid and electrically powered devices meet, the risk of electric shock is heightened. Normal electrical safety features such as equipment grounding and double insulation are typically not enough to protect against this. For this reason, wet locations require special forms of protection. When reaching for your hair dryer after stepping out of the shower, you are protected by a GFCI that is designed to shut down power to the device in the event that a ground fault is detected. This has been required by Code (NEC) in all new construction in the United



States since 1975. Since then, the number of electrocution deaths in the US has steadily declined.¹

Healthcare facilities are a prime example of an environment where these risks are magnified, and the use of special protective measures must be carefully evaluated. Critical patient care areas are defined as “Those special care units, intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, delivery rooms, operating rooms, post-anesthesia recovery rooms, emergency departments, and similar areas in which patients are subjected to invasive procedures and connected to line operated, patient-care-related electrical appliances.”² Due to the nature of the procedures performed in these areas, a variety of fluids are often present, including: saline and other irrigation solutions, IV fluids, and liquid antiseptics, not to mention blood, sweat and other bodily fluids. It is not uncommon for these fluids to accumulate on patients and staff, or spill near energized equipment or onto the floor. In addition, patients in these areas are at an even greater risk because they are sedated or otherwise incapable of self-preservation.

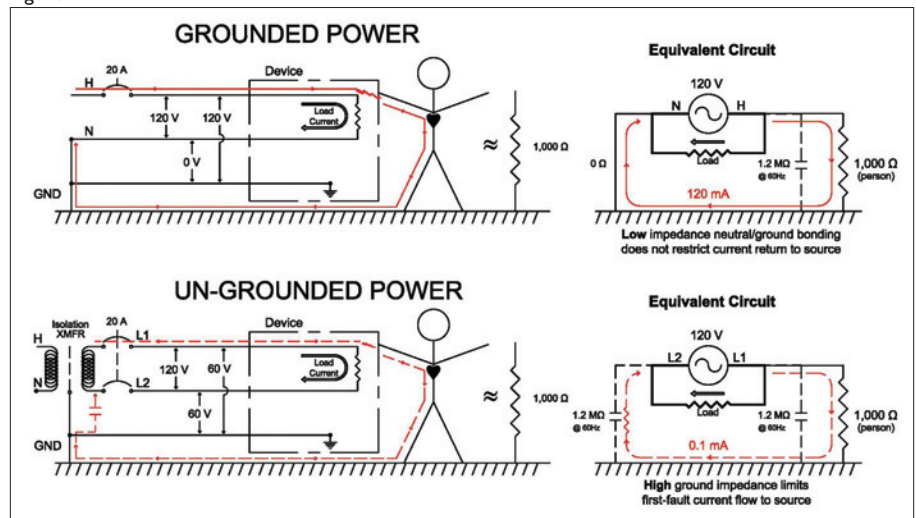
Obviously, the risks of severe injury or death warrant special protection in these areas. With that being said, you may be surprised to know such protection is voluntary for healthcare facilities under the current state of regulation. Many facilities, in fact a majority, realize the benefits of GFCI or isolated power systems in protecting pa-

tients and staff and lowering potential liability issues. However, a vocal minority still question the effectiveness of these systems and claim that the level of risk is insufficient to justify the added expense. This is not to say that there is no risk, just that the perceived cost of mitigation was not proportional. While recent debates on this topic have swirled around the long anticipated rewrite of NFPA 99, the consensus is that operating rooms represent the greatest risk for shock hazards and therefore should require enhanced protection in the form of GFCI or an isolated power system. The draft revision of this document includes new language to classify newly constructed or renovated operating

rooms as wet procedure locations requiring special protective measures. Although an Operating Room may not be a wet procedure location at all times, it is impossible to predict when wet conditions will occur. Accidental spillage of fluids occurs frequently, not to mention that many procedures utilize liters of irrigation fluid that often ends up on the floor. In order to build consensus, an opt-out provision was included allowing facilities to designate specific operating rooms as dry areas as long as they are justified through a formal risk assessment. This assessment must include all relevant stakeholders including physicians (anesthesiologists and surgeons), nurses, and biomedical staff. It should also include analysis of a reasonable worst case scenario based on the current and future uses of the space.³

When deciding what type of special protection to utilize, designers should ask the following question. Can interruption of power under fault conditions be tolerated in these areas? Critical branch power requires a redundant source of supply to ensure that vital equipment is maintained in the event of a power failure. Loss of supply involving time critical procedures and life support equipment, even for a few minutes, can prove fatal. This is the primary reason that ground fault interrupters are not typically utilized on these circuits. In the event of a fault to ground, a GFCI would shut down power to the equipment in order to prevent a serious shock from occurring. Unfortunately, the circuit cannot be reenergized until the fault has been cleared. It may require specialized equip-

