



Transfer Switch Selection Criteria and Changes in the 2005 National Electrical Code®

White Paper

April 2008
New Information

Introduction

When applying Automatic Transfer switches for National Electrical Code® emergency systems, Legally Required Standby Systems and Health Care Essential Systems, the design engineer has a variety of equipment choices. In addition, automatic transfer switches will be required under the new Article for Critical Operations Power Systems (COPS). The challenge is to provide the right switch for the application. This is a balance of meeting the required codes and applicable standards, and providing the right equipment and investment to meet the critical needs of the application. While all these systems are critical in their own way, a hospital operating room could be considered more critical than a water pumping station, and a data center could be considered more critical than a commercial office building server. Each application has its own unique requirements.

In order to make the proper selections, it is important to understand the codes and standards, and how they are applied. Changes made in recent years to codes and standards can also have a profound effect on emergency system design.

With the variety of transfer switches available, it is no less important to understand the features required to meet the codes, and the desirable construction features best suited for the application. Only with an understanding of these items can the knowledgeable selection of transfer switch be made to assure a proper, cost-effective installation.

I. Codes and Standards

When applying any electrical product, electrical designers refer to codes and standards to insure a safe and reliable installation. Standards are developed by authorities to use as guidelines for designers to reference to insure uniform construction with minimum acceptable performance criteria.

There are many codes and standards that apply to the construction and application of transfer switches. Local, state or federal law and/or respective utility standards determine those that apply. There are a large number of standards that directly, or indirectly apply to transfer switches. Portions of those standards may only apply in certain applications.

John Ziomek, P.E., LEED A.P.
Application Engineer
Eaton Corporation
New York, NY

Some of the most applied standards related to transfer switch **applications** include:

NFPA 70	National Electrical Code®
NFPA 99	Standard for Health Care Facilities
NFPA 110	Standard for Emergency and Standby Power Systems
IEEE 241	Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gold Book™)
IEEE 446	Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book™)
IEEE 1015	Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (IEEE Blue Book™)

Some of the most applied standards related to transfer switch **construction and testing** include:

UL 1008	Standard for Transfer Switch Equipment
UL 489	Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 1087	Molded-Case Switches
UL 1066	Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures
UL 891	Dead-Front Switchboards
UL 1558	Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
ANSI C37	Low-Voltage Power Circuit Breaker Standard

The most adopted standard is the National Electrical Code®. The sections that most affect transfer switch selection include Article 517 "Health Care Facilities", Article 700 "Emergency Systems", Article 701 "Legally Required Standby Systems", Article 702 "Optional Standby Systems", and Article 708 "Critical Operations Power Systems". Changes to these articles in the 2005 and 2008 National Electrical Code®, affect not only transfer switches, but how engineers must design all parts of an emergency power system. These changes are related to selective coordination.

Changes made added selective coordination to Emergency Systems (Article 700.27), Legally Required Standby Systems (Article 701.18), and COPS Article 708.52 (D) and 708.54. It is also indirectly added to Health Care Facilities through Article 517.26, which refers to, and ties in the requirements of Article 700.

II. Selective Coordination

The National Electrical Code® defines coordination (selective) in Article 100 as “Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings.” The changes as described above now require emergency and other systems indicated above, to be selectively coordinated. This presents the electrical designer with the challenge of specifying overcurrent protective equipment to achieve total selective coordination. This includes all of the overcurrent devices in the emergency system, and can require special attention in transfer switch selection. Selective coordination needs to be achieved not only on the generator side of the transfer switch, but on the load side as well. This means that evaluation for bolted fault conditions will include not only the typically moderate available fault currents that can be delivered by the generator, but also the typically higher fault currents that can be delivered by the utility on the load side of the ATS.

Few would argue that selective coordination is desirable for continuity of power during low to mid level faults. Many would argue its effectiveness for very high fault currents including those in the instantaneous range. The code changes, when proposed, were met with stern opposition. In applying the code prior to the changes, the design engineers would typically focus on selectively coordinating for the most common faults such as overload and arcing faults. Selected coordination for the extremely rare “bolted fault” would be balanced with a design that minimizes arc flash hazards. Some of the concerns associated with this change are that it would limit the design engineer’s options, forcing a design that can result in a higher arc flash hazard. It can require more costly systems despite that there is no evidence or substantiation of a real world problem from lack of selective coordination in the higher current ranges, while arc flash incidents occur regularly.

