APPLICATION AND INSTALLATION GUIDE

AUTOMATIC TRANSFER SWITCHES

CATERPILLAR®

Foreword

This section of the Application and Installation Guide generally describes wide-ranging requirements and options for Caterpillar® Automatic Transfer Switches (ATS). Additional engine and generator systems, components and dynamics are covered in other sections of this Application and Installation Guide.

Information and data related to specific ATS models is available from a variety of sources. Refer to the overall introduction of this guide for additional references.

Systems and components described in this guide may not be available or applicable for every ATS. Refer to the Product Specification Sheets for specific options and compatibility. While much of the content of this guide is applicable to all ATS, the primary focus of this guide is on the North American ATS market.

Section Contents

1. Introduction

Modern utility systems are generally reliable but human error or the uncertainty of weather can and does call for emergency or standby power availability. These systems are found in a wide range of environments, including industrial, commercial, office, military, remote, medical, malls, public safety, academic or scientific sites. In all cases, safety as to personnel or destructive fires and outages must be designed in and accounted for.

While emergency power can be supplied by multiple utility services or by on-site power generation, on-site generator sets will provide the maximum control and reliability. Whether with a second utility source or on-site generation, a means must be provided to transmit power to the loads from either source, and transfer the loads from one source to the other, such as an Automatic Transfer Switch (ATS).

An ATS is defined as: a device used to switch a power supply from normal to emergency when a power failure occurs.

The seven major functions of an ATS are:

1. Carry current continuously,
2. Detect power failures,
3. Initiate emergency source,
4. Transfer load,
5. Sense restoration of normal,
6. Re-transfer load to normal,
7. Withstand and close-in on fault currents.

ATSs are used for both low voltage (LV) and medium voltage (MV) applications. Low voltage is classified as 0-1kV and medium voltage is classified as 1kV – 15kV, 15kV and above is not discussed in this guide. LV ATSs are designed to fulfill Underwriter Laboratories (UL), Inc. standards contained in UL-1008.

While many of the concepts discussed in this guide are applicable to the International market, the focus of this guide is on the North American ATS market.

1.1. Transfer Switch Basics

A transfer switch is a critical component of any standby power system. When the normal (preferred) source of power is lost, the transfer switch transfers from the normal source of power to the emergency (alternate) source of power. This permits critical loads to continue running or begin running again, once the transfer is made. After the normal source of power is once again available, the transfer switch transfers back to the normal source from the emergency source.

Operation of the transfer switch from normal to emergency and back to normal can be a manual type operation or an automatic type operation. It depends on the type or configuration of the transfer switch equipment. If loads are critical, an ATS will most likely be used to ensure the fastest possible transfer. A hospital operating room is an example of a critical load. An ATS might also be used when operators are not conveniently available who could make a manual transfer. If loads are not quite as critical, but still cannot go for any extended period of time without power, a manual transfer switch could be used.

1.1.1. Non-Automatic (Manual) Transfer Switch

Transferring loads can be done with a manually operated device, also referred to as a non-automatic transfer switch. In such applications, operating personnel should be readily available and the load is not of a critical nature requiring immediate restoration of power. A refrigeration plant is an example of a less critical need. While the refrigeration plant could not live with an extended power outage, it may be able to tolerate a brief down time while a manual transfer is made.

From a very simplistic standpoint, double-throw knife switches and safety switches have been used as manual transfer switches. Because these devices are marginal adaptations, lack a high degree of reliability, and the restricted operation requirements can be abused; personnel are reluctant to operate them. Since the non-automatic transfer switches are part of the emergency power supply system, they should have the same UL 1008 electrical ratings as the ATSs feeding the more critical loads. For these reasons, only switches specifically designed for manual transfer applications should be considered.

There are two types of non-ATSs:

- Manually operated non-automatic,
- Manually initiated, electrically operated.

1.1.2. Manually Operated Non-Automatic

Manually operated non-automatic transfer switches provide all the mechanics to effect the transfer from source to source. The actual transfer of power, however, is accomplished by true hand operation of the transfer switch mechanism. In many installations where non-critical loads are being served, specifications may call for manual or non-automatic transfer switches. This method may be used because operating personnel are present and the loads are not of a critical nature requiring unattended operation.

1.1.3. Manually Initiated, Electrically Operated

Manually initiated, electrically operated non-automatic transfer switches are similar to the manually operated version just described except that an electrical operation feature is added to the switch. The switch electrically transfers power when a pushbutton, usually mounted on the switch's enclosure, is pushed. If necessary, the switch can also be manually operated.

1.1.4. Automatic Transfer Switch

The most convenient and reliable method to transfer power is with an ATS. In general, the ATS includes controls to detect when a power failure occurs, and triggers other controls to start the engine when the emergency power source is a generator set. When the generator set reaches the proper voltage and frequency, the switch transfers load circuits from the normal source to the emergency source.

When the normal source is once again ready to supply power, the switch retransfers the load circuits to the normal source. It also triggers controls to shut down the generator set. The standard operation performed by the ATS each time there is a power failure and power restoration is:

- Engine starting,
- Transfer to generator,
- Retransfer to normal,
- Engine shutdown.

2. Transfer Switch Components

ATSs contain basic elements, each performing specific functions. All transfer switches do not carry out these functions in the same way. Included is a summary of those basic functions, with a description of the various means used to accomplish those functions.

An ATS consists of the following basic elements:

- **Power switching device** – the purpose is to transfer the physical load connection between emergency power sources.
- **Transfer mechanism** – purpose is to cause the transfer of the main contacts between emergency sources.
- **Control power** – the purpose of control power is to supply power to the transfer mechanism, which causes transfer of the power switching device.
- **Controls** – the purpose of ATS controls is to monitor normal and emergency power sources and to initiate the transfer between sources, as appropriate.
- **Enclosure** – the purpose of the enclosure is to house the ATS components and to protect them from site environmental conditions.

2.1. Power Switching Device

The purpose of the power switching device is to transfer the physical load connection between alternate power sources.

2.1.1. Types of Power Switching Devices

While the titles are slightly misleading, it is often stated that there are two basic types of transfer switch designs: "contactor type" transfer switches and "circuit breaker type" transfer switches.

Based upon the type of power switching device, there are actually three basic types of power switching devices available in the ATS market today:

- Contactor type switches,
- Circuit breaker type switches,
- Static transfer switches.

2.1.1.1. Contactors

Contactor type transfer switches are widely considered the most frequently specified type of ATS and are designed to limit the number of operating parts to accomplish the required transfer between alternate sources. While referred to as "contactor type" transfer switches, this type of switch does not use motor starting/lighting contactors.

The standard transfer switch must be designed to prevent two sources (a normal source and emergency source) from being connected to a load simultaneously. In the case of the contactor type switch, this is accomplished through the use of an electrically operated, mechanically held contact operation, which will be described in more detail in Section 2.2.

2.1.1.2. Circuit Breakers

"Circuit breaker type" transfer switches are another popular and effective means of transferring load between alternate sources. In the case of automatic transfer application, the term "circuit breaker" is actually misleading. The transfer medium is actually a "switch" and not a circuit breaker. By definition, a switch is a circuit breaker which does not include a tripping element. Circuit breaker type transfer switches can be further categorized by their construction methodology as either molded case switches or insulated case switches.

2.1.1.2.1. Molded Case Switch

A molded case switch is a molded case circuit breaker without a thermal trip element. Molded case switches are often used when a circuit requires a compact, high capacity disconnect device. Supply of a trip element (making it a circuit breaker) is an option. The contacts and arc chutes of the switch are completely enclosed in an insulated housing. These switching devices can be designed to meet a number of UL requirements for molded case circuit breakers, molded case switches and ATSs. Considering the wide range of standards the circuit breaker type transfer switch can meet, they can serve as a viable alternative to the contactor type device.

Typically, molded case switching devices are oversized for the ampacity of the transfer switch. For example, an 800 ampere molded case switch type transfer switch uses 1200 ampere switching devices. Thus the contacts are likely to be larger in the molded case switch design than the contacts used in a contactor type of equal rating.

The molded case switching device is normally used with smaller ampacity transfer switches (e.g. < 1600 amps). It provides for self-protection with a fixed instantaneous trip setting feature and will interrupt a fault current at or above its preset level.

2.1.1.2.2. Insulated Case Switch

Transfer switches also use insulated case type switching devices. Testing for these type devices is rigorous and covers a broad scope just like the molded case type switch. Unlike the molded case type device, the insulated case type switching device can be provided without any type of trip unit. This is true because the insulated case type device has very high withstand and endurance ratings. In addition, the insulated case type switch is available in a drawout configuration, which lends itself to certain specialty transfer switch configurations.

2.1.1.3. Static Transfer Switch

In some site applications, where the emergency power system is required to supply solid-state equipment, such as in a data center, traditional power transfer devices are incapable of transferring loads within the required time frame.

The static transfer switch provides a faster load transfer (typically ¼ of a cycle), than the traditional ATS, which ensures uninterrupted operation of sensitive electronic equipment. In this instance, load retransfer to the preferred input source is virtually instantaneous. Silicon controlled rectifiers (SCRs) are the means by which the static transfer switch transfers power, which allows for the improved transfer times.

This type of switching is typically used when both sources are utilities or one source is an Uninterruptible Power Supply (UPS).

2.2. Transfer Mechanism

The purpose of the transfer mechanism is to switch the main contacts of the power switching device between two power sources. Example: consider a double-throw knife switch to be one type of power switching device. The arm of the operator who actuates the handle of the knife switch serves as the Transfer Mechanism.

Transfer mechanisms can be classified by the way in which they are activated. Those methods include:

- Manual operation,
- Electrical operation.

2.2.1. Manually Operated

Manually operated mechanisms require operating personnel to perform a function by hand, such as directly operating a manual handle. Operation of the handle results in the power switching device being transferred from one source position to the emergency source position. It is important to recognize that UL1008 regulates the conditions under which ATSs may be operated manually. For additional information regarding the use of manual operating handles please reference Section 3.2.

2.2.2. Electrically Operated

Electrically operated mechanisms are powered by motors or solenoids. The electrical operator may be initiated manually (typically via a pushbutton) or automatically.

Automatically operated mechanisms do not require an operator to initiate operation. Through the use of a controls package and pre-programmed operating conditions, the mechanism is automatically set in motion when the programmed operating conditions are met.

There are five primary types of transfer mechanisms used with transfer switches:

1. Single solenoid,
2. Dual solenoid,
3. Unidirectional gear motor,
4. Twin stored energy,
5. Linear motor.

2.2.2.1. Single Solenoid

The single solenoid type transfer mechanism, employed on contactor type switches, utilizes an electrical solenoid with an integrally mounted actuator. The solenoid is directly connected to line voltage.

In an emergency condition, the solenoid is energized, causing the actuator to extend and rotate the mechanically linked cam. As the cam rotates, the contact arm (which is connected to the cam via a connecting yoke) is caused to move from the normal source position to the emergency source position. This results in contact connection to the emergency (standby power) source.

Upon restoration of the normal source, the solenoid is de-energized, causing the actuator to retract and rotate the cam in the opposite direction, resulting in contact connection at the emergency (standby power) source.

Manual transfer of a single solenoid operated transfer switch is possible, but requires all power to be disconnected to the solenoid. Manual transfer is accomplished through the use of a metal rod. The metal rod is typically not attached to the switch permanently.

Single solenoid type transfer switches are typically used on lower amperage rated transfer switches (typically on switches 400Amp and less).

2.2.2.2. Dual Solenoid

In the case of the dual solenoid switch, which is also used in contactor type transfer switches, a solenoid-operated actuator is assigned to independently operate each set of source contacts. One solenoid serves to close the normal source contacts, while the second solenoid serves to close the emergency source contacts.

Dual solenoid type transfer switches are typically used on higher amperage rated transfer switches (typically on switches greater than 400Amps).

2.2.2.3. Unidirectional Gear Motor

This type of mechanism transfers between power sources through the use of a unidirectional motor-driven mechanical device. Rigid shafts or arms are linked to the motor through a ratchet type device or gears. The rotary motion created by the motor is converted to linear motion. The linear motion moves the rigid shafts or arms to operate the switching devices, such as the operating handles on molded case switches.

The unidirectional motor is energized from the source to which the load is to be transferred. This type of transfer mechanism can also be operated manually, often through the use of an integrally mounted operating handle. The operating handle, whether it is ratcheted or rotated, produces the linear motion required to operate the switching devices.

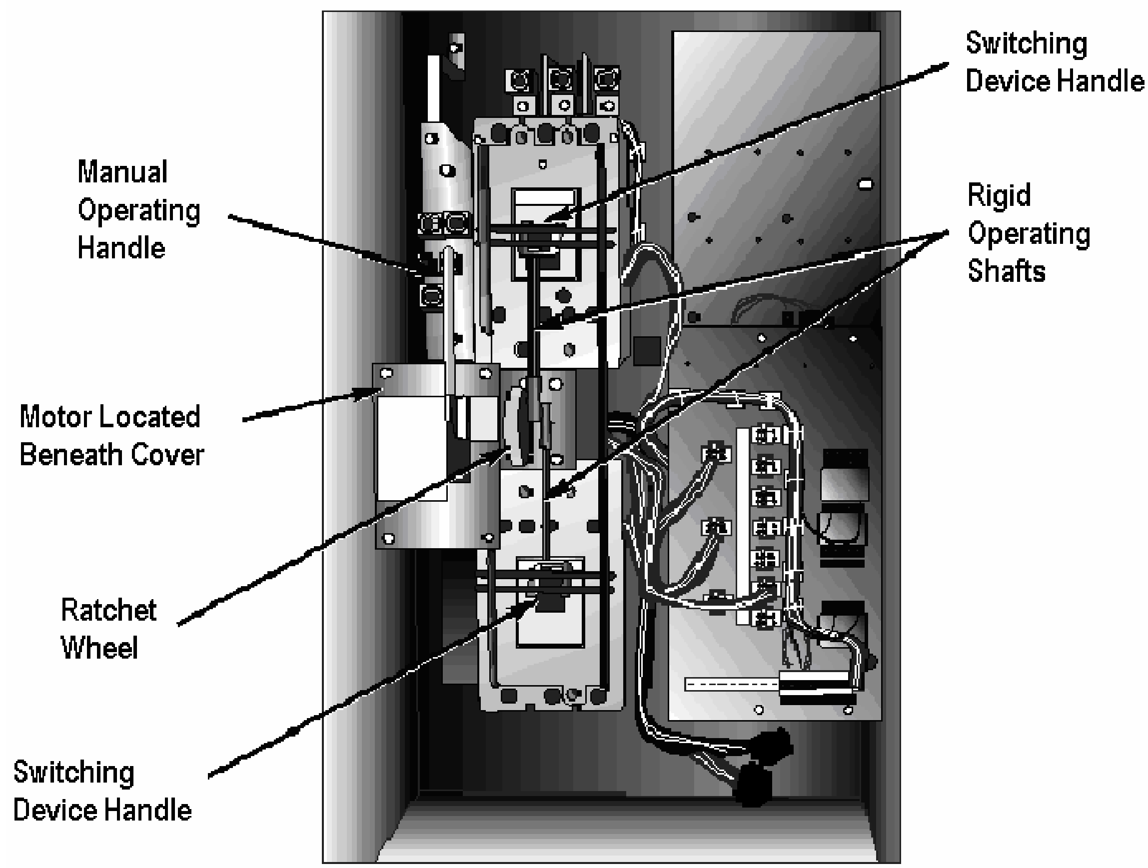

Figure 1 – Circuit Breaker Type ATS with Unidirectional Gear Motor

2.2.2.4. Twin Stored Energy

This type of mechanism utilizes insulated case switches with true two-step stored energy mechanisms as the switching devices (Figure 2). The stored energy mechanism provides the required mechanical motion to open and close the two sets of main contacts. A rigid mechanical interlock between the main contacts of the two switching devices prevents both sets of main contacts from being closed simultaneously. Except for the mechanical interlock, the switching device and the transfer mechanism are automatically provided in the form of the one device, the insulated case switch.

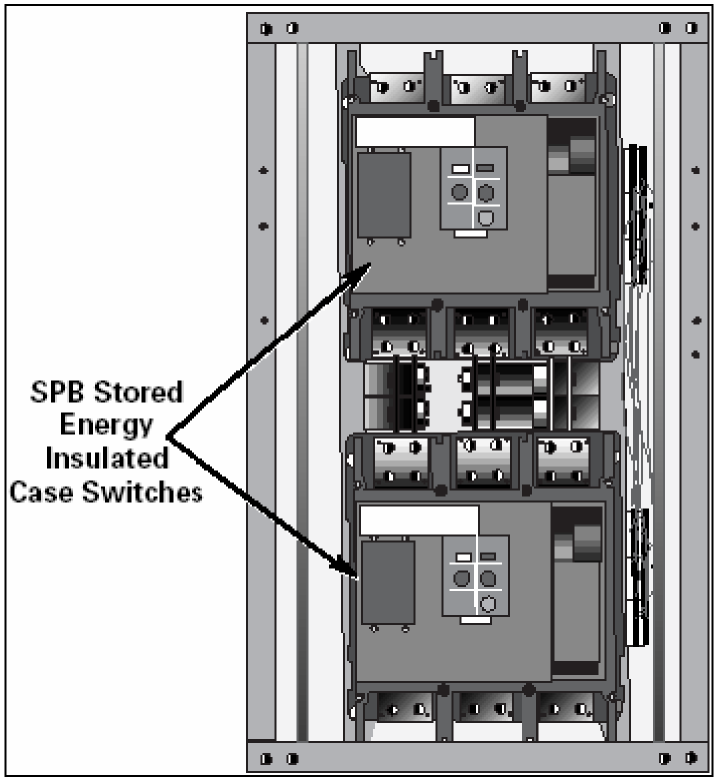

Figure 2 – Insulated Case Design Utilizing a Twin Stored Energy Mechanism with Protective Cover Removed for Clarity

When insulated case switches are used as the switching devices, each device can be manually opened and closed through the use of manual buttons located on the front of the device. If required, the switching devices can also be configured to be electrically closed and opened. The closing springs can be manually charged using a front mounted manual charging handle.

If it is not desirable to perform the functions just described manually or the transfer switch is to be fully automatic, electrically operated switching devices are available.

This means that the closing springs are automatically charged, as required, through the use of a small integrally mounted electric motor. The motor is energized from the source to which the load is transferred. In addition, the closing and opening functions can be electrically and automatically performed.

2.2.2.5. Linear Motor

The linear motor mechanism is basically a coil with an operating shaft running through the coil. The operating shaft which causes the main contacts to operate is not an integral part of the coil. Since the linear motor electric operator is connected directly to the full line voltage, the circuit requires the use of capacitors. This creates difficulties when voltage rating changes are required. This type of switch cannot be operated manually and cannot be manually switched under full load. In fact, the motor drive circuit must be disconnected prior to manual operation. The motor drive circuit must also be reconnected before the switch will function. The manual operating handle is a separate loose tool.

2.2.3. Control Power

The ATS receives power to transfer from the source to which it is transferring the loads. For example, if the switch is going to transfer from the failed normal source (e.g. utility) to a live emergency source (e.g. diesel generator set), the power to make the switch transfer must come from the output of the diesel generator set.

Voltage must be provided to the transfer switch components that require power to operate – solenoids, control relays and controller. This voltage is typically provided through internally mounted transformers, which must match the application voltage.

2.2.4. Controls Logic

The purpose of the ATS controls logic is to monitor both the normal and emergency power sources and to initiate and control transfer between those emergency power sources. The logic panel, included as part of a transfer switch, provides intelligence supervisory circuits to constantly monitor the condition of the power sources and thus provide the intelligence necessary for the switch and related circuit operation.

Microprocessor-based logic provides a far more comprehensive list of capabilities to the ATS world than previously available with relay logic or solid state logic. Normally, microprocessor-based logic comes in the form of a self-contained unit that can be mounted on the enclosure door (Figure 3). The biggest differences between microprocessor logic from one manufacturer to another are the features available and ease of use.

Figure 3 – Caterpillar microprocessor-based controller

3. Design Criteria

The primary purpose of an ATS is to transfer loads between alternate power sources. This section will outline the various design criteria that are taken into consideration in the design of a transfer switch.

3.1. Current Ratings

In a typical emergency power system (EPS), ATSs are located in that portion of the distribution bus that feeds branch circuits (see Figure 4). Due to its location in the distribution network, four design criteria related to current carrying capability must be taken into consideration in the design of the switch and when applying it into a specific EPS.

