Isolated Power Systems – Explanation

Isolated Power Systems were first introduced into the hospital environment as a means of reducing the risk of explosions in operating rooms and any other area where flammable anesthetizing agents are used.

Many feel that since hospitals no longer use flammable gases, isolated power is of no benefit. **This is not true!** Today medical and nursing sciences are becoming progressively more dependent on electrical apparatus for the preservation of life of hospitalized patients. For example, year by year more cardiac operations are performed, in some of which the patient's life depends on artificial circulation of the blood; in other operations, life is sustained by means of electric impulses that stimulate and regulate heart action. At the same time the equipment, doctor or nurses may be standing in prepping solution, blood, urine and other conductive fluids that greatly reduce resistance to passage of unintended electrical current. **Isolated Power** reduces the ignition hazard from arcs and sparks between a live conductor and grounded metal and mitigates the hazard of shock or burn from electric current flowing through the body to ground. Reference to these facts may be found in the **Standard For Health Care Facilities NFPA 99** and **National Electrical Code NFPA 70**.

It is the purpose of this document to explain the other advantages that **Isolated Power Systems** offer. Such as:

1. **Reduced shock hazard**
2. **Continuity of power**
3. **Something for nothing–noise reduction**
4. **Advance warning of equipment failure**

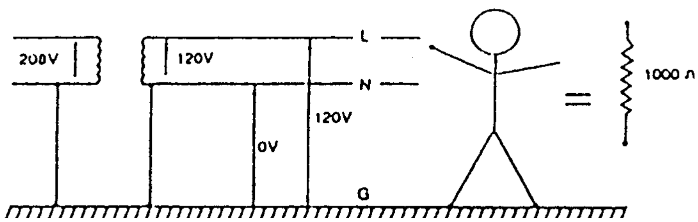
Please note the copy of NFPA News Brief referring to electrical shocks in operating rooms which have installed grounded power.

In conclusion, we feel Isolated Power supplies special protection against electrical shock in "wet locations" or any area where the interruption of power cannot be tolerated.

1. Reduced Shock Hazard

A. THE GROUNDED SYSTEM

Diagram 1



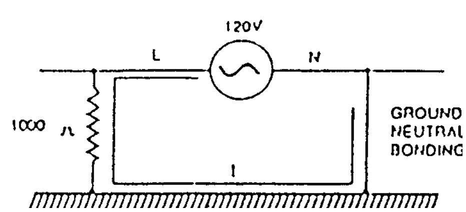
Conventional grounded system with a typical 1000 Ohm person

Diagram 1 shows the schematic of a conventionally grounded system. The neutral of the transformer is bonded to ground, which, if adequately sized, will provide an equipotential bond between the neutral and ground conductors. As the diagram shows, normally we would expect 0 Volts from ground to neutral and 120 Volts from the line conductor to either ground or neutral.

If we assume that a person has a body resistance of 1000 Ohms, and comes into contact with the live conductor, we can expect the following result, as shown in the equivalent circuit, **Diagram 2**.

Diagram 2

$$I = \frac{V}{R} = \frac{120}{1000} = 120\text{ mA}$$



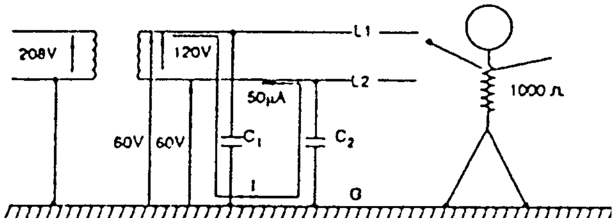
Schematic representation of 1000 Ohm person in contact with live conductor

A current of 120 mA would flow from the line conductor–via the 1000 Ohm person–and return to the neutral via the very low impedance neutral-ground connection. This 120 mA could prove extremely dangerous for our 1000 Ohm person.

NOTE: Should our person have a reduced ohmic resistance, due to excessive moisture or internal body connections, we could expect potentially lethal current to flow. (In this example, system capacitance has been neglected as its impedance value is many times that of the neutral-ground bonding.)

B. THE ISOLATED POWER SYSTEM (IPS)

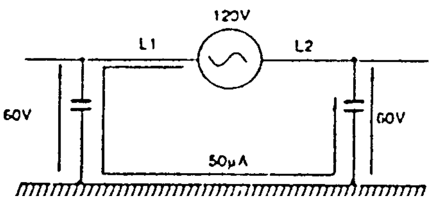
DIAGRAM 3



Isolated Power System with our 1000 Ohm person

Diagram 3 shows the schematic representation of an **Isolated Power System**. The **IPS** is a system in which the transformer neutral-ground connection has been deliberately omitted. In this example we will examine why our 1000 Ohm person is greatly protected from potentially lethal shock hazards. We will first consider the situation of the pure **IPS**, without externally connected equipment (externally connected equipment only increases the system net capacitance and leakage resistance).

DIAGRAM 4



Schematic representation of an Isolated Power System

Diagram 4 assumes a typical equally distributed, balanced capacitive system where the small leakage current, 50 microamps, flow from L_1, via C_1, through the ground, and returns to L_2 via C_2.