To this end, some agencies, inspectors, and jurisdictions have debated as to how or whether to adopt or enforce the total selective coordination requirements. Some have suggested requiring selective coordination on emergency systems down to 0.1 seconds. Others have suggested allowing the registered professional engineer responsible for the design, to make design judgments that balance selective coordination while mitigating arc flash hazards. Nonetheless, many jurisdictions have adopted the 2005 National Electrical Code® as written, and design engineers must achieve total selective coordination.

Some design engineers may look to the use of fuses to achieve selective coordination. Fuse manufacturers publish tables that assure selective coordination by maintaining a certain ratio, typically a 2 to 1 ratio. Many designers object to the use of fuses in the design of power systems. When fuses blow, they must be replaced, and replacements may not be readily available during emergencies. Any replacement fuses must always be of the same type and manufacturer to maintain a selectively coordinated system. Fuses can allow high arc flash energy during low and mid level faults and are difficult to provide with ground fault protection. End users often prefer circuit breakers for these and other reasons, such as space considerations, communications capability and better low and mid level fault protection. In addition, the generator is typically furnished with a circuit breaker to provide adequate protection for the generator since the output fault current capability of a generator is typically very low when compared to utility available fault current.

Circuit breakers can be used to achieve selective coordination. An evaluation of fault conditions during the design phase should be done whether fuses or circuit breakers are utilized. Circuit breakers do not present the same difficulties as fuses. They can easily be reset after a fault and can provide significantly lower let through energy during lower level faults (See **Figure 1**).

Circuit breakers used for overcurrent protection often have instantaneous trip functions to open quickly for high-level faults. By definition, instantaneous trips have no intentional time delay. When you have two circuit breakers in series, and both breakers see a high level fault, they both try to open instantaneously.

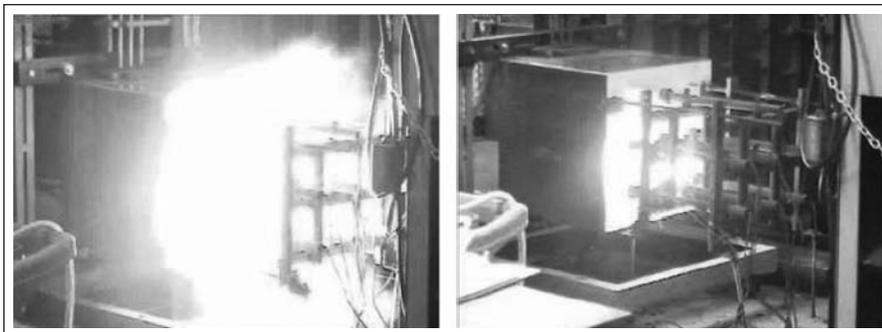


Figure 1. Arc Flash Testing

Fuses can have significantly higher let-through energy at lower fault levels.

This is illustrated in the time current curves shown in **Figure 2**. In this example, the 1600, 800, and 600 ampere circuit breakers are selectively coordinated down to about 0.08 seconds. For faults above about 8000 amperes, the 600 and 800 ampere breakers are not coordinated. For faults above 12,000 amperes, none of the three breakers are selectively coordinated. However, for these rare higher fault levels, much better arc flash protection is provided for anyone providing changes or maintenance work on the protected equipment.

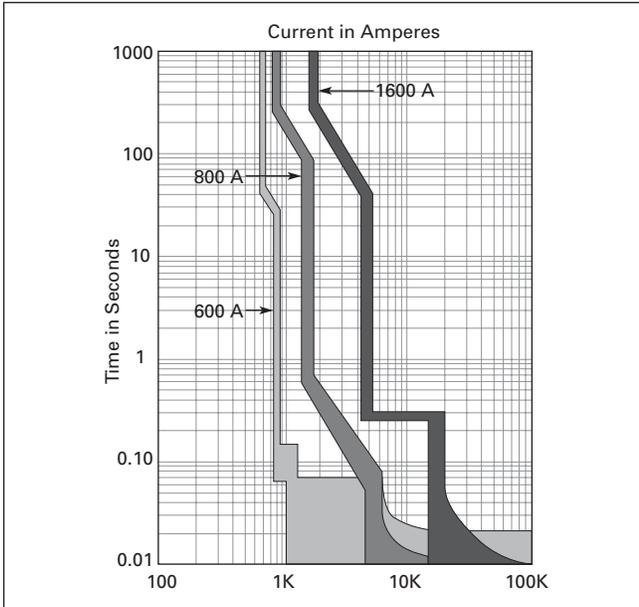


Figure 2. Does Not Provide Total Selective Coordination

There are a variety of ways to achieve selective coordination using circuit breakers. They include using larger frame breakers with high withstand capabilities in selected parts of the power system, using manufacturers tested combinations, etc. These solutions go beyond the scope of this paper. This paper will focus on the most common solution, which involves using power circuit breakers without instantaneous protection.