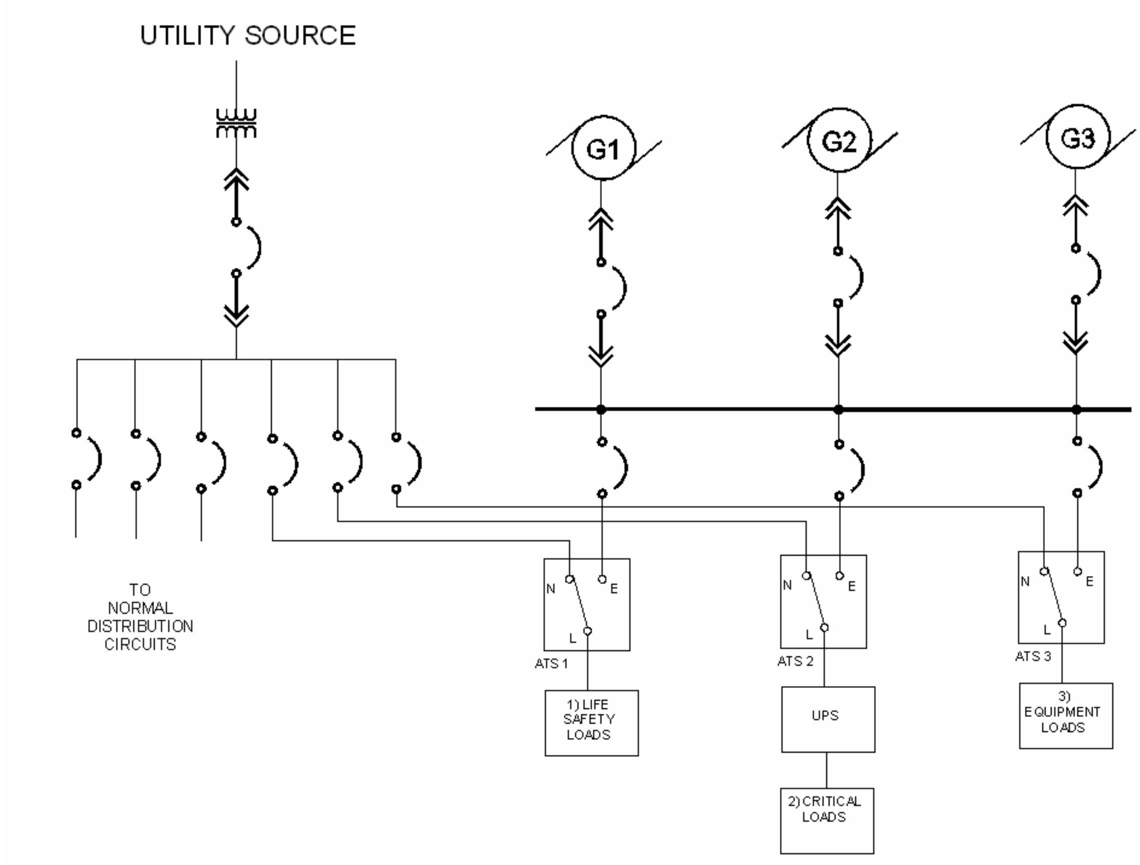

Figure 4 – Emergency Power System (EPS) with Automatic Transfer Switches Feeding Branch Circuits

3.1.1. Inrush Current

When the transfer switch closes onto the emergency power source, the contacts can be subject to a large surge of current. The magnitude of that surge depends on the load, which is placed upon the switching device at the moment of transfer. Loads specifically addressed by UL 1008 include motors, electric-discharge lamps, electric-heating loads, and tungsten-filament lamp loads.

Due to the relatively low resistance of a tungsten-filament lamp when it is cold, the initial current drawn by the lamp may be as high as 17 times what it draws during normal operation, with the inrush lasting up to 14 cycles. Unless a transfer switch has been specifically designed, tested and labeled otherwise, it may not be used to switch loads having greater than 30 percent of its total consisting of tungsten-filament lamp loads.

Motor loads can add up to 6 times their rated current to the load placed on a transfer switch switching between alternate power supplies, under normal circumstances. However, the transfer switch must be designed to handle switching to a power source, which is not in phase with the residual voltage or counter electromotive force (CEMF) created by motor. This can result in an inrush current of up to 15 times the normal operating current.

When closing onto loads with high inrush currents, the contacts of the transfer switch must not be allowed to weld. In order to accomplish this, the contacts must be designed with some minimum level of “bounce” and be constructed with sufficient thermal capacity to prevent welding. One means of meeting these criteria is by constructing the contacts of the switch with a silver alloy.

3.1.2. Interrupt Current

When the contacts of a transfer switch go from one source to another, an arc is drawn from the source the contacts are leaving.

The higher the voltage and the lower the power factor, the longer the duration of the arc. This arc must be extinguished before the contacts connect to the other source or there can be a short circuit from one source to the other. If the arc is not extinguished, serious damage can occur.

When the switch transfers to the emergency source from the normal source, the current interruption can be zero. The transfer switch can also be called upon to interrupt full load currents at full voltage under test conditions. One of the most critical times occur if a motor is drawing locked rotor current at the instant of transfer.

When the switch retransfers from the emergency to the normal source, it is normally required to interrupt the emergency source current at full voltage. An adequately designed switch must interrupt the arc from both the normal and the emergency sources at all current levels.

Two means are often used to ensure that the arc is properly interrupted when the switch transfers from one source to another:

- Wide arc gaps,
- Arc chutes and arc quenching grids.

The arc gap (see Figure 5) is the distance from the stationary contact to the movable contact when the movable contact is fully opened. The arc gap must be wide enough to draw out the arc and provide time to extinguish it. Transfer time should be a minimum of 20 msec to ensure that the arc is extinguished. As a point of reference, a high speed solenoid actuated drive typically ensures contact transfer in 100 msec or less.

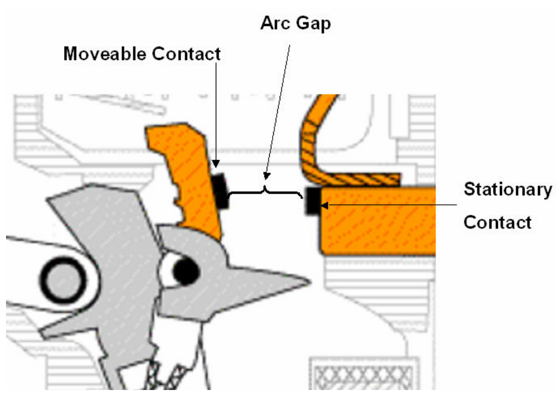

Figure 5 – Arc Gap

In addition to wide arc gaps, arc quenching grids (see Figure 6), consisting of arc chutes are often used to break up the arc as it is drawn into them by the magnetic field created when the arc forms.

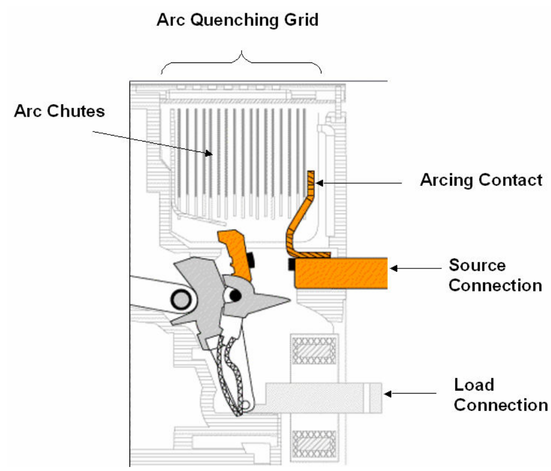

Figure 6 – Arc Quenching

3.1.3. Continuous Current

A transfer switch must continuously carry current to critical loads. Current flows through the transfer switch during both normal and emergency conditions. Unlike other equipment used in EPS applications, a transfer switch is expected to provide continuity of power to the load, uninterrupted, for multiple generations. Other emergency equipment may only be required to provide power for the duration of a power outage. During this continual period of usage, the transfer switch is exposed to fault currents, repetitive switching while powering various types of loads and adverse environmental conditions. The switch must be designed such that these factors do not cause excessive temperature rise, detract from reliable operation or require a substantial amount of maintenance.

In order to achieve these objectives, the contact temperature rise of a transfer switch must be well below that established for an eight-hour rated device. Additionally, the quality of contact must be sustained through proper contact design. Arcing contacts prevent or minimize arcing at the main contacts that would cause contact erosion and affect the ability of the switch to carry current continuously.

A transfer switch is capital investment equipment; therefore, the ability to perform without overheating should not be limited to new or unused switches. For this reason most government agencies require a complete temperature test be performed after the endurance test.

3.1.4. Withstand Fault Current

Transfer switches must be designed to withstand the magnetic stresses and dissipate the heat energy from high fault currents. Withstand current ratings (WCR) vary depending on the switch size and type. Transfer switches should have withstand and close-in current ratings based on the available fault current at its location in the system and the type of overcurrent device to be used. To properly evaluate application and coordination of transfer switches with protective devices, a system short-circuit calculation should be made to determine the symmetrical fault current magnitude and the reactance to resistance (X/R) ratio at each point of application. As the X/R ratio increases, both the fault withstand-ability of a transfer switch and the fault interrupting capacity of an overcurrent protective device become more critical.

A transfer switch must be capable of withstanding the available fault current at its location in the system until the overcurrent protective device clears the fault. The system designer should determine the available RMS symmetrical fault current at the transfer switch location, the X/R ratio, voltage and types of protective devices (current limiting fuse, molded case breaker or power breaker) before a properly rated transfer switch can be selected.

A number of factors account for high withstand current ratings of transfer switches, including the following:

1. Blow-on contacts – In many switching devices, the electromagnetic fields that surround the current-carrying conductor act to force the contacts to separate. Since these electromagnetic forces increase exponentially with current, it can be anticipated that if not properly designed, the contacts may separate during short-circuit currents due to the magnetic effects.
2. Heat – The amount of heat generated at the transfer switch is proportional to the resistance of the parts that carry the current through the switch, multiplied by the square of the current. To provide the thermal capacity needed to cope with this heat, the cross section of the current-carrying parts must be of substantial magnitude to keep the resistance at a reasonable value. It is also necessary to provide

adequate radiating surfaces, along with high-contact pressures, to keep heating to a minimum. Larger transfer switches often utilize segmented contacts that provide multiple paths for current flow through the main contacts. This feature extends the life of the contact by reducing the amount of heat generated during operation.

3. Life of the contact is also extended through the prevention of arcing on the main contacts by the use of arcing contacts. This is discussed in further detail in section 3.1.5 preventing the main contacts.

4. Delay in Transfer – It is necessary to account for the voltage drop that is normally experienced with large fault currents. The design must ensure that the voltage drop does not cause the switch to be automatically transferred while the switch is carrying the fault current. To ensure that this does not occur, the following design criteria should be met:

   - A mechanically held mechanism to prevent opening during a fault condition, and a time delay to override momentary dips in voltage. The mechanically held mechanism assures that the switch will not transfer until control voltage is applied to the transfer switch operator.
   - To prevent energizing the operator until the overcurrent protective device clears the fault, a time delay is incorporated into the control circuit.

The control current will prevent application of control voltage to the switch operator until a minimum acceptable value for proper transfer has developed.

For additional information on withstand rating terms and calculations, see Appendix 12.2: Systems Data Sheet Example.

3.1.5. Protecting the Main Contacts

The main contacts of the transfer switch can be prematurely worn down and damaged by the arcs created when transferring from a live source. Arc runners and arc chutes are often employed to drive the arc, created during this transfer, out away from the main contacts.

As soon as the arc is formed during the transfer operation, it is drawn away from the current-carrying area of the main contacts by an arc runner. The damaging effects of the arc are absorbed by the arcing tip at the top of the arc runner, and away from the current-carrying area of the movable contact.

In larger-size switches, separate arcing contacts are often used (Figure 7). When the switch begins to transfer, the main contacts open first while the arcing contacts remain closed (Figure 8). Since the main contacts are opening under load, an arc is formed between the arcing contacts. The stationary arcing contact serves to draw the arc away from the main contacts, with the arc being pulled into the arc chutes.

This design serves to extend the life of the contact by protecting the main contacts, which are designed to continuously carry current, but not designed to take the punishment from the arcs.

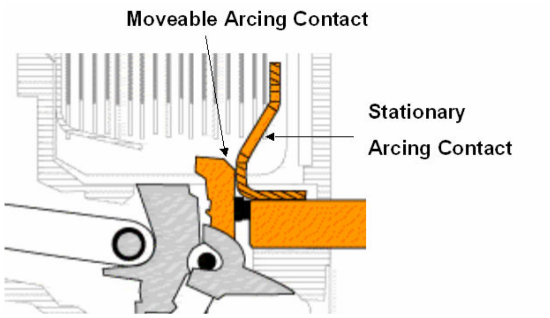

Figure 7 – Main Contacts and Arcing Contacts Closed

Additional criteria:

- Prevent simultaneous closure of normal and emergency source,
- Powered from the live source,
- Convenience to maintain.

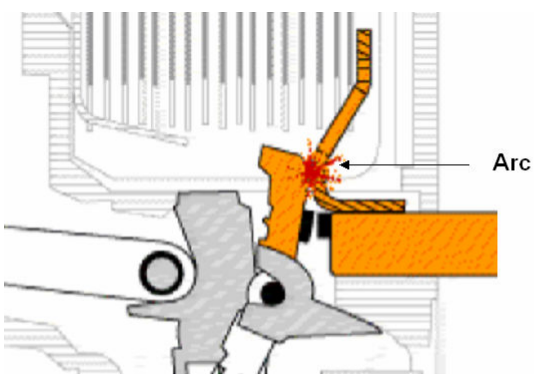

Figure 8 – Main Contacts Open While Arcing Contacts Remain Closed

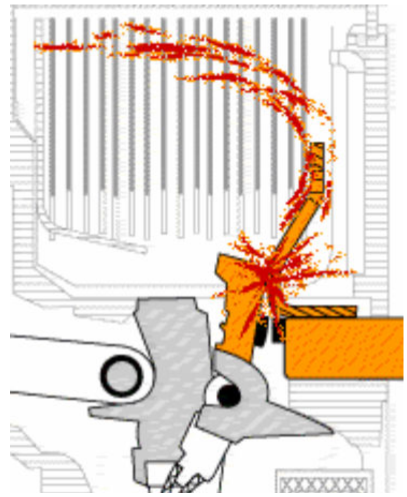

Figure 9 – Arc Being Drawn into the Arc Chutes

3.2. Manual Operating Handles

Manufacturers of ATSs have provided manual operating handles for many years. The reasons for providing a handle for an ATS include:

- *Installation:* For use during installation to manually place the switch in the proper position.
- *Maintenance:* For periodic inspections and maintenance to verify the mechanical operation of the switch and for ease of contact inspection.
- *Emergency Operation:* To switch from a dead source to a live source if the electrical operator has failed.

In the first two cases, the manual operator is used on dead sources. In the third case, it is used to switch from a dead source to a live source.

UL1008 permits an external operating handle or an internal operating handle. The internal handle is designed for maintenance purposes and must be so labeled. When an internal handle is used, contacts must be protected and both mechanical and electrical hazards must be considered. UL clearly states that power should be removed from the unit prior to servicing on all manufacturers internal operators. An internal removable operating handle that is listed by UL in accordance with UL1008 standards for safety should be provided.

3.2.1. Specifications

Some specifications have been issued that add restrictive, unnecessary, and potentially dangerous requirements for manual handles.

The requirements issued state:

- The manual handle shall provide the same contact-to-contact transfer speed as the electrical operator to prevent flashover;
- The manual handle shall be externally operable.

These specifications described are restrictive because they are design features centered on one manufacturer's guide specifications. They are unnecessary for the proper and safe operation of an ATS; and they are potentially dangerous because all safeguards are not considered.

3.2.2. Manual Operation Under Load Dangers

There are many possible dangers present when attempting to conduction manual transfer switch operation while under full load, a few of these are explained below:

- It is possible to close a transfer switch into a generator, which is attempting to crank, thereby forcing the emergency generator source to "bog down" as it attempts to assume full load prior to reaching proper voltage and speed.
- Manually transferring fault currents in excess of switch rating would create a danger for anyone operating the manual handle of any transfer switch.
- Manually operating the switch with overload currents present of six times switch rating unless the contacts are protected in enclosed arc chambers.
- Manual operation by unauthorized personnel could disconnect critical loads.
- Manual operation of a switch that has malfunctioned without first determining the reason for that malfunction and whether manual operation is safe.
- Manually operating the switch without disconnecting the electrical operator, causing the mechanism to drive back against the person operating the switch.

If the handle is external, additional dangers may exist:

- Increased possibility of unauthorized persons operating the switch,
- Possibility of a moving handle (during automatic operation)

injuring someone standing or walking near the switch,

- Complete disregard of the potential hazards, service difficulties and operational problems induced by manual operation.

3.3. Safeguards

The following safeguards are recommended for manual handle transfer switches:

- Fully enclosed arc chambers provide protection to the operator against arcing, and also prevent flashover;
- The handle is long and well isolated from electrical or mechanical hazards;
- Proper instructions and labels are provided on the switch to assure safe operation;
- The handle is designed to operate the product within required UL guidelines.

3.4. Summary

The internal handle, with the proper instructions and safeguards as listed, provides a safe and dependable operating system.

It is recommended that specifications include “provide a manual handle for manual operation of the transfer switch during maintenance.”

It is strongly suggested that operating personnel are made familiar with proper procedures for manual transfer and that all factors be considered before this operation is performed.

The ATS has been designed with operator safety and load protection in mind. External “load break” manual handles on ATSs ignore many aspects of those proven design principles.

4. Controls

Controls serve to make transfer switches “automatic.” In an emergency power system with a generator set as the emergency source of power, ATS controls are designed to detect a power failure of the normal source and to signal the generator set to start. When the generator set reaches the proper voltage and frequency, the controls signal the switch to transfer from the normal source to the generator set. When the normal source is available and ready to supply power again, the controls detect that return and signal the switch to retransfer to the normal source. In order to carry out these functions, the following time delays and components are frequently specified and supplied with the ATS controller:

- Voltage sensing,
- Frequency sensing,
- Time delays,
- Engine control contacts,
- Test switch,
- Communications.

4.1. Voltage Sensing

To detect a power failure, voltage sensing of the normal source is required. Voltage sensing on at least a single phase of the emergency source is also needed to determine its availability. Single phase sensing is used on single-phase sources, while sensing on three-phase systems may be one of the following:

- Single-phase on normal and emergency sources,
- Three-phase on normal source and single-phase on emergency source,
- Three-phase on normal and emergency sources.

Single-phase sensing on a three-phase system would only be recommended in applications where possible loss of a single phase would not cause problems with the connected load equipment.

Controls utilize this voltage sensing capability to determine either an under-voltage or over-voltage condition of the normal and emergency sources.

4.1.1. Under-voltage

ATS controls utilize under-voltage sensors to continuously monitor both the normal source and emergency power sources. Under normal operating conditions, the controller identifies the normal source as the preferred source of power and will not permit the load to be disconnected from both sources simultaneously when either or both are acceptable.

Under-voltage sensing uses two parameters for determination of source condition and required switch action:

1. Pickup setting – The pickup setting determines the voltage that the control will consider acceptable for the transfer switch contacts to close on the source and connect the load.
2. Dropout setting – The dropout (or differential) setting determines the voltage that the control will consider unacceptable and initiate a transfer operation towards the emergency source

The pickup and dropout settings may be fixed or adjustable depending on the control type:

1. If fixed, typically the pickup setting will be 85% of the nominal system voltage and the dropout differential setting will be fixed at 75% of the pickup setting;
2. If adjustable, the pickup setting range is typically 85 to 100% of nominal system voltage and the dropout range is 75 to 98% of the pickup setting.

The under-voltage sensors include a time delay before the controls initiate a time delay start. This time delay allows the control to ignore very brief voltage dips that may result from short-circuit faults and re-closure operation, etc. Under-voltage sensing time delay can either be fixed, typically at 0.5 seconds, or adjustable, typically from 0.1 to 1.0 seconds.

4.1.2. Over-voltage

As with under-voltage, two settings are used for over-voltage sensing:

1. Pickup setting – determines the voltage that the control will consider acceptable for the transfer switch contacts to close

on the source and connect the load;

2. Dropout setting – determines the voltage that the control will consider unacceptable and initiate a transfer operation towards the emergency source.

Again, the pickup and dropout settings may be fixed or adjustable depending on the control type:

- If fixed, typically the pickup setting will be 85% of the nominal system voltage and the dropout differential setting will be fixed at 75% of the pickup setting;
- If adjustable, the dropout setting range is typically 105 to 110% of nominal system voltage while the pickup setting range is typically 103 to 105% of nominal voltage. The pickup setting or "restore" value must be set below the dropout or "fail" setting. Typically, by a minimum of 2% below the dropout value.

The over-voltage sensors also include a time delay before signaling the control to begin the start time delay. This time delay prevents initiation of the start time delay under spurious over-voltage conditions caused by any number of system events such as static, lightning or breaker closures. Typically, this time delay is adjustable from 0.5 to 120 seconds.

4.2. Frequency Sensing

Controls are also equipped to sense the frequency of both the normal and emergency sources.

