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Automatic Transfer Switch Applications for MRI Equipment

White Paper

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Magnetic resonance imaging (or MRI) has proven to be a powerful tool to help doctors provide an accurate diagnosis for patients. Because time is of the essence for many patients, the uptime of MRI machines is crucial. The proper application of automatic transfer switches is critical to maintaining the reliability of MRI machines during utility power interruptions when the emergency standby system is operating.

MRI basics

Magnetic resonance imaging (or MRI) has long been a useful, noninvasive medical imaging tool to help doctors visualize the internal structure of the human body. Because time is of the essence for many patients, the uptime of MRI machines is crucial, so doctors can use the images produced to prescribe a course of care as quickly as possible.

Because of the sensitive nature of the MRI's scanner, electronic noise must be filtered out or eliminated altogether. The last thing a doctor needs to be concerned about is whether the MRI image is a true and accurate representation of the patient's scanned anatomy. Medical equipment requiring three-phase AC electrical power is driven by power supplies that produce voltage transients and electrical noise. Although isolation transformers, step-down transformers and transient voltage surge-suppression (TVSS) devices can improve power quality, these devices do not eliminate electrical noise altogether. For this reason MRI manufacturers recommend bi-directional, high frequency noise filters to shield the power supply to the MRI machine and critical equipment close to it.

High frequency noise on the power distribution system can be filtered to eliminate system disturbances. The parallel, low-pass noise filter has a line-to-neutral capacitor as its main element. This filter allows the high frequency noise to be shunted away from the load. It is also bi-directional. To understand how a capacitor acts as a filter, all you need to understand is impedance. Impedance is a measure expressed in ohms of the total opposition (resistance, capacitance and inductance) offered to the flow of alternating current.

> NFPA 99 D.4.2.1: *Input power circuits shall be provided with low pass filters…for preventing injection of high frequency energy (noise) into the power line.*

High frequency noise "looks like" high frequency alternating current to the capacitor. Normal 60 Hz alternating current is considered a very low frequency. A capacitor represents high impedance to the high frequency currents on a 60 Hz line frequency. It passes only the fundamental and low frequency currents. This bi-directional filter blocks the high frequency noise coming from the line or the load. The filter is represented on a network diagram as a resistor-capacitor (RC) circuit or network. (RC circuits can be used to filter a signal by blocking certain frequencies and passing others.) RC circuits behave in a predictable way, which can be explained by the filter's time constant. A filter capacitor's time constant is the time it takes for the capacitor to charge to 63.2% of the supply voltage when charged through a given resistance, or the time to discharge to 36.8% of the supply voltage value through the same resistance.

Programmed transition automatic transfer switches are necessary for MRI loads

In an emergency standby power system, the function of the automatic transfer switch is to connect electrical loads to either of two independent power sources. In the case of most health care facilities, the power sources are the serving utility and a standby generator or system of multiple standby generators in parallel. When the health care facility suffers an interruption in utility power, automatic transfer switches accurately sense the loss of utility power, signal the emergency standby generators to start, and transfer the electrical loads to the generators.

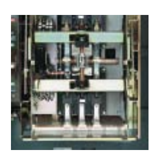
> NFPA 99 4.4.3.2.5: *The automatic transfer switch shall disconnect the alternate source of power and connect the load to the normal power source.*
>
> IEEE Std. 446-1995, section 4.3.8: *The automatic transfer switch shall disconnect the alternate source of power and connect the load to the normal power source.*

A typical operating time for an open transition transfer switch is approximately 6 cycles, or 100 milliseconds (msec). However, the MRI machines' noise filters require time for their capacitors to discharge before reapplying power. Some MRI manufacturers require a minimum delay of 400 msec or 24 cycles in either direction (utility to emergency and emergency to utility). This time delay is required to allow the filter capacitors to dissipate their stored energy before reapplying voltage to the circuit. Failure to do so can damage the capacitor, resulting in a rupture or explosion due to over-voltage, and ultimately jeopardizing the integrity of the MRI machine.

Programmed transition automatic transfer switches

A simple and reliable solution to this problem of safely transferring MRI loads is the programmed transition or delayed transition transfer switch. Programmed transition switches incorporate an adjustable time delay to control the contact transfer time of the switches' contact mechanism.

The appropriate setting for the delay time depends upon the MRI manufacturer's recommendation. The MRI equipment manufacturer calculates the time delay from the RC time constant of the filter capacitor. Programmed transition transfer switches have adjustable time delays ranging from 0 to 120 seconds. These adjustable delays are standard on bypass isolation transfer switches, which are often used for critical and life safety circuits in health care facilities.