Power circuit breakers are frequently used because of their many features. The major feature is that their robust design allows them to hold in, or stay closed during fault conditions. They can stay closed for faults typically up to their interrupting rating for up to 1/2 second or 30 cycles.

With no instantaneous function in the circuit breaker trip unit, the breaker will trip when the fault current exceeds the short time delay setting in the circuit breaker. Power circuit breaker trip units typically have short time delays adjustable in 0.1 second (6 cycle) increments. By increasing the short time (and where applicable, ground fault) settings of breakers in series which are closer to the power source, this insures selective coordination even for high-level faults. Although the designer can be certain that breaker coordination has been achieved, one must also be certain that all associated equipment in the circuit can also withstand the fault currents for the full time delay introduced in the system.

Figure 3 shows a typical power system with power circuit breakers. The 1600 and 800 ampere circuit breakers do not have instantaneous trip functions. They do have adjustable short time settings for an effective design. It is readily seen that the 1600 and 800 ampere breakers coordinate not only with themselves, but also with the 600 ampere molded case circuit breaker. By using power circuit breakers, total selective coordination is assured for all current levels.

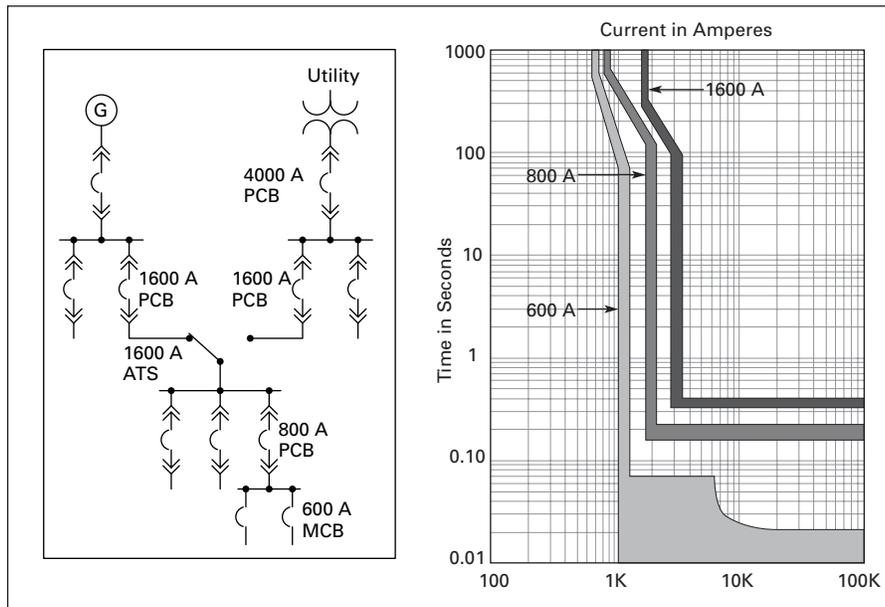


Figure 3. Selectively Coordinated Power System Utilizing Power Circuit Breakers
The transfer switch must have short time ratings consistent with the power circuit breakers.

For emergency and other discussed systems, attention must now be paid to the transfer switch construction. Prior to the changes in the 2005 NEC, designers were only concerned that the transfer switch had a withstand rating equal to the available fault current of the power system with the minimum protection required by the transfer switch manufacturer. Now it is most important that the specified transfer switch have suitable short time current and time ratings consistent with the system design. In most cases this requires transfer switches constructed utilizing power circuit breakers.

The UL 1008 standard for transfer switches only requires testing for withstand ratings for fault currents for three cycles. The changes made to UL 1008 in 2002 allowed manufacturers to test and label for short time ratings in addition to withstand ratings. By testing to this revised standard, manufacturers can certify and label their switches for specific short time current and time rating. This allows designers to be assured the switches can be properly applied in a selectively coordinated system.