4.2.1. Normal Source Monitoring and Protection

Provides monitoring and protection based on source 1 frequency set points.

4.2.2. Emergency Source Monitoring and Protection

Provides monitoring and protection based on the source 2 voltage and/or frequency set points.

4.3. Time Delays

Several time delays are provided; the first time delay overrides any momentary normal source outages that would cause false engine starts and switch transfers. This delay must be short enough so that the emergency source can be connected within code required time periods. The typical range is 0 to 6 seconds.

Another time delay is needed to be sure that when the normal source is restored, it is a sustained restoration and ready to assume the load. This delay is normally adjustable from zero to 30 minutes. The controls should bypass this time delay in returning to the normal source if the emergency source fails and the normal source is available.

A time delay is often provided to allow the engine to run unloaded for cooldown before the controls shut it down. In a power failure, it is usually desirable to have the load transferred to the engine generator set as soon as it reaches proper voltage and frequency. However, there are times when it is desired to sequence various transfer switches onto the generator set. Therefore, for these applications, the controls should include a time delay on transfer to emergency that is adjustable from zero to one minute.

4.3.1. Time Delay Normal to Emergency (TDNE)

Provides a time delay when transferring from the normal source to the emergency source. Timing begins when the emergency source becomes available. Permits controlled transfer of the load circuit to the emergency source.

4.3.2. Time Delay Engine Start (TDES)

Provides a time delay of the signal to initiate the engine/generator start cycle in order to override momentary power outages or voltage fluctuations of the normal source.

4.3.3. Time Delay Emergency to Normal (TDEN)

Provides a time delay of the re-transfer operation to permit stabilization of the normal source. Timing begins when the normal source becomes available. If the emergency source fails during timing, then re-transfer is immediate overriding the time delay.

4.3.4. Time Delay Engine Cooldown (TDEC)

Provides a time delay of the signal to initiate the engine/generator stop cycle after the re-transfer operation. This allows the engine/generator to cooldown by running unloaded. Timing begins on completion of the re-transfer cycle.

4.4. Engine Start Contact

Controls must include a contact that signals the engine controls to start when the normal power fails.

4.5. ATS Testing

Periodic testing is necessary to maintain the emergency power system in good condition. Therefore, controls are equipped with a manually operated switch to simulate a normal source failure.

The controls described here are standard and meet most of the application needs for ATSs. A number of other controls are available to handle specific needs:

4.5.1. Test Switch/Pushbutton

ATSs should be provided with a test button that simulates a loss of the normal power source. All programmed time delays (TDNE, TDEN, etc.) will be performed as part of the test. Engine run time of the test is equal to the plant exerciser programmed set point.
All tests are failsafe protected.
If one of the optional test operators is chosen, then the standard test pushbutton is disabled.

Programmable set points include:

- Load or no load testing, or disabled,
- Engine run time is equal to the plant exerciser setting.

4.5.1.1. 2-Position Test Selector Switch (TSS)

Provides a 2-position, maintained contact selector switch marked "Auto" and "Test." The test is a load test and will continue until the TSS is returned to the "Automatic" position. The TSS is failsafe protected.

4.5.1.2. 3-Position Test Selector Switch (TPSS)

Provides a 3-position, maintained contact selector switch marked "Auto," "Test," and "Off." The TPSS is failsafe protected. Transfer switch operation is determined by the switch position. Transfer switch operations are as follows:

- "Auto" — Automatic operation mode;
- "Test" — A Load test is performed until the switch is moved to another position;
- "Off" — The automatic transfer controller and engine start contact are disabled. A white pilot light is provided to indicate that the FPSS is in the "Off" position.

4.5.1.3. 4-Position Test Selector Switch (FPSS)

Provides a 4-position, maintained contact selector switch marked "Auto," "Test," "Engine Start," and "Off." The FPSS is failsafe protected. Transfer switch operation is determined by the switch position. Transfer switch operations are as follows:

- "Auto" — Automatic operation mode;
- "Test" — A Load test is performed until the switch is moved to another position;
- "Engine Start" — A no-Load test is performed until the switch is moved to another position;
- "Off" — The automatic transfer controller and engine start contact are disabled. A white pilot light is provided to indicate that the FPSS is in the "Off" position.

4.6. Communications

Emergency power systems and their associated distribution are vital links within any installation. The ATS is an integral part of many systems. Various means of communicating ATS parameters are available predominately being; annunciator panels and communication devices, which allow the ATS to communicate with a customer's SCADA or "Building Management System (BMS)."

4.6.1. Ethernet

Ethernet is a large, diverse family of frame-based computer networking technologies that operates at many speeds for local area networks (LANs).

For switchgear it provides a way for individuals to remotely monitor and/or control the switchgear with a PC.

4.6.2. Modbus

Modbus is a serial communications protocol published by Modicon for use with its programmable logic controllers (PLCs). Due, in part, to the fact that it is an open protocol and charges no royalties, it has become the standard communications protocol used in industry to connect electronic devices. This protocol allows for communication between multiple devices connected to the same network and is often used to connect a supervisory computer with a remote terminal unit (RTU) in supervisory control and data acquisition (SCADA) systems.

Versions of the Modbus protocol exist for serial port (e.g. Modbus RTU) and Ethernet (e.g. Modbus TCP). Some ATS products include optional Modbus RTU network cards which reside on the back of the controller board and are part of the controller assembly. The purpose of this card is to allow the controller to be available on a Modbus network as a slave device. This allows a master device, such as a programmable logic controller (PLC), to obtain information from the controller and have that information available for control, data acquisition and monitoring.

Every Modbus network consists of one master device and at least one slave device. All devices on the network are daisy-chained using a twisted pair cable, with each slave device assigned a unique address which is a factory default for each Modbus card. This address enables the master to distinguish between the various slaves on the network. It also allows the master device to send a query command to the addressed slave. When the addressed slave receives this command it will send back an appropriate response to the master.

LonWorks is a control network that is used in a myriad of applications, including factory automation, process control, building networks and vehicle networks. LonWorks allows up to 32,000 devices in a peer-to-peer configuration and also provides a complete set of network management functions. The LonWorks data link is a proprietary form of CSMA/CD over twisted pair, coax and fiber. Some manufacturers produce adapters which allow connection to the Internet via Ethernet or dial up modems.

Figure 10 – ATS Remote Monitoring Software Screens

4.6.3. Remote Monitoring and Control

There are two types of remote monitoring systems which are typically used: isolated monitoring and system/group monitoring.

Isolated monitoring systems are systems which monitor a single product. These systems are variable dependant on individual manufacturers.

The system/group monitoring systems most commonly used are the Building Management System (BMS) and Supervisory Control and Data Acquisition (SCADA) described below.

Building Management System

Building Management System (BMS) is a computer software program, usually configured in a hierarchical manner, to control, monitor and manage all the equipment installed in the building. Customers frequently integrate the monitoring and control of their emergency power system components with their BMS.

To accomplish this integration, a means by which to communicate electric power systems (EPS) parameters to their system is required. Typically a dedicated PLC on the switchgear master controls is used for integrating with the BMS.

SCADA

Supervisory Control and Data Acquisition (SCADA) systems are typically used to perform data collection and control at the supervisory level. The supervisory control system is a system that is placed on top of a real time control system to control a process that is external to the SCADA system.

The SCADA system can utilize either the Modbus connection or the Ethernet connection to monitor and control the switchgear and ATS.

4.6.4. Annunciator Panels

With various transfer switches scattered throughout a facility, a remote annunciator panel provides the simplest form of remote indication and control of multiple ATSs. These panels are available from various manufacturers in standard and custom configurations with a host of available options. These options include the ability to remotely test, monitor the position, indicate source availability and bypass time delays for individual Transfer Switches.

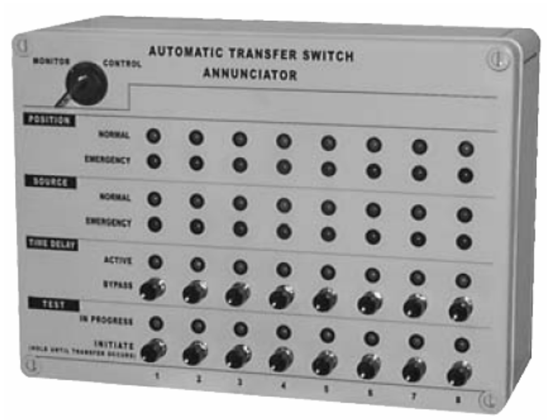

Figure 11 – Remote Annunciator

5. Motor Load Transfer

Some loads, especially large three-phase motors greater than 50 HP, receive severe mechanical stress if power is transferred out of phase while the motor is still rotating. Also, back EMF generated by a motor can result in over currents that can blow fuses or trip circuit breakers.

5.1.1. Motor Protection Alternatives

Four different control methods can be employed to address these problems:

5.1.1.1. In-Phase Monitor

This feature compares the phase angle between both sources of power and prevents transfer until the two are approximately in phase (within a self adjusting range). When the two voltages are within the desired phase angle and approaching the zero phase angle, the in-phase monitor signals the transfer switch to operate and reconnection of the load takes place. The in-phase monitor, used with transfer switches that operate within 10 cycles can be used to safely transfer motors without exceeding normal starting currents.

Advantages:

The advantages of using an in-phase monitor when transferring large motor and/or transformer loads are:

- Permits the motor to continue to run with little disturbance to the electrical system and the process that is being controlled by the motor;
- A standard double throw transfer switch can be used with the addition of the in-phase monitor.

5.1.1.2. Motor Load Disconnect Control Circuit

Motor disconnect control circuits may also be used to transfer motor loads. These circuits should not be used if the motors cannot be deenergized, even momentarily, during the transfer of power sources.

This load control disconnects a large motor via its control circuit for an adjustable period of time prior to transfer in either direction.

For switching multiple motors, the motor disconnect contact with staged restart disconnects the motors prior to transfer and brings them back on line sequentially.

A62 Sequential Motor Load Disconnect Circuit: Normally closed set of auxiliary contacts that open 0-60 seconds prior to transfer, after transfer, or both in either direction then re-close in timed sequence after transfer.

5.1.1.3. Timed Center-Off Position ("Delayed Transition")

When transferring large motors, UPS systems and/or transformers between two sources of power that have the potential to be unsynchronized, consideration must be given to the elimination or reduction of transients. These may occur when loads are disconnected from the first power source and immediately connected to the second source.

When a running motor is suddenly disconnected from its power source, the residual voltage developed due to generator action will decrease in amplitude and frequency as the motor slows down. Depending on the type number and application of the motors involved, the decaying action may take a considerable amount of time. Similarly when a transformer is disconnected from the line, time is required for its magnetic field to collapse. Release of stored energy in the transformer generates a surge even though the two power sources are in synchronism when a transfer is initiated. The transient caused by the momentary high current flow described above can exceed the instantaneous trip settings of protective devices in the system and can be severe enough to trip circuit breakers, cause damage to motor shafts, couplings, etc.

Another solution to this problem is to introduce a delay in the transition between two live sources. Transfer switches equipped with a delayed transition feature provide an adjustable time delay after the opening of the closed contacts and before the closing of the open contacts for transferring large motor and/or transformer loads. This delayed transition time allows for motors to coast down and transformer fields to decay, thus allowing inductive loads to be re-energized after transfer with only normal inrush starting currents. The delayed transition design is an effective method of handling these applications and can be utilized as an alternative to a standard transfer switch equipped with an in-phase monitor.

Delayed transition switches can also be used for load shedding of selected circuits or other applications which require a means to disconnect the load from either source.

The delayed transition transfer switch is ideally suited for pumping stations, sewage treatment plants, hospital X-ray equipment, or wherever the bulk of the load being controlled consists of large motors and/or transformers. Further, many UPS manufacturers strongly recommend the use of delayed transition type transfer switches to ensure proper operation and sequencing of their equipment. The delayed transition feature allows a typical UPS system sufficient delay to recognize a power failure and transfer to batteries, acknowledge the return of input power and allow the rectifier to walk-on to the new source, reducing any transfer anomalies.

Advantages:

The advantages of using delayed transition when transferring large motor and/or transformer loads are:

- Consistent operation under all conditions, including manual (pushbutton) operation;
- Operation is totally independent of the synchronism of the power sources, eliminating the need for in-phase monitors or extensive motor disconnect control wiring between the transfer switch and motor control centers;
- The delayed transition function adapts itself for use in multiple generator systems and paralleling systems to permit load shedding by switching the main contacts to a center-off or disconnected position;
- Allows typical UPS systems to function properly while switching between line input sources.

5.1.1.4. Description and Operation

The delayed transition transfer switch functions as discussed below:

Upon failure or reduction of the normal source, and the availability of the emergency source, the drive solenoid is energized and pulls the main contacts out of the normal position and locks them mechanically in the open transition position.

An adjustable time delay is then energized. After the preset time has elapsed, the drive solenoid is energized and pulls the main contacts out of the transition position and locks them mechanically in the emergency closed position. The emergency power source is now feeding the load. When the voltage sensing detects the restoration of the normal source for a predetermined time period, the drive solenoid is energized and pulls the main contacts from the emergency position and locks them mechanically in the open transition position. After the preset time delay has elapsed, the drive solenoid is energized and pulls the main contacts out of the open transition position and locks them mechanically in the normal closed position. The normal power source is now feeding the load.

5.1.1.5. Momentary Paralleling

Closed transition switches combine delayed transition operation during a source failure with a control system that allows momentary paralleling (100 ms) of two acceptable sources, thereby limiting the impact of transfer on the load. Reference the section on closed transition transfer (Section 7.3.3) for further details.

5.1.1.6. Motor Load Shedding Delayed Reconnection

Motor load shedding delayed reconnection refers to methods used to prevent overloading the emergency source during a normal power outage. On-site generator sets are often used as the emergency source of power. Such generator sets often have limited capability to supply the total inrush and starting currents of the connected load. For economical purposes, generator sets are commonly sized to provide full load current plus a limited motor starting capability. In such cases, it becomes essential to delay reconnection of some of the loads when transferring from the normal power source to the on-site generator.

Article 517 of the NEC requires that the equipment system load (primarily motor load) transfer switches in hospitals be equipped with time delay relays that will delay transfer of the connected load to the generator set. The purpose is to assure that the more important emergency system loads are connected first and established within ten seconds of failure. The transfer switches feeding the motors are then sequentially transferred to the generator set. Another reason for load shedding is the need to "power down" certain loads, such as those utilizing SCRs, to avoid damage to, or failure of, such components during transfer. Following are various solutions in use today to help solve these problems by adding circuit features to transfer switches.

Emergency source overloading prevention methods are:

- Transfer switches with individual time delay circuits on transfer to emergency;
- Transfer switches with signal circuit for definite disconnection of a single load prior to transfer and reconnection after transfer;
- Transfer switches as indicated in the previous point, but with multi-signal circuits to sequence several loads onto the generator.

5.1.2. Electronic Variable Frequency Drives (VFDs)

Special consideration should be given to systems that utilize VFDs to control motor operation. These electronic devices often consist of SCR assemblies to change the voltage and frequency applied to the motor to vary its torque and speed.

With some VFDs, interruption of the input, whether it is caused by transfer switch operation or other momentary power outages, causes the device to see a low voltage input. To maintain motor speed, some control sensors immediately change the conduction angle of the controlling SCRs to compensate for low line condition. The result is that upon immediate reapplication of power, the controlling SCRs are turned fully on, causing a severe current inrush. This current inrush is of such a magnitude that protective devices such as fuses can blow, or the SCRs themselves can be irreparably damaged.

This particular problem can be only partly solved by conventional in-phase transfer or other load disconnect arrangements, because other extraneous interruptions of power will also confuse the VFD voltage sensing circuitry.

Some systems include high speed voltage sensing circuitry that detects momentary power outages and shuts down the VFD entirely. Upon reapplication of voltage, the SCRs go from an off condition to a soft start current-limiting startup that automatically protects the solid state switching devices.

When other provisions are lacking, the motor load disconnect control circuit can be considered for transfer of SCR controlled loads for the VFDs and other loads such as used by communications companies. The contact, which must be integrated by the VFD manufacturer, simply signals the SCR control to "power down" before transfer and permits a soft restart after transfer. As indicated above, such controls may protect the SCRs during a power interruption when the transfer switch is operating, but offer no protection when the power interruption is extraneous to the transfer switch.

6. Switching the Neutral Conductor

Automatic transfer and bypass switches are made in two-, three- and four- pole versions. The two- and three- pole varieties are generally understood as to usage and ampere/voltage rating of the load carrying contacts. The use of the fourth pole to switch the neutral is less commonly understood. Questions of when to switch the neutral or not in standby power systems must be answered in light of NEC 230-95 and NFPA 70-2005. These standards refer to ground fault protection requirements.

The safety and advantages of Ground Fault Protection (GFP) can only be realized if proper grounding and consideration of neutral switching is taken. When neutral switching is dictated, then the determination of fourth pole contact ratings, synchronization, reliability and integration with GFP must be taken into account. Since April 1989 UL has required more stringent test conformance of the neutral pole and this has a bearing on the designer's choices for standby power systems.

These switches are made in two, three- and four-pole versions. The use of a transfer switch in traditional two- or three-pole applications, as pertains to automatic voltage sensing of normal source failure and the commands to start and cut over to a standby source, is straightforward. Typically these installations are two-pole for single phase and three-pole for three phase circuits. The neutral may or may not require switching which would dictate an additional pole on the transfer switch. The neutral and its relation to grounding, in terms of safety to personnel and equipment for standby systems, must first be understood.

6.1.1. Grounded vs. Ungrounded Neutrals

The NEC differentiates between system and equipment grounding. A system ground (Figure 12) is a connection to ground from one of the current-carrying conductors of a distribution circuit or of an interior wiring scheme.

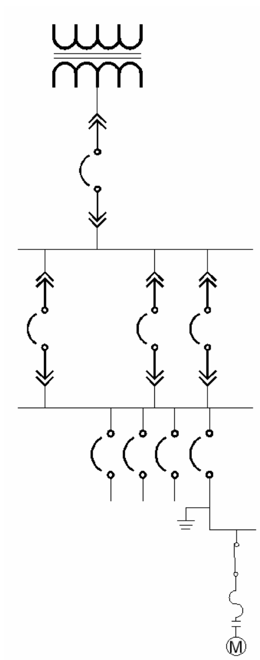

Figure 12 – System Ground on an Ungrounded System

An equipment ground (Figure 13) is a connection to ground from one or more of the non-current-carrying metal parts of the wiring system or of apparatus connected to the system. As used in this sense, the term "equipment" includes all such metal parts as metal conduits, metal raceways, metal armor of cables, outlet boxes, cabinets, switch boxes, motor frames and metal enclosures of motor controllers.

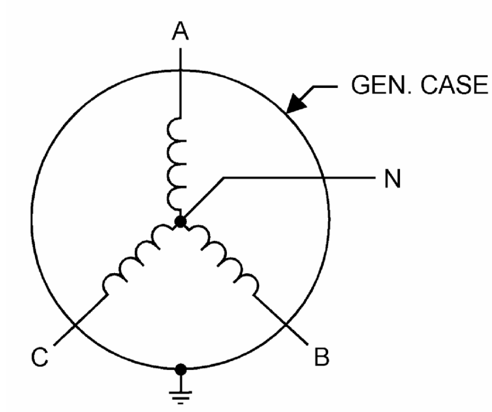

Figure 13 – Equipment Ground Ungrounded Neutral

A system neutral ground (Figure 14) is a connection to ground from the neutral point or points of a circuit, transformer, rotating machine or system. The neutral point of a system is that point which has the same potential as the point of junction of a group of equal non-reactive resistances if connected at their free ends to the appropriate main terminals or lines of the system.

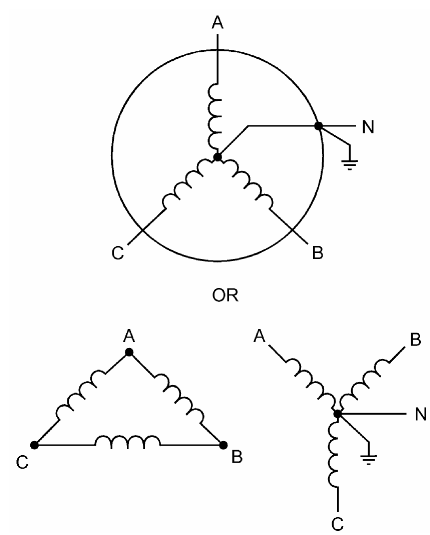

Figure 14 – System Neutral Ground

An ungrounded system (Figure 15) features no intentional connection between the system conductors and ground. What is easily forgotten though is the capacitive coupling that always exists between system conductors and ground. Because of the danger to personnel and possible damage to equipment and property, should there be leakage to ground due to shorts or high impedance paths, the NEC decrees that certain grounding practices and detection of these faults be designed into systems.