BTPC transfer switch, with open, closed or programmed transition (left); enlarged detail of internal switch mechanism (right).

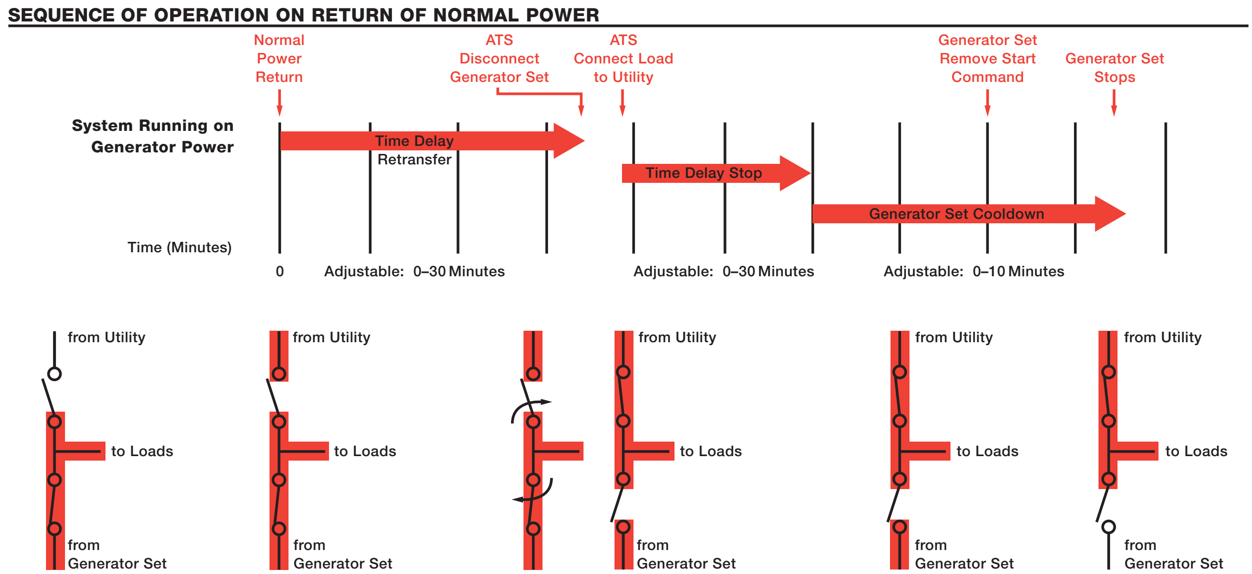


Figure 1 - A delayed transition of operation.

Closed transition transfer switches

Closed transition transfer switches are ideal for circuits containing MRI loads. These transfer switches momentarily parallel the utility power source and the emergency standby generator power. This momentary paralleling of two sources typically lasts 100 msec (6 cycles) or less, and it provides the least amount of system disturbance, because both sources are synchronized by voltage, frequency and phase angle.

Closed transition transfer switches can actively synchronize both power sources before paralleling them. Active synchronizing controls look for synchronism of both sources but include control of the generator set engine governor to force the generator to synchronize with the utility. These controls also require reliable fast contact switching (5 cycles) and tight phase angle (less than 15 degrees) and minimum frequency window differentials (less than 0.5 Hz). However, since the switch is controlling the governor, the controls can be adjusted to limit gain, controlling the rate of change of the generator frequency during synchronizing. This minimizes the possibility of connecting the generator to the utility in an out-of-phase condition.

Closed transition equipment also prevents the momentary interruption of power when both sources are present, such as exercise, test and retransfer. Closed transition switches revert to open transition when one of the sources is not available. The switch can also be programmed to delay in the neutral position for the appropriate amount of time to allow the filter capacitor to discharge, in the case of MRI line filters. However, closed transition switches are not a substitute for uninterruptible power supplies (UPS), where *On* is required by the nature of the load equipment. Closed transition switches are also available in bypass isolation configurations.

Recommendations

- Utilize programmed transition or closed transfer switches for MRI loads.
- Program the transition delay time according to the manufacturer's recommendations.
- Bypass isolation transfer switches with programmed or closed transition are acceptable for MRI loads.

About the author

Ken Box is employed by Cummins Power Generation as the southeast regional manager for Power Electronics. Previously, Ken was the director of sales for Cummins Power South in Atlanta, Georgia. Ken's professional career spans 33 years, and he has held positions with Westinghouse, Bussmann, McNaughton-McKay Electric, IEM and Shallbetter, Inc. Ken holds a bachelor's degree in electrical engineering from the Georgia Institute of Technology. His current responsibilities include providing application engineering support for power generation products to customers in the health care, waste water and data center industries. Ken is a published author, an active IEEE member and a licensed professional engineer.

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