Figure 1

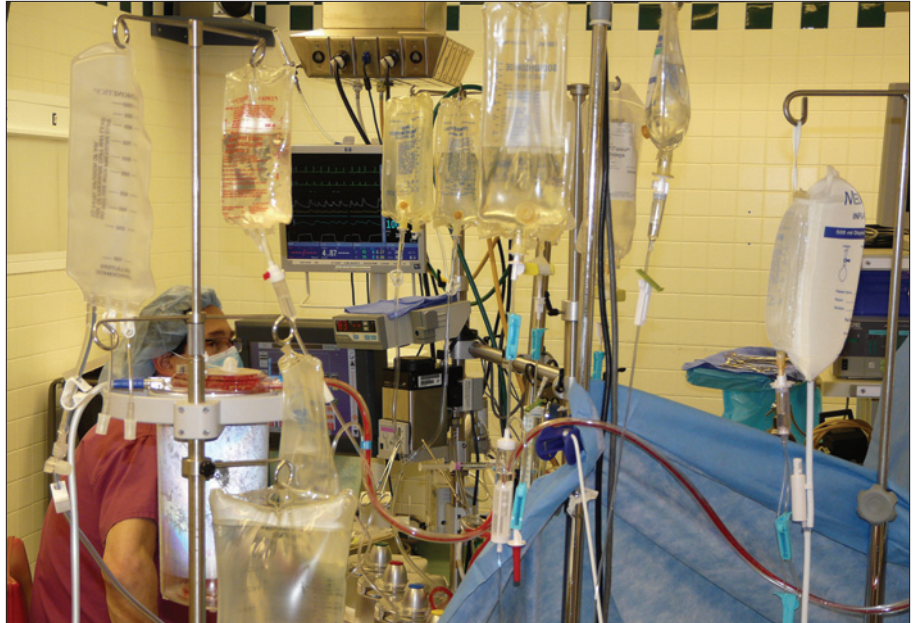


ment and several hours to locate and eliminate the source of a fault. Obviously, the risk of interruption of a critical branch circuit has to be taken very seriously.

Isolated power is a type of ungrounded distribution system that is isolated from the grounded service supplying power to the facility via an isolation transformer. It provides personnel protection against shock due to ground faults by limiting the amount of maximum current that can flow from either line conductor through the ground plane. Because the secondary side of the isolation transformer is not referenced to ground (no neutral), high impedance exists between each line and ground (refer to figure 1). The magnitude of this impedance is dependent on an accumulation of insulation resistance and capacitive coupling in the branch conductors and connected equipment. Therefore, any current that leaks from one side of the circuit is restricted from returning to the opposite line by high line-to-ground impedance. A person even directly contacting one of the energized lines (L1) does not experience a significant shock. Current flow back to the source (transformer secondary) is blocked by extremely high impedance to ground from the opposite line (L2). In the example below, the effective fault current flowing through a patient with a lowered body resistance of approximately 1,000 ohms is 0.1 mA compared to the 120 mA that would be expected to flow if the same patient contacted the hot conductor in a conventional grounded power system.

In addition to limiting ground currents to safe levels, isolated power systems also provide full time monitoring of all branch circuits via the line isolation monitor or LIM. This device continuously monitors the line-to-ground impedance of the power system and initiates an alarm in the event that a first fault has developed, such as plugging in a defective device. The alarm notifies staff to the problem, but because the system effectively tolerates a first fault, hazard is avoided. In this manner, the LIM is predictive.

As stated above, the costs of installing and maintaining these systems are still a large concern. PG LifeLink has been a leader in this field for over 50 years and continues to find new ways of increasing value and lowering the total cost of ownership on these systems. The onetime cost of installing Isolated Power panels typically



represents around 6-8% of the total electrical distribution equipment installed in a newly constructed hospital. However, the incremental cost over similar grounded distribution equipment is only a few thousand dollars per operating room. This is small in comparison to the hundreds of thousands of dollars worth of other materials and equipment that are required in such a setting. Even the labor premium is minimal. Our modern panels are factory assembled and can be installed in roughly the same amount of time as a standard panelboard. Maintenance and required testing have also been reduced by today's microprocessor based Line Isolation Monitors which require only annual testing versus the monthly requirements of older units. We can provide several suggestions to designers and contractors that will assist in making a project as economical as possible. Improved quality and additional features such as advanced alarm logging functions and our one of a kind LIM-Connect™ Line Isolation Monitor remote interface software improves compliance and the efficiency of facility maintenance departments.

Conclusion

Many areas of modern healthcare facilities represent the confluence of electrically powered devices, conductive fluids in and around the work area, and a reduction in body resistance. Isolated Power systems are a highly effective protective layer in the overall safety scheme of healthcare facili-

ties. The ungrounded supply provides inherent first fault to ground tolerance, meaning that equipment faults cannot generate dangerous ground currents. All critical circuits and equipment are continuously monitored for potential first fault occurrences. When the Line Isolation Monitor determines that a dangerous fault current could potentially occur if the insulation system were further compromised by significant secondary fault, an alarm is sounded to notify attending personnel. This extra layer of protection afforded by the ungrounded continuously monitored power system means that personnel receive an early warning, can complete their procedure in safety, and notifies maintenance staff so that the situation can be repaired before the next case. In our judgment, based on logical analysis, the benefits of these systems easily outweigh the incremental costs. They provide a safer overall system than grounded power and they should be considered standard equipment for critical care areas. □

References

- ¹ Consumer Product Safety Commission GFCLs Fact Sheet, CPSC Document #99, <http://www.cpsc.gov/cpscpub/pubs/99.html>
- ² NFPA 99 Healthcare Facilities, 2005, section 3.3.138.1
- ³ Ehrenwerth J, Seifert HA: *Electrical and Fire Safety. In Clinical Anesthesia*, Edited by Barash PG, Cullen BF, Stoelting RK, Sixth Edition, Lippincott, Williams & Wilkins; Philadelphia. 2009



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