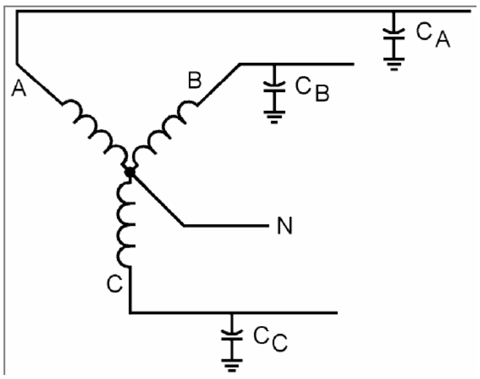

Figure 15 – Ungrounded System Capacitively Coupled to Ground

The utilities generally provide power to large users via three phase grounded wye distribution. The power transformer feeding the user will have its neutral grounded. For a system having a neutral conductor that is not grounded, the possibility of destructive transient voltages appearing from line to ground during switching of a circuit having a line to ground fault is very likely (Figure 16).

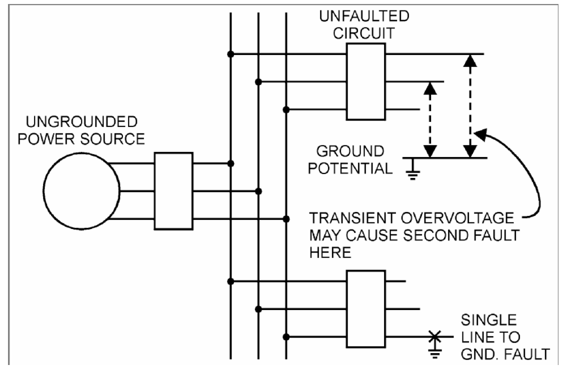

Figure 16 – Transient Overvoltage Due to Ground Fault Interruption on Ungrounded System (May Cause Other Faults to Occur on System)

In addition, an ungrounded neutral system developing a fault to ground may go unnoticed until a second ground fault causes a line-to-line fault which can be of major proportions (Figure 17).

These ungrounded systems are designed into critical industrial processes that cannot afford tripping of protective devices should a ground fault develop. Such a condition could shut down operations or parts of processes that could result in an explosion or loss of product being processed.

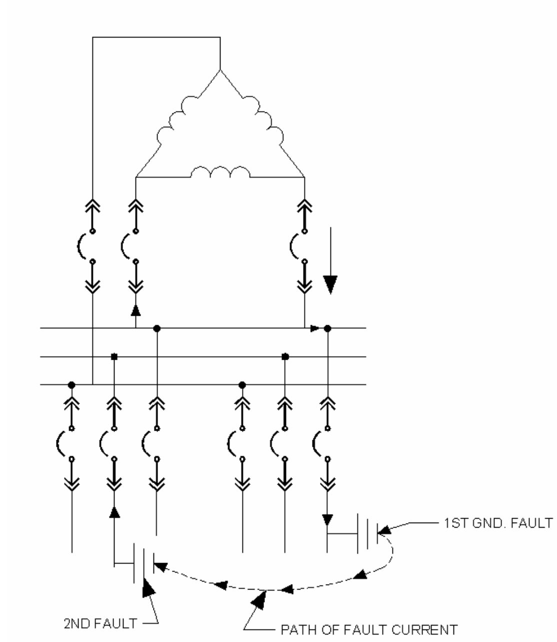

Figure 17 – Undergrounded Neutral System Developing Second Fault to Ground

A system featuring neutral grounding has many advantages over the ungrounded system. That is:

- Greater safety for personnel and equipment,
- Increased service reliability,
- Lower operating and maintenance expense,
- Reduced magnitude transients,
- Simplified ground-fault location.

The NEC requires that ground fault protection must be used for all solidly grounded wye services. This requirement first appeared in the NEC in 1971 (230-95). It stated, "Ground fault protection of equipment shall be provided for solidly grounded wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase to phase for each service disconnecting means rated 1000 amperes or more" (Figure 18).

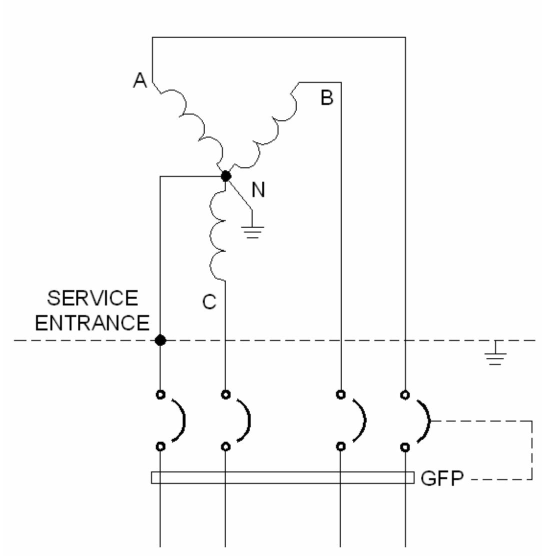

Figure 18 – Source Featuring Grounded Neutral at Transformer and Service Entrance with GFP Sensor

The reason behind this requirement was awareness that sustained arcing on grounded 480Y/277 volt systems could be very damaging.

The selection of 1000 amperes or more for ground fault protection was made with the belief that smaller overcurrent devices with long trip times of 1000 amperes or less would probably clear an arcing ground fault in sufficient time to limit damage. A designer could under this rule, choose as many as six 800 amperes mains in a 480Y/277 volt switchboard (4800 amps of service) without having to install ground fault protection.

Ground fault protection equipment is designed to detect phase to ground faults ignoring overloads and phase-to-phase faults. Three methods of detection are employed:

- Zero Sequence – detects vector unbalance of current sum in each phase and the neutral. Outputs if not zero;
- Residual Connected – uses 3 or 4 CTs and 4 time relays. Any leakage to ground will output a signal;
- Source Ground – detects current flow through system grounding conductor, which is connected between neutral and ground.

None of these methods are totally without problems. Proper operation requires that detection will monitor all fault currents to ground. Should there be multiple grounding of the neutral, it is possible that proper operation of the GFP device will not monitor the total fault (Figure 19).

Therefore, it is important to ensure that grounding of the neutral not take place at multiple locations so as to create unintended paths and defeat the GFP sensor. The NEC further limits neutral grounding via the "separately derived system" rule. That is, a system source such as a transformer or a generator can have its neutral grounded at only one place. The correct place to ground the service neutral is at the main panelboard or switchboard. It is not permitted to be grounded at other points.

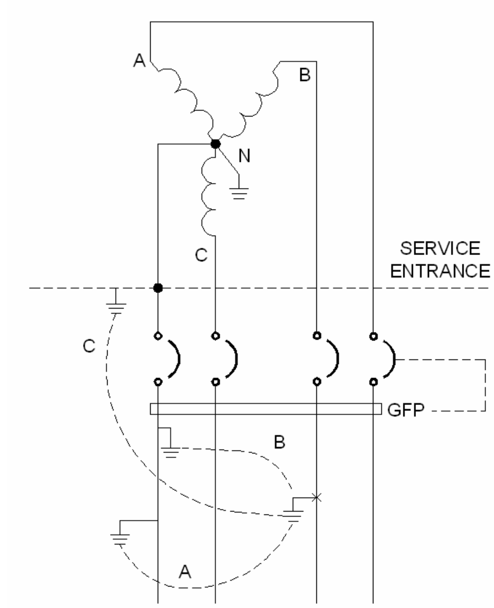

Figure 19 – Multiple Grounding of Neutral Allows Fault Current to Flow Back Through Neutral via Paths A&B (Flow via C is Outside GFP Sensor)

6.1.2. Three Pole Transfer Switches

A correctly grounded standby generator system including the transfer switch is shown in Figure 20.

Note that a three-pole transfer switch is used and the generator set does not have its neutral grounded at the generator although the housing is grounded.

Should a fault develop to ground only one path exists and the GFP sensor would signal the unbalance. Since the neutral is common to both the normal and standby sources, the generator is not considered separately derived. Under this scheme the neutral is not grounded at the housing.

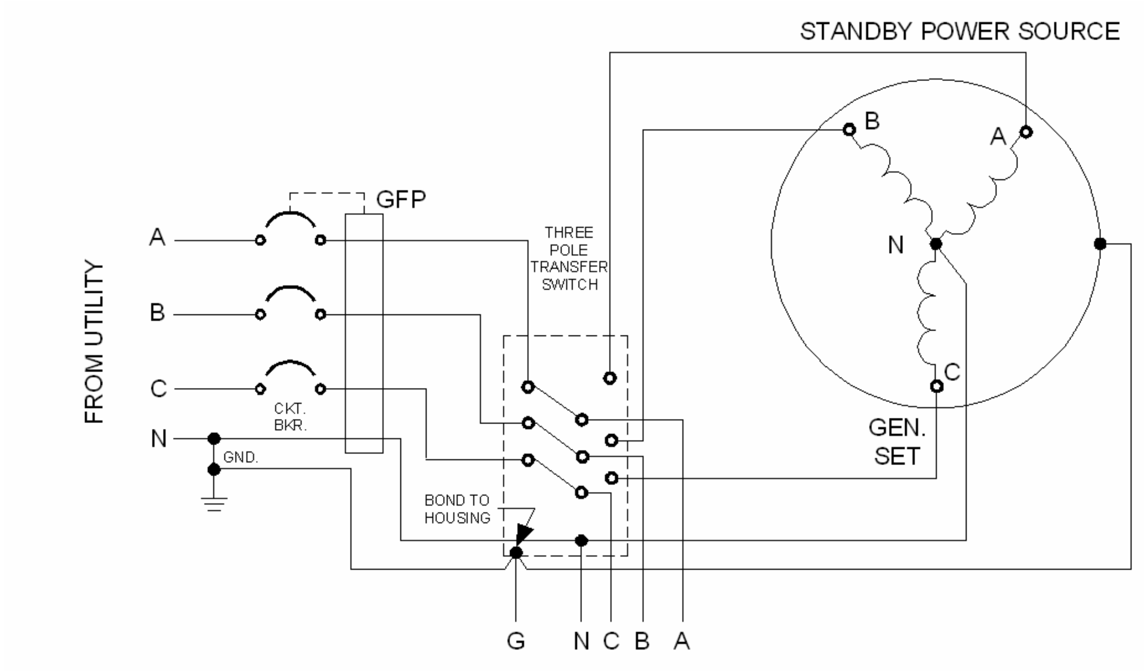

Figure 20 – Correctly Grounded Standby Power Source

Figure 21 depicts the division of current that would occur in the event of a ground fault. Some portion would return outside the GFP sensor.

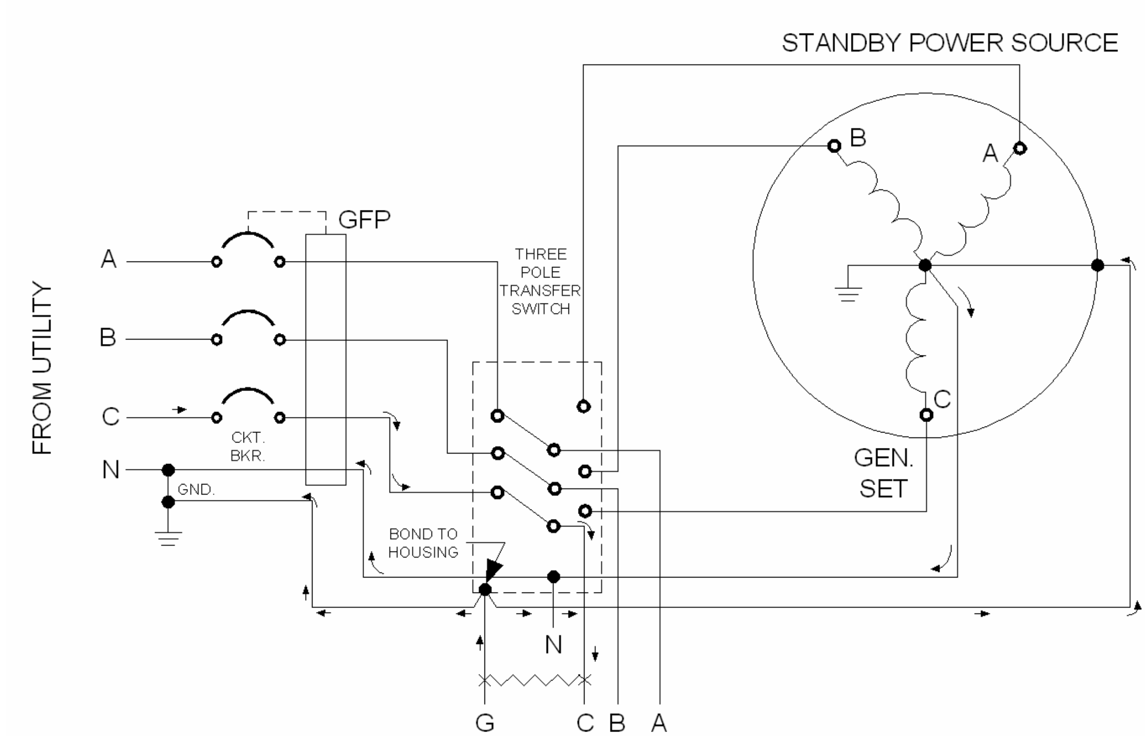

Figure 21 – Generator Set Grounded to Neutral at Housing Neutral Bus Isolated from Housing of Transfer Switch

Yet another problem with a generator neutral ground is shown in Figure 22. In this case the neutral current can divide and return via the generator set ground path. This also will fool the GFP sensor into monitoring less fault current than may be flowing.

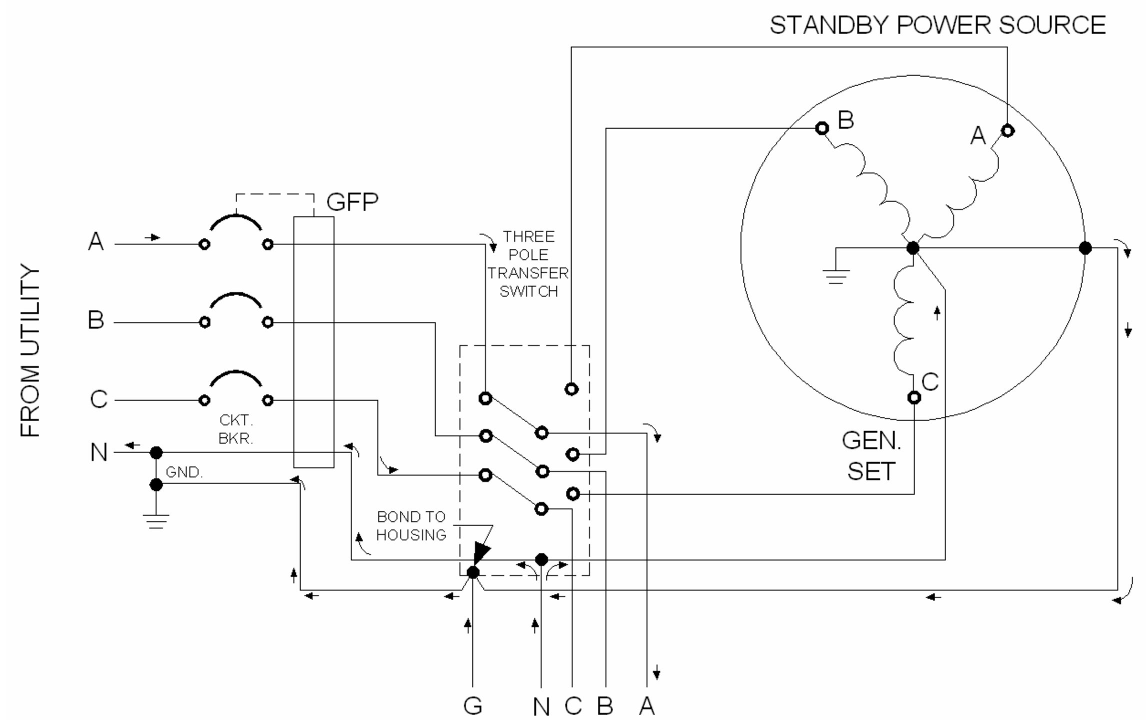

Figure 22 – Neutral Current Returning to Ground (Partial Current Outside GFP)

In all of the previous cases, the three-pole transfer switch must have contact structures that are able to withstand the fault currents for the time that is taken before sensing and the protective devices clear the circuit. Transfer switches that are properly designed will have relatively high withstand and close into fault current values for this demanding work. Also in the above cases the neutral current carrying line was solidly connected and not switched. Should the designer want to ground the generator and still adhere to code and avoid the problems of split return paths and improper GFP sensing the use of a four-pole transfer switch is called for.

6.1.3. Four Pole Transfer Switches

Four pole switches are employed to ensure that the generator can be grounded without compromising the NEC. That is, the generator set can be wired as a separately derived system by grounding the neutral at the generator set as long as the neutral is no longer solid through the transfer switch. This of course infers that neutral be switched at the same time as the phases. This scheme will also insure GFP operation as intended. Figure 23 shows a four-pole transfer switch wired with a generator set having its neutral grounded at the housing. In this wiring the neutral return path is deliberately open for ground return currents by the transfer switch contacts. This will also avoid nuisance tripping in the case of an unbalanced load. In effect, the generator set is now completely isolated from the utility service and presents an effective and safe alternative to solid neutral lines.

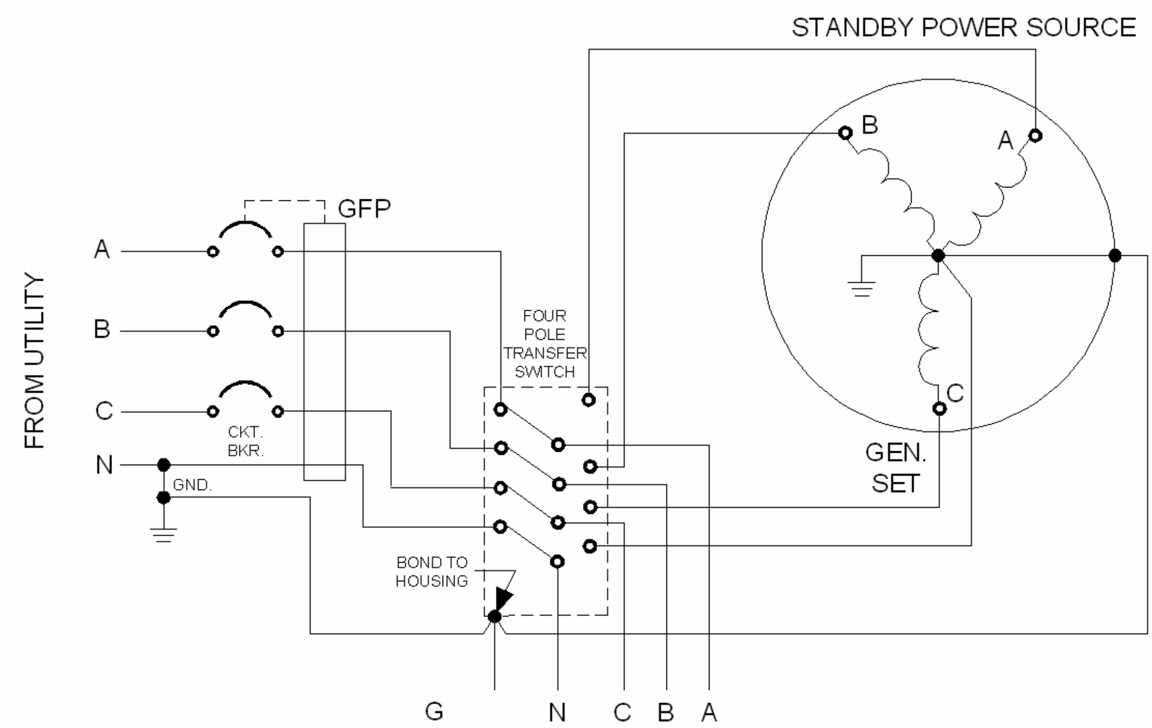

Figure 23 – Use of a 4 Pole Transfer Switch to Permit Grounding of Generator Set at Site

A designer has the tools to now configure a standby system as either separately derived or not. If the system needs are for not grounding the generator set at its site then a three-pole transfer switch with a solid neutral should be employed. If the generator set needs to be grounded at its site then a four-pole transfer switch must be designed into the system. This will ensure that the neutral is switched, isolating the normal or utility supply.

Lastly, should the designer decide to switch the neutral, consideration to contact ratings and performance should be taken into account.

6.1.4. Fourth Pole and UL Requirements

As of April 1989, UL 1008 required that the fourth pole of a transfer switch be tested and proven to have ratings equal to its phase contacts if not of the same construction. And that bus spacing is closer to line than its line-to-line spacing or it has a different means of support for its neutral bus. That means that the neutral contact must be capable of withstand and close into fault ratings at least equal to the phase contacts. The fact is not all transfer switches employing a fourth pole are constructed in like fashion.