NOTE: On a correctly installed system there will be a very small leakage resistance in parallel with the system net capacitance, but this value, being so low, may be neglected for the purpose of this example.

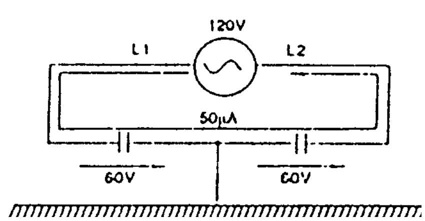
We can measure the voltage drop across the system capacitance by using a high impedance voltmeter. In a balanced system as shown, we can expect to measure 60 Volts from each line to ground. (Leakage current may at this time be measured by connecting a mA or microamp meter from either L_1, or L_2 to ground.)

NOTE: This is not recommended on a grounded system!

We may now examine our circuit parameters more closely by using Ohm's Law and **Diagram 5**

DIAGRAM 5

$$Z = \frac{V}{I} = \frac{60}{50 \times 10^{-6}} = 1.2 \times 10^{6} \text{ Ohms}$$



Reduced schematic of an Isolated Power System

The impedance value of C_1 and C_2 is 1.2×10^6 Ohms, giving a line-to-ground capacitance value of:

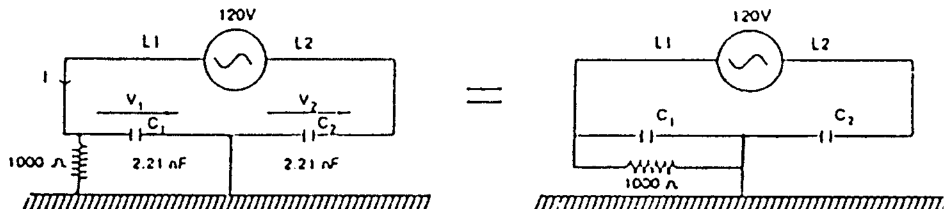
$$C = \frac{1}{\omega . \times c} = \frac{1}{2 \times \pi \times 60 \times 1.2 \times 10^{6}}$$

$$C = 2.21 \times 10^{-9} \text{ Farads}$$

Isolated Power Systems – Explanation

Now we can calculate what happens should our 1000 Ohm person come into contact with either L_1 or L_2. This situation may be represented by the equivalent circuit shown in **Diagram 6**.

Diagram 6



1000 Ohm person in contact with one line conductor and ground

We can now calculate the voltage that will be present across our 1000 Ohm person.

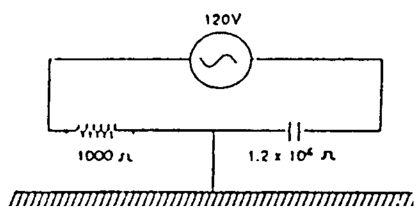
First we calculate the total leakage current from L_1 to L_2.

C_1 in parallel with 1000 Ohms $= \dfrac{1.2 \times 10^6 \times 1000}{1201000} =$ 999 Ohms

We may round this number to 1000 Ohms, showing that the impedance of our person has in fact completely shunted the C_1 capacitance.

We may now reduce our equivalent circuit as follows:

Diagram 7



Reduced schematic of Isolated Power System with 1000 Ohm person in contact with line conductor

Leakage current is now: $\dfrac{120V}{1201000} =$ 100 microamps

Our 1000 Ohm person coming into contact with L_1 has approximately doubled the leakage current to 100 microamps, which is still an extremely low level.

Voltage across the person would be: $\dfrac{1000}{1201000} \times 120 = 0.1V$

Voltage across C_2 would be: $\dfrac{1.2 \times 10^6}{1201000} \times 120 = 119.9V$

Current passing through our 1000 Ohm person would be: $\dfrac{120V}{1201000} =$ 100 Microamps

Let's compare the grounded system vs. **IPS** with our grounded 1000 Ohm person in contact with the line conductor in each system.

V. Person = Voltage across our 1000 Ohm person
I. Person = Current flowing through our 1000 Ohm person

	Grounded	**Isolated Power System**
V. Person	120V	0.1V (with 50 microamp leakage)
I. Person	120mA	100 microamp (with 50 microamp initial leakage)
		(5.0V and 5mA theoretical maximum values with a LIM reading of 5mA)

Clearly, the **Isolated Power System** offers considerably greater protection to the operator and patient.

C. THE LINE ISOLATION MONITOR

The line isolation monitor is a device which continually monitors the impedance (resistance and capacitance) from all lines (single and three phase) to ground and indicates what current could flow to a patient of body resistance 1000 Ohms, should the patient come into contact with a line conductor (i.e. defective equipment).

A note on interpretation of the LIM reading: many variables exist to exactly what current could flow to the patient:

1. The value of 1000 Ohms may vary between less than 100 Ohms to 20,000 Ohms depending on the condition of the patient (moisture content, muscle condition, dry skin, etc.).
2. Parallel leakage return paths will also bypass a portion of the leakage current from the patient.