III. Transfer Switch Construction

There are many options available to the engineer specifying transfer switches for emergency and other discussed applications. Standards help to establish minimum performance criteria, but the many manufacturers, construction types, and available options require many decisions. Over-specifying can result in a very reliable but costly design. Under-specifying can result in a less expensive design, but may not meet code, safety, reliability, etc., as required by the application. Understanding the major construction types and features is required to make the right selections. The major construction types and features can be grouped into switch type, operation, transition, bypass and controls. An overview of these items are described as follows:

Switch Type

Transfer switch switching mechanisms are often categorized into contactor type or breaker type. This has become the traditional description, although neither one is truly accurate. Contactors are NEMA devices used for purposes like motor starting and lighting control. The contactors used in motor starting are magnetically held devices designed for much higher operations and lower withstand ratings than the standards require for transfer switches. In many instances, the contacts, arc chutes, and arcing horns in transfer switch “contactors” are more like those found in circuit breakers than those found in motor contactors.

Transfer switches referred to as “breaker” type switches are frequently not circuit breakers, but molded case switches having much larger frame sizes than the rating of the ATS would indicate. In other cases they can be molded case circuit breakers or power circuit breakers. The important distinction between these switching devices is the standards to which they are designed and tested. More rigorous testing on some of these devices provides important performance advantages. An overview of these devices is as follows.

“Contactor” Type Transfer Switches

In “contactor” type transfer switches, the main switching poles and their arc chutes are typically exposed. Benefits of the contactor type switch is that the contacts can easily be inspected in a de-energized switch during maintenance. They also frequently have the lowest cost. The most common standard required for transfer switches is UL 1008. In order to meet this standard, all transfer switches, regardless of power switching mechanism, must meet the testing requirements of the standard. One of the more rigorous tests is the endurance test. It requires thousands of operations under several load conditions and larger switches must be further tested under no-load as well. The endurance testing requirements are shown in **Table 1**.

Table 1. -ATS Endurance (UL 1008 Table 30.2)

Switch Ampere Rating	Rate of Operation	Number of Cycles of Operations		
		With Current	Without Current	Total
0 – 300	1 per minute	6000	—	6000
301 – 400	1 per minute	4000	—	4000
401 – 800	1 per minute	2000	1000	3000
801 – 1600	1 per 2 minutes	1500	1500	3000
1601 and above	1 per 4 minutes	1000	2000	3000

Molded Case Switches and Molded Case Circuit Breakers

Molded case switches and molded case circuit breakers are also frequently used for the main switching devices in transfer switches. The power switching poles are completely enclosed and barriered within the molded case which many design engineers prefer as an additional level of safety. When applied in transfer switches tested to UL 1008, they are tested to the same criteria as the contactor type switch including endurance and short circuit testing. It is an additional benefit that they are also tested to additional UL standards which cover molded case switches (UL 1087) or molded case circuit breakers (UL 489). Standards UL 489 and UL 1087 are more stringent than UL 1008 as far as follow-up testing. UL factory surveillance for molded case switches and breakers require not only continual physical re-examination of the components used, but also periodic follow-up re-testing. For these reasons many engineers prefer molded case transfer switches versus contactors.

Power Circuit Breakers

Power circuit breakers are used in transfer switches as small as 200 amperes, although they are typically applied in switches from 800 to 5000 amperes. Power circuit breakers are designed, manufactured and tested to the requirements of ANSI C37.13 and UL 1066. They can be incorporated in designs which meet the requirements of UL 1558 switchgear and can be rated to interrupt 200,000 amperes at 480 volts.

Power circuit breakers have many features which are desirable in critical switchgear as well as transfer switches. They have 30 cycle short time ratings, typically equal to their interrupting rating, which allows them to be supplied without instantaneous trip functions. In this way, design engineers can easily incorporate them into systems requiring total selective coordination as described above.

Power circuit breakers are designed for maintenance and parts replacement and are typically provided in drawout construction. When used in transfer switches, this can allow for some maintenance and inspection without shutting down the load.

Integral Protection Advantages

The utilization of circuit breakers with integral trip units has several advantages, the most obvious of which is the ability to eliminate a circuit breaker on the incoming side of both or either source side. Without an integral trip unit, should a fault occur on the load side of the transfer switch and ahead of the load side protective device, the circuit breaker upstream of the source side of the transfer switch would perform its intended function and trip. The transfer switch would sense a loss of normal voltage on its line side and initiate generator start and close the generator on the faulted load, resulting in a trip on the generator breaker.