There exist four pole switches that utilize contacts:

- Of different amperage (lower) capacity than the phases,
- That do not actuate by the same means as the phase contacts,
- That have bus supports differing from the phase supports,
- That have bus structures with closer spacing than phase to phase spacing,
- That have synchronizing characteristics differing from phase contact make-break timing.

Since all transfer switches must comply with and meet the requirements for UL 1008, a designer must examine the ratings and specifications of a four-pole transfer switch should the system call for switching the neutral.

At a minimum, the designer should ensure that all four poles are equally rated as to carrying, withstand, close into fault currents and voltage.

The designer should also ascertain that bus supports, spacings, and actuating means are identical for all contacts. The aspect of actuating means can be critical.

If all contacts are actuated by a common shaft, there can be no question of a neutral never having been switched while the phases were. There are switches that have fourth pole contacts actuated by means other than the main phase contact shaft. Interesting results are obtained by transferring the phases to standby power and leaving the neutral connected to the normal power source.

There exists some debate over synchronizing the timing of the fourth pole. For those transfer switches having all contacts actuated by a common shaft, the neutral will swing in harmony with the phase contacts. In fact, if the neutral leads the phase contacts by an amount to ensure make first, break last, then the possibility of transient voltages during switching is diminished or eliminated.

For those switches employing a separate actuating means for the neutral, the possibility of timing differences are much greater. These switches employ the overlapping contact arrangement, which adds to complexity. Four-pole transfer switches with common shafts change position rapidly enough to minimize any currents due to transients.

Although the subject of another discussion, the more recent attention to third harmonic current appearing on the neutral and its attendant emphasis on having greater contact capability, the need for reliable fourth pole operation is even more pronounced.

7. Sizing Automatic Transfer Switches

Serious attention to, and careful selection of, an ATS is important to ensure maximum reliability and adequate capability under both normal and emergency conditions.

The main points to be considered are as follows:

- Loads,
- Voltage rating,
- Continuous current rating,
- Overload and fault current withstand ratings,
- Type of overcurrent protective device ahead of transfer switch.

7.1.1. Loads

Loads, as applied to ATSs, are classified by UL 1008, as (1) total system loads, (2) motor load, (3) electric discharge lamp loads, (4) resistive loads, (5) incandescent lamp loads.

UL requires marking of transfer switches to indicate the type of load they are capable of handling. The marking total systems loads indicates that the transfer switch can be used for any combination of the loads described above under (2) through (5). However, the incandescent load shall not exceed 30% of the total load unless the transfer switch is specifically marked as suitable to transfer a higher percentage of incandescent lamps. Most transfer switches are rated for transfer of total system loads, though some may be marked resistance only, tungsten only, etc. or a combination of these markings. The burden on the system designer is lessened when he chooses switches listed and rated for total system loads.

7.1.2. Voltage Rating

An ATS is unique in the electrical distribution system in that it is one of the few electrical devices that may have two unsynchronized power sources connected to it. This means that the voltages impressed on the insulation may actually be as high as 960 volts on a 480-volt ac system. A properly designed transfer switch will provide sufficient spacings and insulation to meet these increased voltage stresses.

For this reason, the spacings in transfer switches should not be less than those shown in Table 22.1 of UL 1008, regardless of what type of component may be used as part of the transfer switch. For the purposes of this guide, the voltage ratings will be limited to low voltage applications where transfer switches are rated 600 volts or less. Common ac voltage ratings of ATSs are typically 120, 208, 240, 480 or 600 volts, single or three-phase. Standard frequencies are 50 or 60 hertz.

Transfer switches may also be provided for other voltages, when required.

7.1.3. Solid or Switched Neutral

For three phase applications, it is necessary to choose between three pole and four pole transfer switches.

Three pole switches represent a solid neutral where four pole switches represent a switched neutral. Two pole transfer switches are typically used for single-phase applications. For more information see section 6

7.1.4. Continuous Current Rating

An ATS current rating is determined very simply by adding up the total amps required; i.e. lights, heating, and motors. When sizing an ATS, motor full load currents only are considered.

Momentary surges caused by loads such as lighting or motors can be ignored. Select a transfer switch rating that is either equal to or greater than the calculated continuous current and rated for the class of connected load (i.e. tungsten lamp). Sometimes it is desirable to select a size of transfer switch, which is the same as the overcurrent device ahead of it on the normal side. Although this many not be necessary, it is a convenience which will allow for the addition of future loads while remaining within the capacity of the system.

7.1.4.1. Example

Select an ATS for use in a three-phase, 480-volt, 60 Hz system for use with the following three-phase balanced load.

- 300 kW lighting load,
- 450 kW heating load,
- 200 hp motor load.

Select a transfer switch with a rating closest to, but greater than the total load current. In this example, a 1200-amp transfer switch rated 480 volts would be selected. In addition the power factor of the motor is assumed to be .85 and the efficiency is assumed to be .90.

$$\begin{matrix} Motor \\ FullLoad \\ Current \end{matrix} = \frac{hp \times 746}{PF \times EFF \times V \times \bar{3}}$$

$$I = \frac{kW \times 1000}{V \times \bar{3} \times power\_factor}$$

$$300kW\_lightning\_load - I = \frac{300x1000}{480x1.732x1.0} = 360amps$$

$$450kW\_lightning\_load - I = \frac{450x1000}{480x1.732x1.0} = 541amps$$

$$200hp\_motor\_load - I = \frac{200x746}{.85x.9x480x\sqrt{3}} = 235amps$$

$$Total\_Load = 1136amps$$

7.1.5. Overload and Fault Current Withstand Ratings

The protective device within the service entrance switchgear on the normal source (circuit breaker or fuse) protects the downstream apparatus, including the ATS. However, if a fault condition develops between the ATS and the load, the ATS could be required to handle currents well beyond its continuous rating.

Under a fault condition when the switch closed and on normal service, an ATS be required to withstand the energy let the normal service protective device while device interrupts the fault. The maximum current of an ATS in this fault condition called the withstand rating. To obtain a withstand rating; a higher continuous duty rating transfer switch can be used.

7.1.6. Overcurrent Protection

Since transfer switches are often subjected to currents of short duration exceeding the continuous duty rating, the ability of the transfer switch to handle higher currents is measured by its overload and withstand current ratings.

The overload rating refers to the ability of a transfer switch to handle normal inrush currents encountered in switching lighting, transformer, and motor loads. Generally an ATS should have a minimum overload rating 15 times the continuous duty rating for .5 second. The withstand current rating pertains to the ability of an ATS to withstand the magnetic and thermal stresses of high fault currents until the fault is cleared by an overcurrent protective device. The overcurrent protective device is usually located external to the transfer switch although there are transfer switches that do include integral overcurrent protection. To differentiate between the two, one recognized standard defines the following type designation:

Transfer switch; Type A means an ATS that does not employ integral overcurrent devices

Transfer switch, Type B means an ATS that employs integral overcurrent devices.

UL 1008 includes minimum requirements for withstand current ratings.

For a sample withstand current rating see Section 12.2.

7.2. Enclosure Ratings

The National Electric Manufacturers Association (NEMA) provides standards for enclosures to ensure safe operation under various conditions. Two major categories of classification are for switchgear in non-hazardous locations and those in hazardous locations.

7.2.1. Non-Hazardous Locations

In non-hazardous locations the specific enclosure types, their applications, and the environmental conditions they are designed to protect against, when completely and properly installed, are as follows (see Figure 24 and Figure 25):

Type 1 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts and to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt).

Type 1A is similar to Type 1, but also includes gasketing material. Type 1A is not officially recognized but is often included in specifications.

Type 2 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 3 Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and to remain undamaged by the external formation of ice on the enclosure.

Type 3R Identical to Type 3 except Type 3R does not protect against ingress of solid foreign objects and may be ventilated.

Type 3S Identical to Type 3 with additional protection against sleet, ensuring the external mechanism(s) remain operable when ice laden.

Type 3X Identical to Type 3 with an additional level of protection against corrosion and against the external formation of ice on the enclosure.

Type 3RX Identical to Type 3 except Type 3RX does not protect against ingress of solid foreign objects, may be ventilated, and provides an additional level of protection against corrosion and against the external formation of ice on the enclosure.

Type 3SX Identical to Type 3 but also provides additional protection against corrosion and sleet, ensuring the external mechanism(s) remain operable when ice laden.

Type 4 Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose directed water); and to remain undamaged by the external formation of ice on the enclosure.

Type 4X Identical to Type 4 but also provides an additional level of protection against corrosion (usually by incorporating stainless steel or nonmetallic composites) and against the external formation of ice on the enclosure.

Type 5 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and settling airborne dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 6 Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose-directed water and the entry of water during occasional temporary submersion at a limited depth); and to remain undamaged by the external formation of ice on the enclosure.

Type 6P Identical to Type 6 but also provides an additional level of protection against corrosion, ingress of water (occasional prolonged submersion), and protection against the external formation of ice on the enclosure.

Type 12 Enclosures constructed without knockouts for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 12K Identical to Type 12 with the addition of being constructed with knockouts.

Type 13 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection to the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against the spraying, splashing, and seepage of oil and non-corrosive coolants.

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	1 *	2 *	4	4X	5	6	6P	12	12K	13
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (falling	X	X	X	X	X	X	X	X	X	X
Ingress of water (Dripping and light splashing)	...	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects	...	...	X	X	...	X	X	X	X	X
Ingress of solid foreign objects (Settling airborne dust, lint, fibers, and flyings **)	...	...	X	X	X	X	X	X	X	X
Ingress of water (Hosedown and splashing water)	...	...	X	X	...	X	X	...	...	...
Oil and coolant seepage	...	...	...	..	...	...	...	X	X	X
Oil or coolant spraying and splashing	...	...	...	...	...	...	...	...	...	X
Corrosive agents	...	...	...	X	...	...	X	...	...	...
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	X	X	...	...	...
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	X	...	...	...

* These enclosures may be ventilated.

** These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.

Figure 24 – Comparison of Specific Applications of Enclosures for Indoor Non-Hazardous Locations (NEMA 250-2003)

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	3	3X	3R*	3RX*	3S	3S X	4	4X	6	6P
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of water (Rain, snow, and sleet **)	X	X	X	X	X	X	X	X	X	X
Sleet ***	...	...	...	...	X	X	...	...	...	...
Ingress of solid foreign objects (Windblown dust, lint, fibers, and flyings)	X	X	...	...	X	X	X	X	X	X
Ingress of water (Hosedown)	...	...	...	...	...	...	X	X	X	X
Corrosive agents	...	X	...	X	...	X	...	X	...	X
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	...	...	...	X	X
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	...	...	...	X
* These enclosures may be ventilated.										
** External operating mechanisms are not required to be operable when the enclosure is ice covered.										
*** External operating mechanisms are operable when the enclosure is ice covered.										

Figure 25 – Comparison of Specific Applications of Enclosures for Outdoor Non-Hazardous Locations (NEMA 250-2003)

7.2.2. Hazardous Locations

Manufacturers who specialize in hazardous location equipment should be used for consultation when selecting equipment for hazardous locations.

In hazardous locations, when completely and properly installed and maintained, Type 7 and 10 enclosures are designed to contain an internal explosion without causing an external hazard. Type 8 enclosures are designed to prevent combustion through the use of oil-immersed equipment. Type 9 enclosures are designed to prevent the ignition of combustible dust.

Type 7 Enclosures constructed for indoor use in hazardous (classified) locations classified as Class I, Division 1, Groups A, B, C, or D as defined in NFPA 70.

Type 8 Enclosures constructed for either indoor or outdoor use in hazardous (classified) locations that is classified as Class I, Division 1, Groups A, B, C, and D as defined in NFPA 70.

Type 9 Enclosures constructed for indoor use in hazardous (classified) locations classified as Class II, Division 1, Groups E, F, or G as defined in NFPA 70.

Type 10 Enclosures constructed to meet the requirements of the Mine Safety and Health Administration, 30 CFR, Part 18.

Figure 26 summarizes the requirements for enclosures in hazardous locations.

If the enclosure in a hazardous location is to be outdoors or additional protection is needed from Figure 24 or Figure 25, a combination-type enclosure is needed

.

Provides a Degree of Protection Against Atmospheres Typically Containing		Enclosure Types 7 and 8, Class I Groups **				Enclosure Type 9, Class II Groups			
(See NFPA 497M for Complete Listing)	Class	A	B	C	D	E	F	G	10
Acetylene	I	X	...	...	...	...	...	...	...
Hydrogen, manufactured gas	I	...	X	...	...	...	...	...	...
Diethyl ether, ethylene, cyclopropane	I	...	...	X	...	...	...	...	...
Gasoline, hexane, butane, naphtha,	I	...	...	...	X	...	...	...	...
Metal dust	II	...	...	...	...	X	...	...	...
Carbon black, coal dust, coke dust	II	...	...	...	...	...	X	...	...
Flour, starch, grain dust	II	...	...	...	...	...	...	X	...
Fibers, flyings *	III	...	...	...	...	...	...	X	...
Methane with or without coal dust	MSHA	...	...	...	...	...	...	...	X

* For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.

** Due to the characteristics of the gas, vapor, or dust, a product suitable for one Class or Group may not be suitable for another Class or Group unless marked on the product.

Figure 26 – Comparison of Specific Applications of Enclosures for Indoor Hazardous Locations (*NEMA 250-2003*)

7.2.3. NEMA Enclosure Type Numbers vs. IEC Enclosure Classification Designations

IEC Publication 60529, "*Classification of Degrees of Protection Provided by Enclosures,*" provides a system for specifying the enclosures of electrical equipment on the basis of the degree of protection provided by the enclosure.

IEC 60529 does not specify degrees of protection against mechanical damage of equipment, risk of explosions, or conditions such as moisture, corrosive vapors, fungus, or vermin. The NEMA Standard for Enclosures for Electrical Equipment does test for environmental conditions such as corrosion, rust, icing, oil, and coolants. For this reason and because the test and evaluations for other characteristics are not identical, the IEC enclosure classification designations cannot be exactly equated with the enclosure Type numbers in this standard.

The IEC designation consists of the letters IP followed by two numerals. The first numeral indicates the degree of protection provided by the enclosure with respect to persons and solid foreign objects entering the enclosure. The second numeral indicates the degree of protection provided by the enclosure with respect to the harmful ingress of water.

Figure 27 provides an equivalent conversion from the enclosure Type numbers in this standard to the IEC enclosure classification designations. The enclosure type numbers meet or exceed the test requirements for the associated IEC Classification; for this reason Figure 27 cannot be used to convert from IEC classifications to enclosure Type numbers.

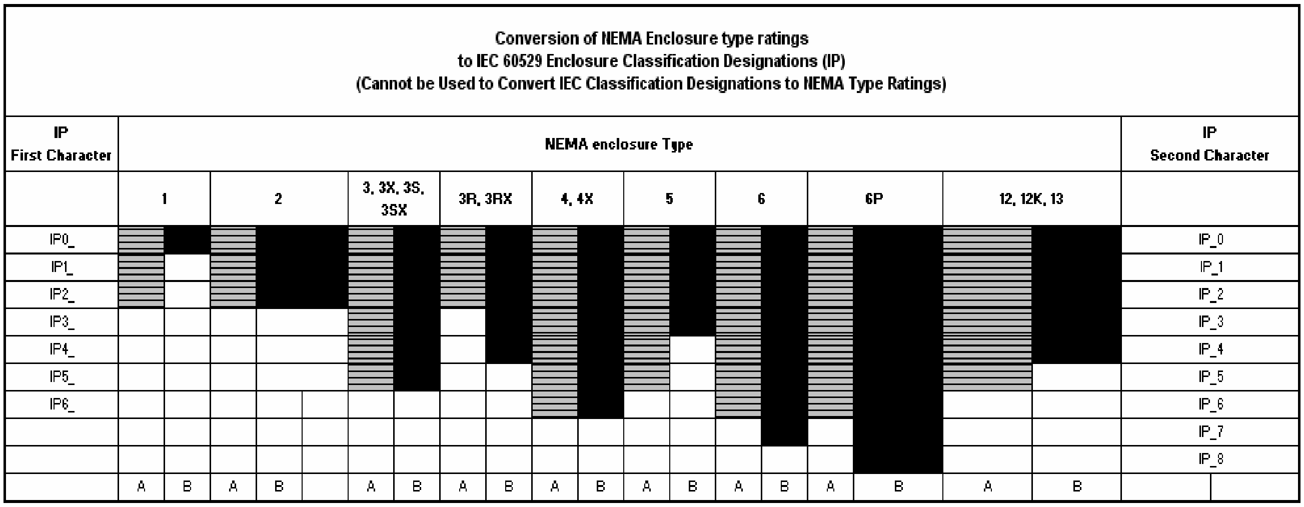

Figure 27 – IEC Enclosure Classification

A shaded block in the "A" column indicates that the NEMA enclosure type exceeds the requirements for the respective IEC 60529 IP first character designation. The IP first character designation is the protection against access to hazardous parts and solid foreign objects.

A shaded block in the "B" column indicates that the NEMA enclosure type exceeds the requirements for the respective IEC 60529 IP second character designation. The IP second character designation is the protection against the ingress of water.

7.3. Transfer Switch Configurations

Three basic types of transfer switches have been discussed up to this point:

- Non-automatic (manually operated),
- Non-automatic (electrically operated),
- Automatic.

This section will concentrate on transfer switches with different configurations. In most instances that means the switch performs in a certain manner for a specific type application. There is a difference between a transfer switch type and its configuration.

Example: The type of switch would be one of the three types just outlined (non-automatic manual/electrical or automatic). The application could call for the switch to perform in a certain way to accomplish its function. This means the switch must be configured to do the job. The logic might be configured in a certain way, the switch might be physically configured in a certain way, or it could be a combination of the two. Even though the switch is configured a certain way for the application, it might be a non-automatic type or an automatic type switch. These things are dependent upon the specific design. All switch designs do not offer all the same choices. In addition, previous discussions centered around fixed switching devices.

If insulated case switches or insulated case circuit breakers are used as the main switching devices, drawout switching devices may also be available. The transfer switch can, therefore, be configured as fixed or drawout.

The rest of this section will present brief explanations of a number of different switch configurations:

- Open transition,
- Delayed transition,
- Closed transition,
- Maintenance bypass/bypass isolation,
- Service entrance.

7.3.1. Open Transition

An Open Transition Transfer (OTT) switch is also called a break-before-make switch. It is configured in such a way that the power output is broken (interrupted) before the transfer to the new source is made. There is a definite break in power as the load is taken off one source and connected to another. While this type of transfer is simple, the time delay between break and make creates an unacceptable power interruption for critical loads, such as computers. For this reason, the OTT configuration is more appropriate for less critical applications.

Typically, this type of switch uses voltage sensors and time delay circuitry to activate the operation of the switching mechanism in the desired sequence. With ATSs, the logic controls the operation. Whether the switch is transferring to the emergency source or retransferring to the normal source, it operates in the same sequence, break-before-make (Figure 28)

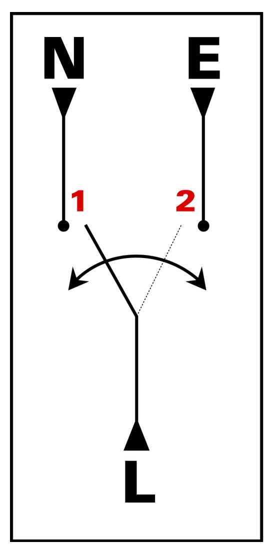

Figure 28 – Open Transition Operation (Break-Before-Make Operation – No Center Off Position)

7.3.2. Delayed Transition Transfer Switches

As previously explained, a delayed transition transfer switch, also referred to by some manufacturers as a “programmed transition” feature, provides an adjustable time delay after the opening of the closed contacts and before the closing of the open contacts for transferring large motor and/or transformer loads. This delayed transition time allows for motors to coast down and transformer fields to decay, thus allowing inductive loads to be re-energized after transfer with only normal inrush starting currents.

The delayed transition design is an effective method of handling these applications and can be utilized as an alternative to a standard transfer switch equipped with an in-phase monitor.

The delayed transition transfer switch is ideally suited for pumping stations, sewage treatment plants, hospital X-ray equipment, or wherever the bulk of the load being controlled consists of large motors and/or transformers.

Further, many UPS manufacturers strongly recommend the use of delayed transition type transfer switches to ensure proper operation and sequencing of their equipment. The delayed transition switch allows a typical UPS system sufficient delay to recognize a power failure and transfer to batteries, acknowledge the return of input power and allow the rectifier to walk-on to the new source, reducing any transfer anomalies.

7.3.2.1. Application Information

When transferring large motors, UPS systems and/or transformers between two sources of power that have the potential to be unsynchronized, consideration must be given to the elimination or reduction of transients.

These may occur when loads are disconnected from the first power source and immediately connected to the second source.

When a running motor is suddenly disconnected from its power source, the residual voltage developed due to generator action will decrease in amplitude and frequency as the motor slows down. Depending on the type number and application of the motors involved, the decaying action may take a considerable amount of time.