D. CONCLUSION

We have examined how the **Isolated Power System** can help protect the patient from electrical shock hazards. We have made these calculations first order, and as simple as possible so that only a basic knowledge of Ohm's Law is sufficient to understand the system concepts.

The principles are no different outside the operating room.

Only the definition of "wet location" is present to recommend that **IPS** is the better solution – and then only as far as continuity of supply is concerned.

ICU and CCU areas where the patient may be connected to several pieces of equipment – all which contain their respective leakages, both resistive and capacitive, greatly add to the possibility of hazardous leakage currents flowing. We must never neglect the fact that a leakage on a grounded system will return via the low impedance of the parallel paths to ground – for example, our 1000 Ohm person.

The **Isolated Power System** does not have this low impedance connection. It has a high impedance capacitive/resistive return path. This provides an additional layer of safety to protect both operators and patient alike.

2. Continuity Of Supply

Probably the strongest argument for the application of **isolated power** is where continuity of supply is paramount.

Article 517-20(a) of the 1993 National Electrical Code states that 15 and 20 ampere, 125 Volt, single phase receptacles supplying wet locations shall be provided with ground fault circuit interrupters if interruption of power under fault conditions can be tolerated, or an **isolated power system**, if such interruption cannot be tolerated.

With **isolated power systems** at one fault to ground the circuit breaker does not trip, maintaining power to the equipment. This gives the hospital personnel a choice of what to do since the equipment may be supporting the patient's life. At the same time during such an occurrence, the Line Isolation Monitor would clearly alarm as to the fault condition so that action may be taken.

3. Something For Nothing – Noise Reduction

The increased use of sensitive electronic systems in the hospital environment has created a growing need to supply these systems with "clean" voltage, free of noise and transients. Many types of data storage and monitoring equipment may be extremely sensitive to line transients and line noise which is frequently present on voltage feeders.

The **Isolated Power System** contains a high quality shielded isolation transformer which provides a convenient and effective means of greatly reducing or even eliminating line-to-line and line-to-ground noise on voltage feeders.

Many manufacturers of voltage-sensitive equipment have recognized the problem created by transients and noise on their equipment's input line and have provided a measure of protection as an integral part of their equipment. This protection, however, may not be adequate for frequent or serious disturbances.

Although the primary reason for **Isolated Power System** design and installation was not to achieve this noise reduction, but to provide a low leakage secondary power system, we must consider the "built-in" advantages of this system again when comparing **isolated power** with conventionally grounded systems.

4. ADVANCED WARNING OF EQUIPMENT FAILURE

It is required that all hospital biomedical equipment that may come into contact with the patient be periodically tested for leakage currents. As previously mentioned, many large hospitals may have well in excess of 10,000 pieces of equipment. This creates a nightmare situation for the hospital electrician/biomedical engineer or whoever is in charge of equipment testing.

As with all testing, the values of leakage found at the time of test were just that. A few minutes, hours, or even a few days later, the equipment may have been exposed to environmental conditions which caused further decline in insulation integrity. Liquid spillage, cable damage, equipment misuse, or just plain heat aging through continued usage are all factors which may contribute to the decline in the insulation value.

Any help that can be given to let the equipment operator know that his/her device is in a correct and safe condition is a benefit to both patient and operator alike.

Isolated Power Systems contain a Line Isolation Monitor (LIM). This device continually monitors all potential parallel leakage paths to ground. The LIM monitors all circuitry from the isolation transformer via circuit breakers and power and ground modules and finally to each piece of connected equipment.

Should a faulty piece of equipment be plugged into any of the output sockets of the **Isolated Power System**, then this would immediately cause the LIM to alarm, a warning that such an event had just occurred.

The operator can now choose to remove the equipment or continue to use it by taking extra caution that this may cause a serious hazard to the patient or operator should either come into contact with the other line conductor.

If we compare the same occurrence on a grounded system, and use as an example, a line-to-ground fault, then we are back to our colorful situation as described in **Section 2**.

When initially energized, a piece of equipment may operate correctly and be in a safe condition. However, during operation, malfunction may occur due to spillage of liquid or cable damage (cart running over power cable or equipment being dropped). In any case, the result would be the same. The level of electrical safety has now been reduced. Such occurrences on an **Isolated Power System** would, as described above, result in the LIM alarming and a warning being issued of potential fault hazard.

5. CONCLUSION

Isolated Power Systems provide many advantages and levels of protection over conventional grounded systems. The grounded system is excellent where unskilled operators or electrically unknowledgeable people come into contact with everyday equipment. It's operation is simple and any failure generally results in equipment or circuit disconnection, very quickly within less than 1 cycle. However, grounded power systems are a potential killer should a grounded person come into contact with a line conductor. How many of us has never received some form of electric shock?

Isolated Power Systems are the best solution for reliable and safe power, particularly in the hospital environment. It has been the intent of this paper to try to explain to the decision-makers, in layman's terms, some of the main benefits to having **isolated power** in their facilities.

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