A feature referred to as a “bell alarm” or “overcurrent trip switch” provides a secondary advantage to an integral trip unit. This feature consists of a switch that changes state when the circuit breaker automatically trips as a result of an overcurrent or fault condition. When a circuit breaker type ATS with integral trip unit is utilized, the integral trip unit would trip under the load side fault condition, and the bell alarm contact immediately blocks the generator start signal, thus eliminating the application of a fault on the generator.

Operation

Transfer switch operation comes in three modes; automatic operation, non-automatic (electrically-operated), and manual operation. For the most critical loads, automatic operation is not only desirable, but also frequently required by code. With automatic operation, the transfer switch controls continuously monitor the normal and emergency or alternate source voltage.

For typical automatic operation the controls will monitor the normal source voltage. When it falls below the preset voltage limit for a predetermined time, the control closes a contact to call for the emergency generator to start. The transfer switch can be used between two utility sources in which case the start contact would not be used. It can be used between two generator sources as well. The controls will then monitor the emergency source voltage and frequency. When they are within acceptable limits, the switch automatically transfers the load to the emergency source. When the control senses that the normal source voltage (and sometimes frequency) has been restored within acceptable limits, it can automatically retransfer the load to the normal source, or in some cases only retransfer after manual intervention.

With a manual transfer switch, there is not typically any control panel, voltage sensing or electrical operation. There may, or may not be indicating lights denoting switch position. Switching between sources is performed manually, by the operator. This type of switch is the most basic and is most common in less critical residential applications.

Non-automatic controls allow for electrical operation, but it is accomplished by manual intervention. Local or remote switches can be used to transfer to either source. It allows the operator to control switching without necessarily coming in close contact with the main switching device. It is not typically used for critical loads where automatic operation is required.

Transition

The transfer switch can be provided as open transition, delayed transition, or closed transition. The main switching mechanism can be two-position or three-position. The most basic configuration is open transition with a two-position switch. This switch is either in the normal source or emergency source position. It is break-before-make in its operation, but the mechanical configuration of the switch is such that there is no maintained off position.

An alternative arrangement is the three-position, open transition switch. It is a make-before-break configuration, but it is mechanically configured to allow for a center OFF position where it is not connected to either source. Another application is when the switching devices are circuit breakers and overcurrent protection is provided within the switch, typically for service entrance applications. The center OFF position is then for fire department use. This switch is sometimes specified to deal with transfer of loads with a high percentage of highly inductive loads.

Switching inductive loads, such as motors, requires special attention. When power is disconnected from a spinning motor, the motor will maintain terminal voltage and decay over several cycles to seconds as a function of inertia and the motors open circuit time constant. This residual voltage can result in extremely high inrush currents as a result of out-of-phase transfer when switching is performed with both sources available. This event can happen in many scenarios including retransfer to normal, maintenance testing, normal source single phasing, etc.

One method of overcoming this inrush is through the use of an in-phase monitor. This uses a relay to measure phase angle between sources to insure both sources are synchronized (or approaching synchronism to allow for switching time) before transfer. Difficulties can occur with this method due to differences in transfer times and residual voltage decay times. It relies on switch transfer and voltage decay times. Improper application may not minimize the inrush. Also, the in phase monitor is passive so transfer must wait until the sources come into synchronism. Another concern is that as soon as the motor is disconnected from the normal source, the previously determined phase angle changes due to the motor slowing down.

A second method is by use of a three-position transfer switch. The switch is break-before-make and has a center OFF position. Programming allows the switch to pause in this OFF position for a predetermined time set for the power system in which it is applied. The switch stays in this OFF position for sufficient time to allow the residual voltage to decay, typically to about 25% voltage before transfer.

Where the need to minimize load disturbances is critical, a closed transition transfer switch may be used. When both sources of power are available this switch allows a make-before-break transfer with uninterrupted power. Synchronism check relays are used to permit both sources to be paralleled only when synchronized. Transition times are typically limited to 100 milliseconds or less which avoids the need for generator VAR controls.

With the closed transition switch, the 100 millisecond paralleling time means the source to which the load is being transferred will take on load from 0% to 100% in a tenth of a second. While closed transition is intended to minimize voltage disturbances, this block loading can result in voltage disturbances as the source responds the load. This is usually more difficult for generator sources, which are relatively soft.

The transfer switch that provides minimum disturbance is the closed transition, soft load transfer switch. This is a closed transition switch that interfaces with the generator controls to avoid block loading. When transferring to the generator source, both sources are paralleled with the utility carrying 100% of the load. A signal is sent to the generator controls ramping up the load on the generator. The load on the generator increases from 0% to 100% over a programmed time period providing soft loading. When the generator is at (or approaching) 100% load, the utility source is separated. Transfer back to normal works in the reverse manner.