Similarly when a transformer is disconnected from the line, time is required for its magnetic field to collapse. Release of stored energy in the transformer generates a surge even though the two power sources are in synchronism when a transfer is initiated. The transient caused by the momentary high current flow described above can exceed the instantaneous trip settings of protective devices in the system and can be severe enough to trip circuit breakers cause damage to motor shafts couplings, etc.

One solution to this problem is to introduce a delay in the transition between two live sources.

The advantages of using delayed transition when transferring large motor and/or transformer loads are:

- Consistent operation under all conditions, including manual (pushbutton) operation;
- Operation is totally independent of the synchronism of the power sources, eliminating the need for in-phase monitors or extensive motor disconnect control wiring between the transfer switch and motor control centers;
- The delayed transition function adapts itself for use in multiple generator systems and paralleling systems to permit load shedding by switching the main contacts to a center-off or disconnected position;
- Allows typical UPS systems to function properly while switching between line input sources.

7.3.2.2. Description and Operation

The operation of a delayed transition transfer switch is identical to the previously mentioned open transition type with the exception of the drive mechanism. Upon failure or reduction of the normal source, and the availability of the emergency source, the drive solenoid is energized and pulls the main contacts out of the normal position and locks them mechanically in the open transition position.

An adjustable time delay is then energized. After the preset time has elapsed, the drive solenoid is energized and pulls the main contacts out of the transition position and locks them mechanically in the emergency closed position. The emergency power source is now feeding the load.

When the voltage sensing detects the restoration of the normal source for a predetermined time period, the drive solenoid is energized and pulls the main contacts from the emergency position and locks them mechanically in the open transition position. After the preset time delay has elapsed, the drive solenoid is energized and pulls the main contacts out of the open transition position and locks them mechanically in the normal closed position. The normal power source is now feeding the load.

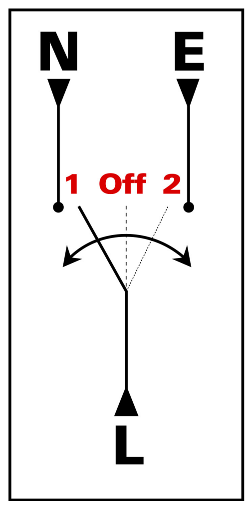

Figure 29 – Delayed Transition Operation (Break-Before-Make Operation – with Center Off Position)

NOTE: "N" Position indicates Neither Source connected

7.3.3. Closed Transition

Since the ATS is the single link between utility and emergency power, operation and testing of the ATS may be a cause of concern for many users. Loads such as electronic equipment, UPS systems, HID lighting, motor starters, etc., are sensitive to even the 30-100 millisecond outage experienced during a typical transfer switch operation.

In addition to these applications, opportunities for peak shaving and utility incentive rates may be passed over because of the inability to accept the short power interruptions inflicted during operation.

The closed transition transfer switch, also known as a make-before-break switch, is designed for such applications. With this feature, there is no interruption in power to the load during transfer operations when both power sources are available.

These products utilize the same switching technology as that previously described, combined with the capability to transfer in a closed transition mode when both sources are within preset parameters. Utilizing a high-speed drive system, the overlap of the normal and emergency sources is less than 100 msec. When one source is not within specified limits, such as during a power failure, the closed transition switch operates in an open transition mode.

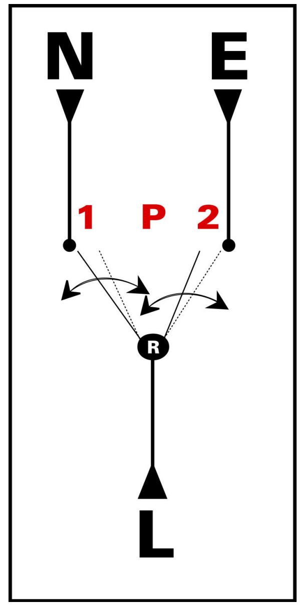

Figure 30 – CTT Switch Used for Emergency Source Testing (Make-Before-Break Operation)

NOTE: "P" Position indicates both sources paralleled for 6 cycles

7.3.3.1. Description and Operation

Generally speaking, closed transition switches have two basic modes of operation. During a failure of one source or an out of specification condition, the switch operates as a standard delayed transition switch. This sequence allows clear separation of an unreliable source from an available one.

Closed transition operation takes place when both sources are within preset voltage and frequency parameters and the phase angle differential is less than five degrees. The closed transition sequence may be initiated by the test switch, a load exerciser clock, peak shaving controls or special utility incentive rate signals.

When a transfer signal is received from one of the above mentioned methods, the engine generator set is started and allowed to reach rated voltage and frequency. The control system compares the phase angle of the two power sources and when the proper relationship is reached, the emergency drive solenoid is energized and the emergency main contacts are closed and locked mechanically.

The normal drive solenoid is then energized; the utility main contacts are opened and mechanically locked in this position.

The overlap time of the two sources is less than 100 ms. Retransfer from a generator set to the utility source is also performed in the closed transition mode. If, however, a generator failure occurs, the unit will revert to standard delayed transition operation.

7.3.3.2. Application Information

- Closed transition switches require a momentary (less than 100 ms) paralleling of the standby source with the utility. This usually requires the owner to obtain approval of the installation by the utility;
- The purpose of a closed transition switch is to prevent the momentary outages that occur during transfer of a standard unit. This technology is not a substitute for a UPS system as it does not provide stored energy capability but rather acts in a complementary fashion;
- System application requirements (requirements may vary based on manufacturer):
    - o The generator set must be provided with a stable isochronous governor;
    - o A 24 VDC shunt trip circuit is suggested on one of the feeder breakers, normally the generator feeder. Power for this trip circuit and alarm system backup is typically supplied from the engine starting batteries or an equivalent source.

7.3.3.3. Soft Load

When conditions are most sensitive to generator voltage drop or frequency dips, a variation of the closed transition method of transfer, which further combines the attributes of a closed transition transfer switch with generator paralleling switchgear. By employing automatic synchronizing, active loading controls and a greater interconnect (parallel) time; a soft-loaded/closed transition transfer can be accomplished.

Note that this method of transfer interconnects the utility and generator sources for a longer period (seconds rather than cycles), and greater coordination with the local utility company is necessary. Typically, more sophisticated protective relaying schemes will be required.

7.3.4. Transfer/Bypass-Isolation Switches

Though designed to give consistent operation, the ATS must be periodically maintained to ensure proper operation and system reliability.

Maintenance of the entire system is called for in the National Electrical Code Article 700-4, NEMA Standard ICS2-447 and in NFPA 99.

In some non-critical emergency power systems, it is possible to disconnect the power feeders from the ATS and electrically isolate the switch for servicing. Yet, there are many critical systems where interruption of power is not permissible. In hospital communication systems, data processing centers, airports, etc., power disruption is not permitted. For these systems, the use of a bypass-isolation switch with the transfer switch is essential and often required by code. Bypass-Isolation Transfer Switches are designed to meet the requirements for the inspection and/or maintenance of the transfer switch without power interruption.

7.3.4.1. Construction

The bypass-isolation transfer switch consists of two major modules; the ATS and the bypass-isolation switch.

The ATS module is of identical construction and functionality as that previously described. The switch may be designed to operate in an open transition, delayed transition or closed transition mode.

The bypass section is a basic Transfer switch provided with a quick make/quick break manual load transfer handle and a control/interlock system consisting of both mechanical and electrical interlocks. The bypass should be equipped with normal failure sensing and a time delay to start the engine automatically if the ATS has been removed for service and a failure occurs.

Figure 31 shows the physical layout of a bypass isolation transfer switch with the manually operated bypass-isolation switch mounted above the ATS. The switches are completely interconnected requiring only the normal source, emergency source and load cable connections. Once installed, no cables need to be removed to isolate the transfer switch module for maintenance or inspection. The ATS may be withdrawn for testing or maintenance without disturbing the load.

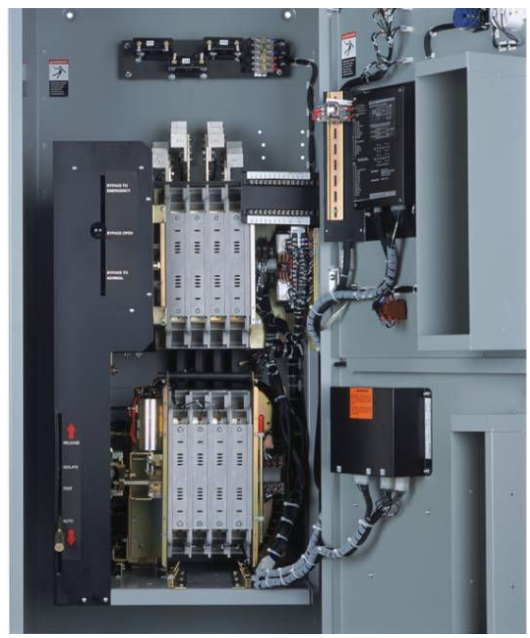

Figure 31 – Bypass Isolation and Automatic Transfer Switches

7.3.4.1.1. Automatic Transfer Switch

The transfer switch module of a bypass isolation transfer switch has three positions:

1. Automatic: The transfer switch is carrying the load, and the bypass switch is in the open position. This is the normal operating position;

2. Test: The bypass switch is closed and feeding the load. The transfer switch has control power and may be operated for test purposes via the test switch on the enclosure door;
3. Isolate: The transfer switch is withdrawn from all power and ready for maintenance. The bypass switch serves the load.

The ATS is installed on a draw-out mechanism, with electrical and mechanical interlocks for secure removal after load bypass. Additionally, the control/logic panel is mounted on the enclosure door and connected by a wire harness and multi-pin disconnect plugs. The transfer switch and/or the control panel may be tested, isolated and removed for maintenance without load interruption.

7.3.4.1.2. Bypass-Isolation Switch

The bypass-isolation switch module is the same basic design as the transfer switch module and thus has the same electrical ratings. Manually operated, it features high speed, quick make/quick break contact action. The bypass-isolation switch has three basic positions:

1. Automatic: Normal bypass contacts open, emergency bypass contacts open;
2. Bypass Normal: Normal bypass contacts closed, emergency bypass contacts open;
3. Bypass Emergency: Normal bypass contacts open, emergency bypass contacts closed;

The bypass isolation design requires no additional load break contacts, which cause load interruption during bypass-isolation functions. The bypass isolation switch contacts are out of the system current path except during actual bypass operation. Therefore, they are not constantly exposed to the destructive effects of potential fault currents.

The normal, emergency and load are connected between the ATS and the bypass-isolation switch through solidly braced isolating contacts that are open when the transfer switch is isolated. All current carrying components provide high withstand current ratings in excess of those specified in UL 1008 standards.

7.3.4.2. Interlocks and Indicators

Bypass-isolation transfer switches should be supplied with all necessary electrical and mechanical interlocks to prevent improper sequence of operation as well as the necessary interlocking circuit for engine starting integrity.

Further, a bypass isolation switch should be furnished with a detailed step-by-step operating instruction plate as well as the following additional indications:

- Normal source available,
- Emergency source available,
- Bypass switch in normal position,
- Bypass switch in emergency position,
- ATS in test position,
- ATS isolated,
- ATS inhibit,

- ATS operator,
- Disconnect switch “off”,
- ATS in normal position,
- ATS in emergency position.

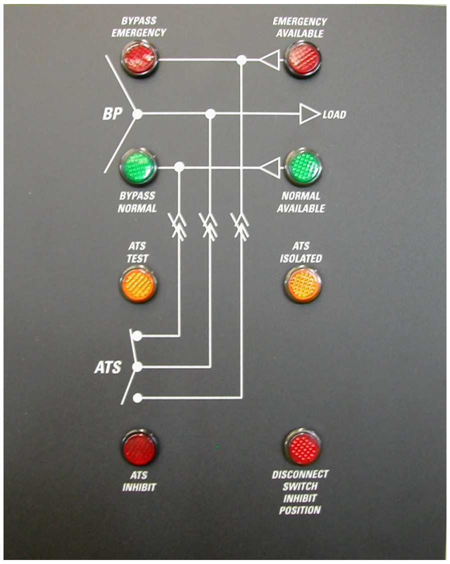

Figure 32 – Bypass-Isolation Diagnostic Indicating Lights

7.3.4.3. Load Transition

With the automatic transfer and bypass-isolation switches set for automatic operation, power comes from the source 1 (utility), through the automatic transfer section and to the loads.

In testing or servicing the bypass isolation switch, the bypass switch must be manually moved from the bypass position to either the source 1 or source 2 position.

Two basic types of load transition features are found in contactor type bypass-isolation switches:

- Break-before-make – this type of switch operation momentarily interrupts power to the load during the bypass procedure (reference Figure 33);
- Make-before-break – the second type of switch operation does not interrupt power to the load during the procedure (reference Figure 34). This is accomplished by means of a mechanical interlock between the automatic and bypass switches.

Care should be taken in the selection of a bypass isolation switch to understand the type of switch operation that is required for the specific application.

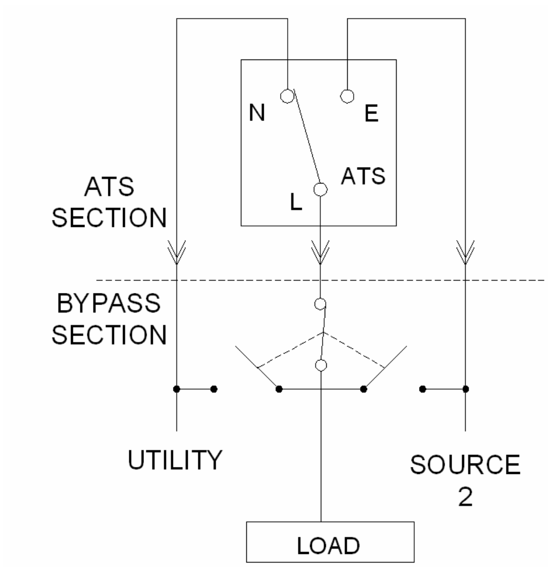

Figure 33 – Break-Before-Make Bypass Arrangement

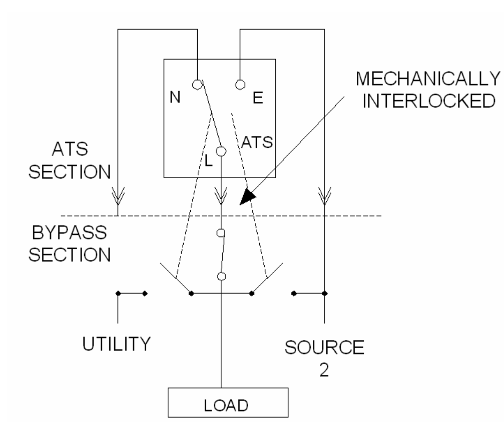

Figure 34 – Make-Before Break

7.3.4.4. Service Entrance Rated

Service Entrance Rated (SER) transfer switches combine the functions of the automatic switching device with a utility circuit breaker, which serves as a disconnect device. The SER must meet all NEC requirements for installation as service entrance equipment.

Service entrance rated transfer switches generally are installed at facilities that have a single utility feed and a single emergency power source. A circuit breaker serves as the utility disconnect and links are provided to connect both neutral and ground conductors.

Service entrance is the point where power supplied by a utility enters a facility.

Just look at the point where power enters a house from the local utility and goes directly into a load center, probably mounted on a basement wall. The incoming power line first goes to a main disconnect, probably a circuit breaker. From there it breaks down into many different circuits through any number of smaller circuit breakers to supply power throughout the house. Industrial facilities, for example, are no different, just on a larger scale.

When there is a loss of power from the utility at a house, everything electrical stops functioning. That is the way it remains until the utility takes care of the problem and restores power. A number of facilities, such as water, wastewater treatment, pumping station and many other industrial facilities cannot tolerate the loss of commercial power. An emergency power source is necessary at any of these facilities to protect against commercial power interruptions. In such a situation, it becomes necessary to have an ATS as close as possible to the point where commercial power enters the facility, the service entrance. The reason most likely is that every load at the facility is critical, and must continue functioning, even though commercial power is lost.

There are two approaches that can be used for the installation of ATS equipment:

- Contactor type ATS installation,
- Breaker transfer pair ATS installation.

7.3.4.5. Contactor Type SER

A contactor type ATS installation would normally be installed immediately downstream of the service disconnect devices of both the utility and standby (emergency) power supplies (Figure 35). This may not be the optimum installation location, but it is the best that can be done with conventional ATS equipment.

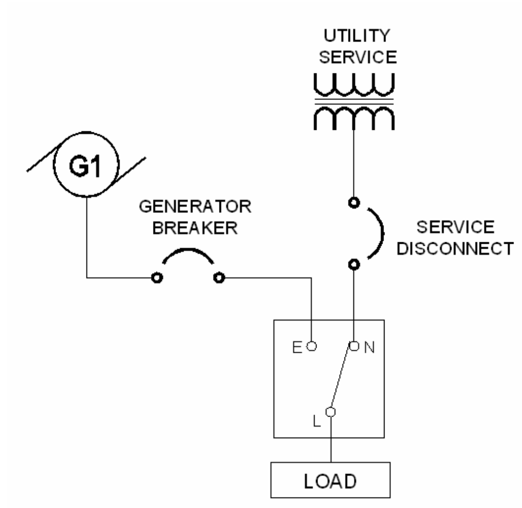

Figure 35 – Contactor Type ATS Service Entrance Installation

7.3.4.6. Breaker Transfer Pair SER

A breaker transfer pair ATS installation using circuit breaker type disconnects, such as the SPB, and a service entrance option eliminates the need for separate upstream disconnect devices and their respective power interconnections. This means the ATS is installed directly at the point of service entrance (Figure 36).

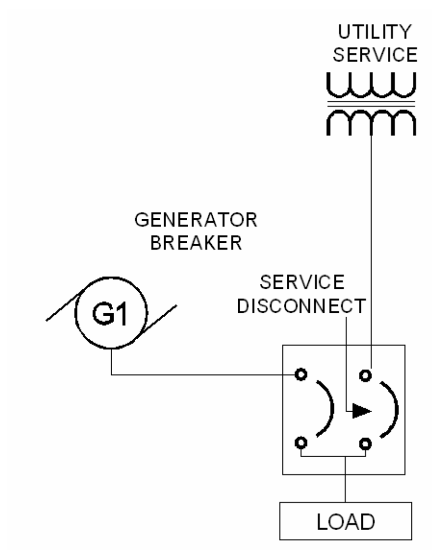

Figure 36 – Breaker Transfer Pair ATS Service Entrance Installation

8. Transfer Switch Applications

There are six common transfer schemes, which will be discussed:

1. On generator set configurations,
2. Utility/generator set ATS,
3. Generator set/ATS/UPS,
4. Multiple generator set/switchgear/ATS,

5. Generator set to generator set ATS,
6. Utility to utility ATS,
7. Multi-source switching systems.

8.1.1. On Generator Set Configurations

The on generator set configuration represents the most basic automatic transfer scheme. It performs similar functions to the utility/generator set ATS. The on generator set configuration, otherwise known as the automatic mains failure feature of a generator set controller, is designed to operate the generating set automatically in event of utility failure, supply power to the load, and shut down the generator when the main power is restored.

This configuration is typically used outside of North America in areas not subject to UL1008.

8.1.2. Utility/Generator Set ATS

The most common application of an ATS is use as a utility/generator set interface. Upon a loss of the normal source (utility), the ATS signals the generator set to start and switches the transfer mechanism to the emergency power source (generator set). When normal power is restored, the ATS switches to the normal power source and signals the generator set to shut down (see Figure 37).

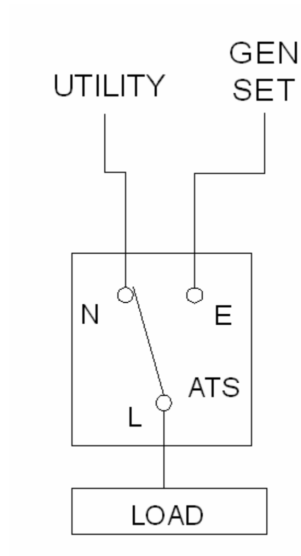

Figure 37

8.1.3. Generator Set/ATS/UPS

An Uninterruptible Power Supply (UPS) system is an assembly of equipment used with electrical loads sensitive to power source disturbances or that require absolute continuity of power. The UPS stores energy for the purpose of providing power during short duration power outages and load switching operations. The UPS continually conditions power and when the normal power source is not available, the UPS provides power to the critical load until the standby power generation can come on-line.

In conjunction with an ATS, the UPS is positioned between the ATS and the load (Figure 38) and will perform its function until the ATS switches the load to the emergency power source.

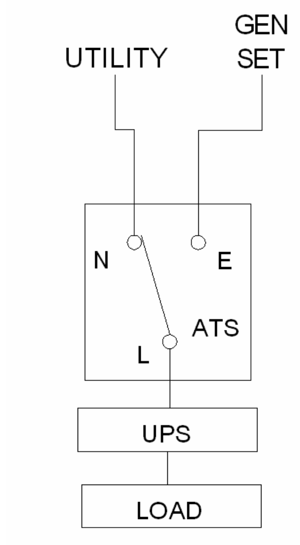

Figure 38

8.1.4. Multiple Generator Set/Switchgear/ATS

A simplified multiple generator set/switchgear/ATS system is shown in Figure 39. In the event that multiple generators are required to power a load, the load distribution must be prioritized and segregated.

In the event of a utility source outage, the UPS will continue to power the priority 1 loads. The ATS will signal the generator sets to start. As soon as a generator set has started, the breaker to the bus bar is closed and the priority 1 loads are switched from the utility source to the generator. Once a second generator has started, it is synchronized to the bus bar, and the ATS connected to the priority 2 loads switches from utility source to generator set power. This process is continued until all generator sets are synchronized on the bus and all loads are powered by the generator sets.

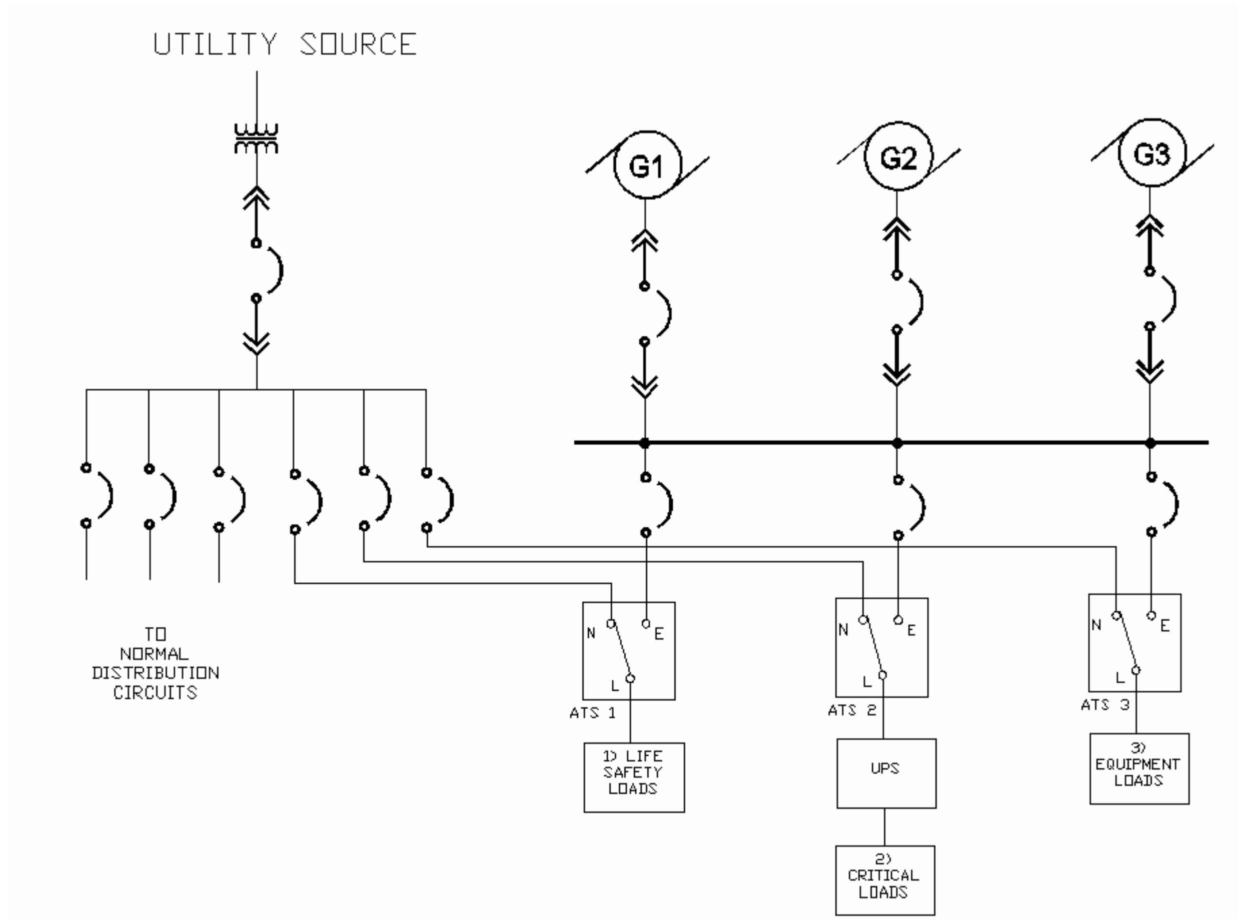

Figure 39 – Multiple Generator Set/ATS/UPS

8.1.5. Gen to Gen ATS

In a generator set to generator set system, the ATS operates two generator sets, one being an emergency power source to the other, running at alternate times to power the load.
The system is similar to a utility/generator set arrangement except that the control system is set to switch load from one generator to the other after a preset time, in addition to performing emergency switching operations.

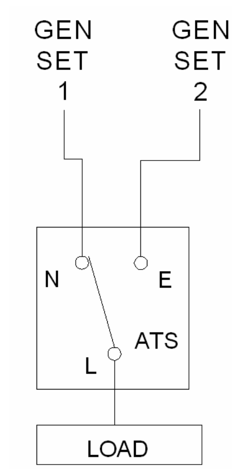

Figure 40

8.1.6. Utility to Utility ATS

If a utility has the ability to provide multiple service connections over separate lines from separate supply points which are not likely to be jointly affected by system disturbances, it can be advantageous to provide an ATS for switching if there is a failure in one of the utility power sources. Since the utility is constantly supplying power, there would not be the startup delay that is experienced with a generator set backup system.

There may still be times during which both utility power sources fail; therefore, certain codes (Hospitals) require backup generator sets.

The controls for a utility/utility ATS are similar to a utility/ generator set ATS except there is no start/stop signal.

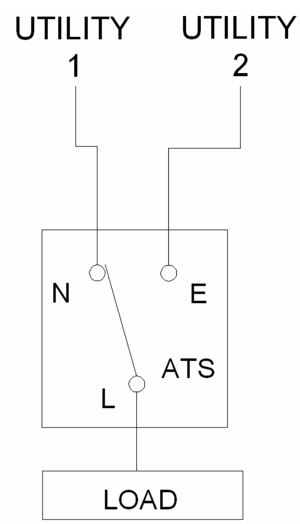

Figure 41

8.1.7. Multi-Source Switching Systems

Multiple source switching systems are designed to switch a single load between multiple available sources of power. These sources may be multiple utilities, generator sets or combinations of the two.

8.1.7.1. Multiple Utility/Single Generator Set

When the primary source fails, the master transfer switch connects the load to the secondary utility. Should the secondary utility source also fail, the engine generator will start and the source selector transfer switch will connect the load to the generator set when it reaches proper operating parameters (Figure 42).

In this application, the unit is utility preferred. That is, if either utility source becomes available, the logic of the system will transfer the load to the available utility and then shut down the generator set until the next utility failure.

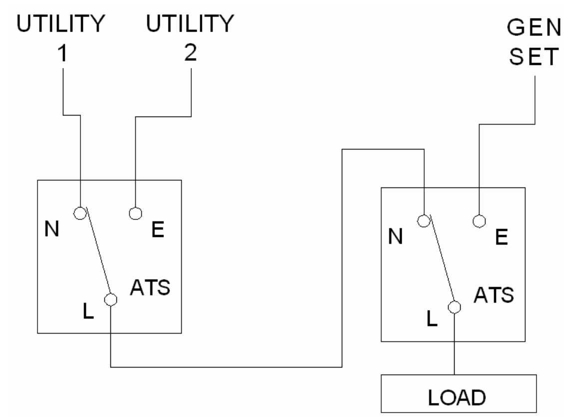

Figure 42 – Multiple Utility – Single Generator Transfer Scheme

8.1.7.2. Single Utility/Multiple Generator Sets

In lieu of a second utility source, these applications include the use of a second generator set to serve as standby power to the load. Two different logic schemes are typically utilized in this application, depending on facility requirements.

8.1.7.2.1. Logic Scheme 1

In this scenario, both engine generator sets are started when a utility failure occurs and the load is connected to the first available generator set. The second set will run on a standby timer for a period of 5 minutes to verify that the first set will continue to run and then shut down.

If the connected generator set fails, the second set will restart and assume the load until utility restoration.

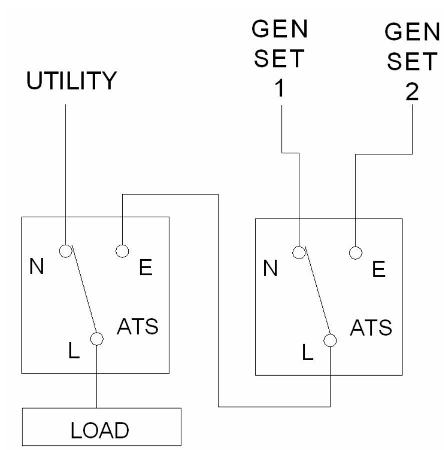

Figure 43 – Single Utility/Multiple Generator Sets– Logic Scheme 1

8.1.7.2.2. Logic Scheme 2

The second logic scheme operates in a similar mode. However, the user is supplied with a prime generator set selector switch, which causes only one of the sets to start on utility failure and act as the primary standby unit. Either unit may be so selected. If the primary unit does not assume the load within a preset period (usually 10 seconds), the secondary unit will be started and the load transferred to it.

The primary unit remains the first standby set and if it successfully starts and maintains operating parameters, the load will be transferred to it and the secondary unit will be shut down until the next failure.

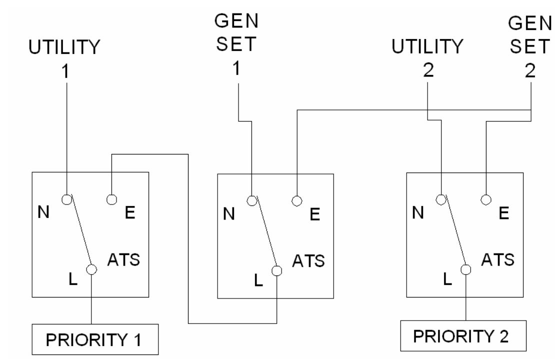

Figure 44 – Single Utility/Multiple Generator Sets – Logic Scheme 2

9. Standards, Testing & Maintenance

9.1. Standards and Ratings

9.1.1. The National Electric Code

The National Electric Code (NEC) provides guidance for safe and proper installation of equipment required for emergency and legally required standby power systems. It also contains rules for those standby systems that are installed for the convenience of operations in a facility (optional standby systems). Finally, it also deals with those systems operated in parallel with the electric utility and is capable of delivering energy back to the utility source.

9.1.2. Underwriter's Laboratories, Inc. (UL)

UL 1008 is the "Standard for Safety Transfer Switch Equipment" and serves as the prevailing standard for the transfer switch market in the United States. The requirements found in this standard "cover automatic, non-automatic (manual), and by-pass/isolation transfer switches intended for use in ordinary locations to provide for lighting and power…"

UL1008 is applicable to equipment rated at 600 Volts or less and includes standards related to the construction, performance, testing, rating and marking of transfer switches. When choosing an ATS it is critical to ensure that it is listed under UL 1008.

Additionally, circuit breaker type transfer switches utilizing molded and insulated case switches or circuit breakers as the main power switching contacts, may also be listed under two additional standards:

- **UL 1087** – Standard for molded case switches,
- **UL 489** – Standard for circuit breakers.

9.1.3. Canadian Standards Association (CSA)

CSA C22.2 No 178 "Automatic Transfer Switches; Industrial Products" is the prevailing standard for transfer switches sold and applied in Canada.

9.1.4. International Electrotechnical Commission (IEC)

Transfer switches should IEC listed under standard 947 " Low Voltage Switchgear and Control Gear" and are suitable for installation in applications where the prevailing standard is the IEC, found primarily outside of North America

9.1.5. National Fire Protection Association

The National Fire Protection Association (NFPA) provides a number of very important and applicable standards:

- **NFPA 70** – *National Electrical Code (NEC)*, developed by NFPA, provides guidance for the proper installation of equipment required for emergency systems, legally required standby systems and optional standby systems. It also contains rules for systems intended for operation in parallel with utility and capable of providing power back to the utility;
- **NFPA 99** – *Standard for Healthcare Facilities*; addresses the requirements for emergency systems in health care facilities;
- **NFPA 101** – *Life Safety Code*; identifies the features necessary to minimize danger to life from fire and provides guidelines to where emergency lighting is essential;
- **NFPA 110** – *Standard for Emergency and Standby Power Systems*; provides performance

requirements for emergency and standby power systems.

9.1.6. National Electrical Manufacturers Association

The National Electrical Manufacturers Association (NEMA) is a US based association which defines standards for many commonplace electrical interconnects, as well as outlining manufacturing standards for electrical products, such as various grades of electrical enclosures.

NEMA ICS 10 – *Industrial Control and Systems: AC Transfer Equipment – Part 2: Static AC Transfer Equipment;* Applies to static automatic and static non-automatic transfer equipment without cross-connection of sources during transfer or retransfer, with or without bypass isolation switches rated 600 volts AC or less, not exceeding 6000 amps, for use on single-phase and polyphase AC circuits.

This standards publication provides practical information concerning ratings, construction, test, performance, and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of respective manufacturing and widespread product availability.

This standard has superseded NEMA ICS2-447.

9.1.7. American National Standards Institute

The American National Standards Institute (ANSI) is a private nonprofit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States. The organization also coordinates U.S. standards with international standards so that American products can be used worldwide.

9.1.8. Institute of Electrical and Electronic Engineers

The Institute of Electrical and Electronics Engineers (IEEE) is an international non-profit, professional organization for the advancement of technology related to electricity.

9.1.9. International Building Code

The International Building Code (IBC), developed by the International Code Council (ICC), has been widely adopted throughout the United States. The code contains safety concepts, structural, and fire and life safety provisions covering various topics of building design including seismic engineering provisions for the design of new buildings.

In compliance with the requirements of IBC-2003, Caterpillar Transfer switches have been certified by a 3rd party agency and have demonstrated the capability of operating (transferring) during a simulated seismic event.

9.2. Testing

A manual operator handle is provided with the transfer switch for maintenance purposes only. Manual operation of the switch must be checked before it is operated electrically. It is important to note that both power sources must be disconnected before manual operation of the switch.

Manual operation is conducted by inserting the handle and operating the transfer switch between the source 1 and source 2 positions. The transfer switch should operate smoothly without binding. Return the switch to source 1 position, remove the handle, and return it to the holder provided.

After completing the inspection, cleaning and servicing of the transfer switch, reinstall the switch cover, and close and lock the cabinet door. Reclose the circuit breakers feeding the utility and generator sources to the switch.

Initiate the electrical transfer test by activating the test switch. After programmed delay times, the controller will send an engine start signal and the switch will complete its transfer by closing into source 2.

Deactivating the test switch will start retransfer to source 1. The switch will complete its retransfer following programmed time delays, allowing the engine generator to run unloaded for a preset cool down period.

Per the NEC, Articles 700 & 701, a periodic test of the transfer switch under load conditions is recommended to ensure proper operation.

10. Controls Testing Standards

Controls are to be factory tested in accordance with the following standards:

- IEEE 472 (ANSI C37.90A),
- EN55022 Class B (CISPR 11) (Exceeds EN55011 & MILSTD 461 Class 3),
- EN61000:
    - EN61000-4-2 (Level 4),
    - EN61000-4-3, (ENV50140) 10v/m,
    - EN61000-4-4,
    - EN61000-4-5, IEEE C62.41 (1.2 X 50ms, 5 & 8 kV),
    - EN61000-4-6 (ENV50141),
    - EN61000-4-11.

10.1. Maintenance

A preventive maintenance program will insure high reliability and long life for a transfer switch. The preventive maintenance program for any transfer switch should include the following items:

10.1.1. Inspection and Cleaning

The switch should be inspected for any accumulation of dust, dirt, or moisture, and should be cleaned by vacuuming or wiping with a dry cloth or soft brush. Do not use a blower since debris may become lodged in the electrical and mechanical components and cause damage.

Remove the transfer switch barriers and check the condition of the contacts. Any surface deposits must be removed with a clean cloth (do not use emery cloth or a file). If the contacts are pitted or worn excessively, they should be replaced. A general inspection of mechanical integrity should be made to include loose, broken or badly worn parts.

10.1.2. Servicing

All worn or inoperative parts are to be replaced using factory recommended replacement parts. Please refer to the applicable replacement parts manual for specific part information and ordering procedures.

The operating mechanism of the transfer switch must be lubricated in accordance with factory recommended lubricant. Please consult ATS O&M Manual for guidance in choosing the appropriate lubricant. The lubricant applied at the factory provides adequate lubrication for the lifetime of the switch. Should debris contaminate the mechanism, clean and apply additional lubricant.

CDT battery replacement: Lithium batteries may last up to 10 years, however it is recommended that battery replacement be included in a 3-5 year service cycle. The battery maintains the exerciser memory only and does not otherwise affect the operation.

11. Glossary of Terms

Ampacity: The current, in amperes, that a conductor or equipment can carry continuously under the conditions of use without exceeding its temperature ratings.

ANSI: American National Standards Institute

Arcing: The effect generated when electrical current bridges the air gap between two contacts or conductors

Arc Chute: A structure affording a confined space or passageway, lined with arc resisting material, into or through which, an arc is directed to extinction.

Arcing Contacts: The contacts of a switching device on which the arc is drawn after the main contacts have parted.

Arc Splitter: Arc splitters are typically metallic plates used to split the arc into series arcs. This process effectually raises arc voltage above system voltage allowing the arc to be extinguished quickly.

Automatic Transfer Switch (ATS): A device that automatically transfers a common load from a normal supply to an emergency supply in the event of failure of the normal supply, and automatically returns the load to the normal supply when the normal supply is restored.

Back-up Power: See Emergency Power

Branch Circuit: The circuit between the final Overcurrent device protecting the circuit and the load.

Bypass Isolation Switch: A manually operated device used in conjunction with a transfer switch to provide a means of directly connecting load conductors to a power source and of disconnecting the transfer switch.

Circuit Breaker Type Switch: Transfer switches known as the circuit breaker type use specially designed switching devices that are typically molded/insulated case switches. A molded case switch is like a molded case circuit breaker without magnetic or thermal trip elements and does not trip on overload or faults. Used when a compact, high capacity disconnect is needed, and is held to a more rigorous testing standard than the contactor type.

Closed Transition Transfer: Transfer between emergency power sources whereby power is maintained to the load throughout the transfer process (make-before-break).

Closing Rating: The RMS symmetrical current a transfer switch can safely close into and conduct during short circuit conditions.

Contactor Type Transfer Switch: Transfer switches that use a contactor type design. The contactor type switches do not use motor starting/lighting type contactors. In fact, contactor type transfer switches used circuit breaker design contacts, arc chutes and arcing horns.

Continuous Current: The amount of current a device can carry constantly at 60 cycles without exceeding the temperature rise, according to ANSI charts.

Drawout: A type of circuit breaker that can be moved into or out of its structure without unbolting, often on a racking mechanism.

Delayed Transition Transfer: Type of open transition transfer whereby an ATS is equipped with a center "off" position in addition to the Normal and Emergency positions, which allows for motors to coast down and transformer fields to decay, prior to re-energizing.

Electrically Operated: A version of the manually operated mechanism, but is electrically operated. Operating personnel must be present to initiate the operation.

Electrically Operated Non-Automatic Transfer: Switch similar to the manually operated version except that an electrical operation feature is added to the switch. The switch electrically transfers power when a pushbutton, generally mounted on the enclosure, is activated. Can also be operated manually.

Emergency Power: Also called alternate, back-up and critical power. If there is a normal power source failure, emergency power can be supplied as an additional source from the utility or an on site generation, from an engine-generator set for example.

Emergency System: A system legally required and classified by government jurisdiction. Applies when loss of the normal power source would be a hazard to safety or human life. Intended to automatically supply illumination and/or power to designated areas and equipment. Characterized by a transfer time of less than 10 seconds.

Enclosure: A case or housing used to protect the contained conductor or equipment against external conditions and to prevent operating personnel from accidentally contacting live parts.

Equipment Ground: A connection to ground from one or more of the non-current carrying metal parts of the wiring system or of electric equipment connected to the system.

Equipment Grounding Conductor: The conductor used to connect the non-current carrying metal parts of equipment, raceways, and other enclosures to the service equipment, the service power source ground, or both.

Emergency Power Supply System (EPSS): Provides a source of electrical power of required capacity, reliability and quality to loads for a length of time and within a specified time following loss or failure of the normal power supply (as specified in NFPA 110 Chapter 4).