Bypass

Since transfer switches are used in critical and emergency applications, regular inspection, testing, and manufacturer’s indicated scheduled maintenance is recommended and often required by code. It is usually preferred to perform this work without load interruption. This can be accomplished by providing an optional bypass switch.

This switch is usually a bypass and isolation switch, which allows the load to be bypassed to the connected source, and the transfer switch isolated so it can be worked on without load disturbance.

It should be noted that transfer switches provided with drawout power circuit breakers provide some ability to inspect and maintain the transfer switch even without bypass. Since the main switching device is a drawout power breaker, the source breaker not feeding the load can be removed for

inspection, maintenance and testing. This construction may be desirable where drawout features are preferred but codes do not require full bypass and isolation of the transfer switch.

Controls

As the name would imply, manual transfer switches usually do not have controls. Non-automatic transfer switches may have basic electrical operation. Modern automatic transfer switches will typically have microprocessor-based controls.

Automatic transfer switch controls monitor source voltage and frequency and indicate switch position. The controls determine when voltage and frequency are acceptable or unacceptable on either source and initiate transfer operation.

The logic incorporates voltage and frequency tolerances and time delays for transfer switch operation. They determine when to send engine start signals and they also often provide exercising timers (with and without load).

Basic units have fixed settings while more advanced units are programmable. Closed transition switches have complex controls to supervise synchronism and switching times. Soft load closed transition switches will even control generator loading.

The most advanced units can also incorporate metering and communication functions.

Transfer Switch Construction Summary

The overview provided for transfer switch major construction features help to understand the number of choices that must be made during design. Additional features or improved construction types can be specified to increase reliability and safety, but there is an associated cost. A summary of the above can be categorized in a relative arrangement of escalating features, flexibility, reliability and investment as shown in **Table 2**.

Table 2. Transfer Switch Selection Criteria

	Switch Type	Operation	Transition	Bypass	Control
Features	Low	Contactors	Manual	No Bypass	Fixed
Reliability	↓	Molded Case	Non-Auto	Drawout	Programmable
Safety	↓	Power Breaker	Automatic	Full Bypass	Programmable & Communicating
Investment	High				

IV. Conclusion

When designing emergency and other discussed systems, the engineer is faced with many design decisions. Code requirements must be met, and can vary by application. Standards are helpful for applying and assuring quality levels for the switches, but many switch construction choices are also application driven. Choices made with respect to switch features can translate into improving levels of safety and reliability, but at the same time can increase project cost. Understanding the applicable codes, the application needs, and equipment construction features is critical to providing a cost-effective reliable design.

References

- "Automatic Transfer Switches, A Performance Comparison – Molded Case Switch Versus Contactor Type", David D. Roybal, Cutler-Hammer Technical Paper TP.15A.01.T.E, June 2001.
- "Optimum Safety, Reliability, and Electrical System Performance Through Balanced Selective Coordination and Protection", K.J. Lippert, C.J. Nochumson, 2007.
- "Transfer Switches Applied in Systems with Power Circuit Breakers", David D. Roybal, IEEE Transactions on Industry Applications, Vol. 37, No. 3, May/June 2001.
- "How UL Listings, Nationally Recognized Testing Standards, IEEE and NEC Relate to Power Transfer Schemes and Equipment", Daniel B. Grover, P.E., Pure Power Magazine, Summer 2004.

About the Author

John Ziomek received the Bachelor of Science Degree in Mechanical Engineering from New Jersey Institute of Technology in 1983. He is an Application Engineer with Eaton Corporation in New York, NY. He was previously a design engineer for ASCO Electrical Products and also a Licensed Master Electrician in New York City.

Mr. Ziomek is a Licensed Professional Engineer in New Jersey, a LEED Accredited Professional, and also an associate member of the International Association of Electrical Inspectors (IAEI).

Eaton Corporation
Electrical Group
1000 Cherrington Parkway
Moon Township, PA 15108
United States
877-ETN CARE (877-386-2273)
Eaton.com



PowerChain
Management®

PowerChain Management
is a trademark of Eaton
Corporation. All other
trademarks are property
of their respective owners.

© 2008 Eaton Corporation
All Rights Reserved
Printed in USA
Publication No. PU01600001E/CPG
April 2008