Feeder Circuit: All circuit conductors between the service equipment (or the generator switchboard) and the final branch circuit Overcurrent device.

Ground: A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or some conducting body that serves in place of the earth.

Grounded Effectively: Intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages that may result in undue hazards to connected equipment or to persons.

Grounded, Solidly: Connected to ground without inserting any resistor or impedance device.

Grounded Conductor: A system or circuit conductor that is intentionally grounded.

Ground Fault Protection: A system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

Grounding Conductor: A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Grounding Conductor, Equipment: The conductor used to connect the non-current carrying metal parts of equipment, raceways, and other enclosures to the service equipment, the service power source ground, or both.

Grounding Electrode: A device that establishes an electrical connection to the earth.

Grounding Electrode Conductor: The conductor used to connect the grounding electrode(s) to the equipment grounding conductor, to the grounded conductor, or to both, at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at the source of a separately derived system.

In-phase Monitor: a device that monitors the relative phase angle between the two power sources serving a transfer switch. This device is used with the controls of an ATS as a permissive control to allow transfer between the two power sources only upon the condition of the two sources achieving a near synchronous condition.

In Sight From (Within Sight From, Within Sight): Where this Code specifies that one equipment shall be "in sight from," "within sight from," or "within sight," and so forth, of another equipment, the specified equipment is to be visible and not more than 15 m (50 ft) distant from the other.

Interrupting Rating: Also "***Ampere Interrupting Capacity (AIC)***", the highest current at rated voltage that a device is intended to interrupt under standard test conditions.

Legally Required Standby System: A system legally required and classified by government jurisdiction. These systems are intended to automatically supply power to selected loads, other than those already classified as emergency. Transfer time from the normal source to the emergency source cannot exceed 60 seconds. (Refrigeration, Communications, Smoke removal, Sewage disposal, Industrial processes).

Logic Panels: Provides the intelligence/supervisory logic circuits necessary for the switch and related circuit operations. There are three forms; Electromechanical Relay, Solid State, Microprocessor-based.

Manually Operated Non-Automatic Transfer Switch: Provide all the mechanics to effect the transfer from source to source. The actual transfer or power, however, is accomplished by true hand operation of the transfer switch.

Manual Transfer Switch: See Non-Automatic transfer switch.

Neutral Conductor: The conductor that is intended to be so energized, that in the normal steady state, the voltages from every other conductor to the neutral conductor are definitely related and usually equal in amplitude.

Neutral Ground: Neutral Ground refers to the connection between neutral and ground. When a neutral-to-ground connection is properly made in accordance with the the NEC , the voltage between any metal part of the electrical system to the earth will be zero volts.

Non-Automatic Transfer Switch: A device operated manually by a physical action, or electrically by a remote control, for transferring a common load between a normal and emergency supply.

Normal Power: The power source used every day in non-emergency situations. Also called the preferred source.

On-site Generation Power: Power produced by the user, typically from an engine generator set (generator set), located in their facility.

Open Transition Transfer: A method of switching the load between sources, where power to the load is intentionally interrupted during switching (Break-before-Make).

Optional Standby System: Intended to protect public or private property or facilities, where life and safety do not depend on the system's performance. Generally, on-site generated power is supplied to selected loads automatically or manually. There is no time limit associated with the transfer. (Commercial buildings, Farms, Residences)

Overcurrent: Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

Overlapping Neutral Pole: In a four-pole switch, the fourth or neutral pole that is switched in an overlapping fashion with the main phase poles. Commonly, the neutral pole is operated to close the neutral before opening phase poles and maintain the two source neutrals connected until after the phase poles have been switched.

Pole: that portion of a device associated exclusively with one electrically separated conducting path of the main circuit of the device.

Preferred Source: See Normal Power

Program(med) Transition: see Delayed Transition Transfer

Separately Derived System: A premises wiring system whose power is derived from a source of electric energy or equipment other than a service. Such systems have no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system.

Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

Service (Rated) Equipment: The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply.

Short Circuit: An overcurrent resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions.

Standby Power: A power source other than that used everyday. Usually refers to a power used with optional or alternative systems.

Stored Energy: A mechanism used to overcome inherent forces opposed to the insulated switch (circuit breaker) closing process, which stores energy until it is needed to help open the breaker.

SCADA – Supervisory Control And Data Acquisition: A system that collects data from various components within a factory, power plant or in other remote locations and then consolidates this data at a central processor which controls the components and manages the data.

System Ground: A connection to ground from one of the current carrying conductors of a distribution circuit or of an interior wiring scheme.

System Neutral Ground: A connection to ground from the neutral point or points of a circuit, transformer, rotating machine or system. The neutral point or a system is that point which has the same potential as the point of junction of a group of equal nonreactive resistances if connected at their free ends to the appropriate main terminals or lines of a system.

Transfer Switch: An automatic or nonautomatic device for transferring one or more load conductor connections from one power source to another.

Trip Unit Device: A device which trips the operating mechanism in case of a short circuit or overload condition.

Twin Stored Energy: A type of mechanism which utilizes insulated case and switches with true two step stored energy mechanisms as the switching devices. The stored energy provides the mechanical motion to open and close the two sets of main contacts

Withstand Rating: the RMS symmetrical current a transfer switch can safely conduct during short circuit conditions.

12. Appendices

12.1. Bibliography

The following information is provided as an additional reference to subjects discussed in this manual.

The following publications are available for order through your Caterpillar dealer.

Note: The information that is contained in the listed publications is subject to change without notice.

Note: Refer to this publication, the respective product data sheet, and to the appropriate Operation and Maintenance Manual for product application recommendations.

LEXX0801

Systems Data Sheet – UL Withstand and Closing Ratings for CTS/CTG Series Automatic Transfer Switches (ATS)

LEXX0603

Systems Data Sheet – Manual Handles for Automatic Transfer Switches (ATS)

1. On-Site Power Generation: A Reference Book, Electrical Generating Systems Association, 1990
2. Enclosures for Electrical Equipment, National Electrical Manufacturers Association, NEMA Standard 250-2003
3. Standard for Health Care Facilities, National Fire Protection Association, NFPA 99, 2005
4. Standard for Emergency and Standby Power Systems, National Fire Protection Association NFPA 110, 2005
5. Standard for Electrical Safety Requirements for Employee Workplaces, National Fire Protection Association, NFPA 70 – 2005, 2005
6. Nash, Hugh O. Jr., “Ground Fault Protection and the Problem of Nuisance Tripping of Critical Feeders” IEEE CH2581-7/88
7. D. Beeman, “Industrial Power Systems Handbook” McGraw-Hill, 1955
8. A. Freund, “Double the Neutral and Derate the Transformer – Or Else!” E C & M, Dec. 1988
9. Learning Module 29: Transfer Switch Equipment, Eaton/Cutler - Hammer

12.2. Systems Data Sheet Example:

SECTION 1 – THE PURPOSE OF TESTING AND UNIT RATINGS

1. Introduction

Automatic transfer switches have been subjected to an extensive test program to show that they comply with and exceed UL 1008 standards as well as the various performance specifications used by most government agencies and major electrical engineers throughout the world. The primary test to assure the dependability of an automatic transfer switch is its ability to close into and withstand high fault currents. The purpose of this publication is to provide basic information on withstand ratings and to document the ratings the ATSs holds under UL 1008. NFPA No. 110 (emergency and standby power systems) requires that the capacity and rating of automatic transfer switches be adequate to withstand the thermal and electromagnetic effects of short circuit currents that may arise in the electrical system. It is important to be able to compare properly the withstand current rating (WCR) of the switch to the available short circuit (fault) current of the system until the protective device clears the fault.

If a transfer switch does not have adequate withstand capability – system failure, fire, injury to personnel or equipment damage may result. A clear understanding of the interrelationship between protective devices, transfer switch and system needs is necessary for a well-designed installation. Some basic information on withstand rating terms and calculations follows the enclosed rating chart.

Underwriters Laboratories (UL) is the independent testing body that has developed the standard UL 1008 which all major transfer switch manufacturers test to. UL lists products that have successfully passed a battery of witnessed tests, including the withstand and close into fault tests described herein.

Manufacturers that complete these tests are then permitted to label their products with the UL mark.

UL made significant changes in April of 1989 regarding the labeling requirements of transfer switches. Prior to that date there had been concern over coordination with some protective devices. UL clarified the labeling procedure and now allows for three rating categories.

- Current limiting fuse,
- Specific class (trip time) of molded case breaker,
- "Umbrella" or "Any Breaker" ratings that take into account all types of molded and insulated case circuit breakers.

These tests are performed for a duration of 3 cycles on units 225 amps and greater, and for 1.5 cycles on 40-150 amp units (with an optional 3 cycle duration for units up to 150 amps; note the three cycle rating on 150 amp and below units is optional as UL has determined that all breakers in this size clear in less than 1.5 cycles). The "Umbrella" or "Any Breaker" rating is therefore the actual UL requirement and definition of the ATS industry 3 cycle (or 1.5 as noted) withstand and closing rating, and should not to be confused with additional, non UL 1008 labeled "withstand only" tests.

The following pages include the UL certified ratings and specific breaker coordination charts, withstand rating data and additional specific information.

The consulting engineer must keep in mind that unless a transfer switch bears an umbrella breaker approval for use with any molded case breaker, care must be taken to assure that the breaker specified for the installation have an equal or shorter trip time when compared to the listed devices. This would limit the application of the switch to projects within the scope of its specific breaker listing.

In addition to this factor, many transfer switch manufacturers perform additional withstand tests on selected products. These additional tests may be either for a higher current valve or a longer duration than their standard UL Listed ratings. The consultant must determine the applicability of these tests and take careful note of the fact that these levels are normally not UL labeled ratings.

Certified Withstand and Closing Ratings in Symmetrical RMS Amperes at 480 Volts AC

Switches Rated for		Wisthstand and Closing Current Ratings per UL 1008					
Model	UL 1008 Switch Rating	Withstand and Closing Ratings when Coordinated with any		Specific Coordinated Breaker Rating		Any Breaker Rating	Minimum UL 1008 Ratings
		Max. Fuse Size Amps	Max Circuit Amps	Max Circuit Breaker Size Amps	Max Circuit Amps	Max Circuit Amps	
TS1	40	50	200,000	400	30,000	10,000	5,000
TS1	80	100	200,000	400	30,000	10,000	5,000
TS1	100	125	200,000	400	30,000	10,000	5,000
TS1	150	200	200,000	400	30,000	10,000	10,000
TS1	200	300	200,000	400	30,000	10,000	10,000
TS1	225	300	200,000	800	50,000	35,000	10,000
TS1	260	350	200,000	800	50,000	35,000	10,000
TS1	400	600	200,000	800	50,000	35,000	10,000
TS	600	750	200,000	800	65,000	50,000	12,000
TS	800	1,200	200,000	1,200	65,000	50,000	16,000
TS	1,000	1,250	200,000	1,600	85,000	50,000	20,000
TS	1,200	1,500	200,000	1,600	85,000	50,000	24,000
TS	1,600	2,000	200,000	2,500	100,000	100,000	32,000
TS	2,000	2,500	200,000	2,500	100,000	100,000	40,000
TS	3,000	4,000	200,000	4,000	100,000	100,000	60,000
TS	4,000	6,000	200,000	5,000	100,000	100,000	80,000
BTS1	100	125	200,000	800	50,000	35,000	5,000
BTS1	150	200	200,000	800	50,000	35,000	10,000
BTS1	225	300	200,000	800	50,000	35,000	10,000
BTS1	260	350	200,000	800	50,000	35,000	10,000
BTS1	400	600	200,000	800	50,000	35,000	10,000
BTS	600	750	200,000	800	65,000	50,000	12,000
BTS	800	1,000	200,000	1,600	85,000	50,000	16,000
BTS	1,000	1,250	200,000	1,600	85,000	50,000	20,000
BTS	1,200	1,500	200,000	1,600	85,000	50,000	24,000
BTS	1,600	2,500	200,000	2,500	100,000	100,000	32,000
BTS	2,000	2,500	200,000	2,500	100,000	100,000	40,000
BTS	3,000	4,000	200,000	4,000	100,000	100,000	60,000
BTS	4,000	6,000	200,000	5,000	100,000	100,000	80,000
TSD1	40	50	200,000	150	50,000	35,000	5,000
TSD1	80	100	200,000	150	50,000	35,000	5,000
TSD1	100	125	200,000	150	50,000	35,000	5,000
TSD1	150	200	200,000	400	50,000	35,000	10,000
TSD1	225	300	200,000	400	50,000	35,000	10,000
TSD1	260	350	200,000	400	50,000	35,000	10,000
TSD1	400	600	200,000	800	50,000	35,000	10,000

SECTION 2 – DEFINITIONS AND CALCULATIONS

1. Purpose

Many questions arise when comparing WCR to the system fault current rating. Too often a switch is rated by a manufacturer in one set of WCR terms and the available system fault currents described with a different set of terms.

The purpose of this paper is to outline the different ways switches may be rated (WCR) and systems are measured.

2. Basic Definitions
    a. RMS Current – The Root Mean Square which is the effective value of an alternating current. It is equal to 0.707 of the peak current for a sine wave. This is the value referred to when people say "current";
    b. Peak Current – The instantaneous maximum value of current – the peak current of a sine wave is 1.414 times its RMS value;
    c. Symmetrical Current – The alternating current which is symmetrical around the zero axis of the sine wave;
    d. Asymmetrical Current – The alternating current which is not symmetrical around the zero axis;
    e. Peak Fault Current – The instantaneous maximum current value that occurs after the start of a fault in any phase;
    f. Available Peak Current – Maximum possible short-circuit current that may exist in a system without protective devices;
    g. Peak Let Through Current – Maximum instantaneous current through the protective device during the total clearing time;
    h. Withstand Current Rating – The rating that defines the ability of the switch to withstand the thermal and electromagnetic effects of short circuit currents for a set period of time;
    i. Withstand and Closing Rating – UL 1008 test for a transfer switch's ability to close into and withstand a fault current. These are the ratings which will actually appear on the UL label of the product.

Note: For diagrams of typical current wave forms, see Figure 45 and Figure 46.

3. Available Fault Current

Available fault current information can often b supplied by the utility company. If this information is not available, approximate fault current can be calculated by knowing the transformer impedance (usually 2 to 5% of full load ampere rating of the transformer).

For a single phase system, transformer let through current is:

$$1 = \frac{\text{kVA (of trans)} \times 1000}{Z \times \text{Line Volts}}$$

Where Z is transformer impedance in percent divided by 100.

For three phase systems:

$$1 = \frac{kVA \times 1000}{1.73\, Z \times \text{Line Volts}}$$

Example: 500 kVA transformer 2.5% Impedance 480 Volts, 3 phase

$$\frac{500 \times 1000}{1.73\,(.025)\,(480)} = 24{,}085 \text{ amps}$$

This figure is somewhat lower if a long run of cable introduces substantial additional impedance. Available fault current determine the rating that a transfer must meet.

4. Comparison of Terms

The following values have all been used to describe identical circuit conditions:

a. Available short circuit current RMS 120,000 amps;
b. Peak Let Through Current (1/2 cycle) 30,000 amps;
c. Peak Asymmetrical Current 56,000 amps;
d. Peak Symmetrical Current 40,000 amps;
e. Withstand Rating – 3 cycles RMS 28,000 amps.

U.L. Withstand and Closing Ratings for CTS/CTG Series Automatic Transfer Switches (ATS)

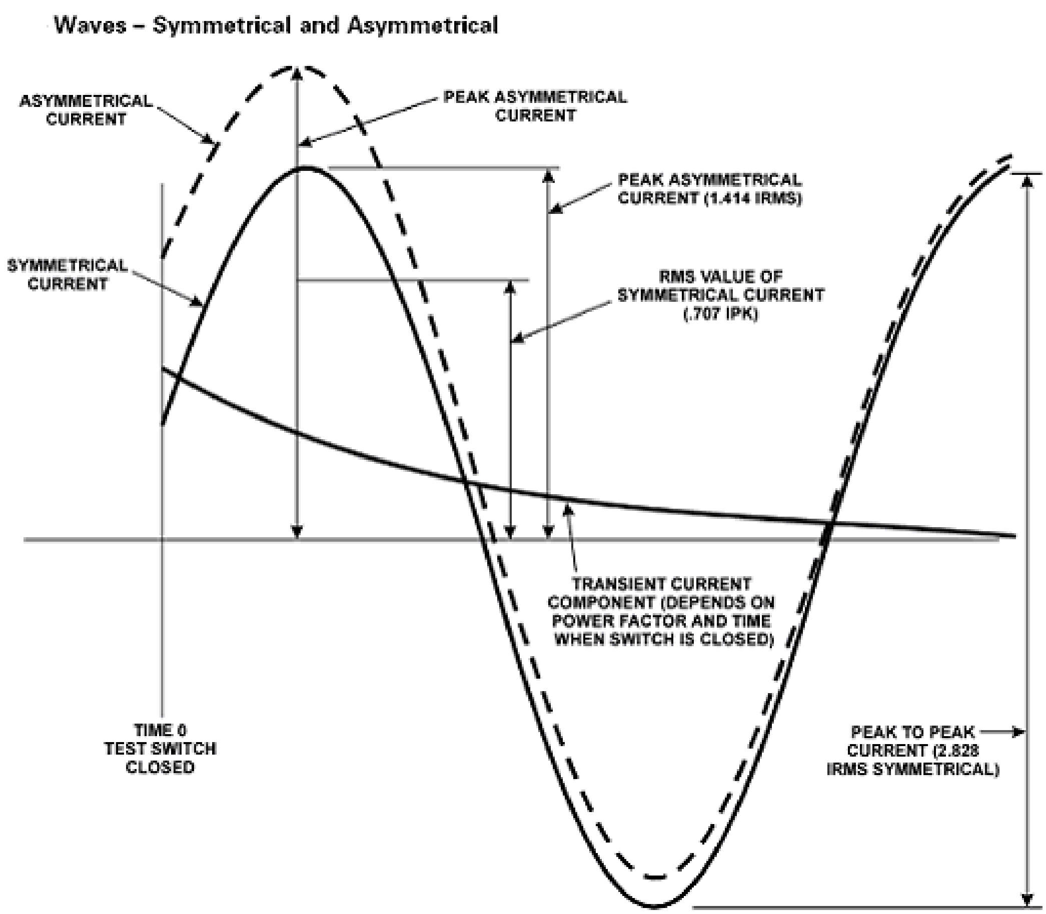

Figure 45

Current Limiting Fuse Effects

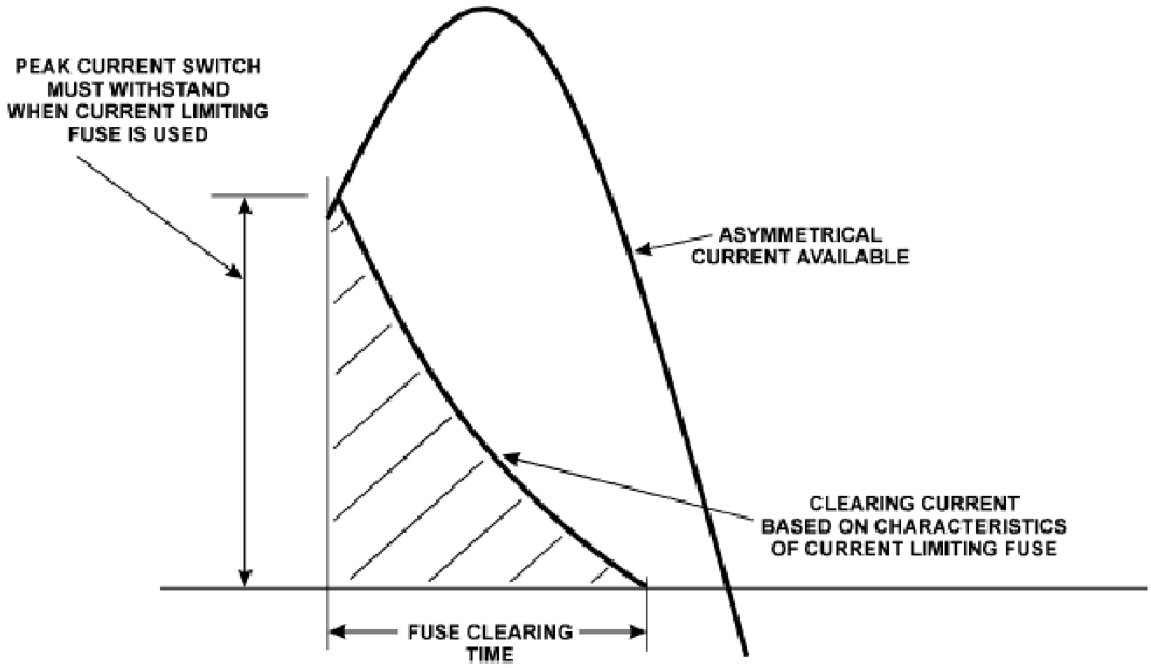

Figure 46

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