

TSEWG TP-9: AUTOMATIC TRANSFER EQUIPMENT**INTRODUCTION.**

An automatic transfer switch (ATS) is used to transfer power from one source to another. An ATS often includes controls that detect a power failure and triggers other controls to start the backup power source, such as an engine generator. When the generator reaches the operating voltage and frequency, the ATS transfers the loads from the normal source to the generator. An ATS often includes controls to retransfer power back to the normal source after it has been restored. Thus, the ATS can coordinate the complete sequence of operation, including engine starting, transfer of power to the generator, retransfer back to normal after power is restored, and subsequent engine shutdown.

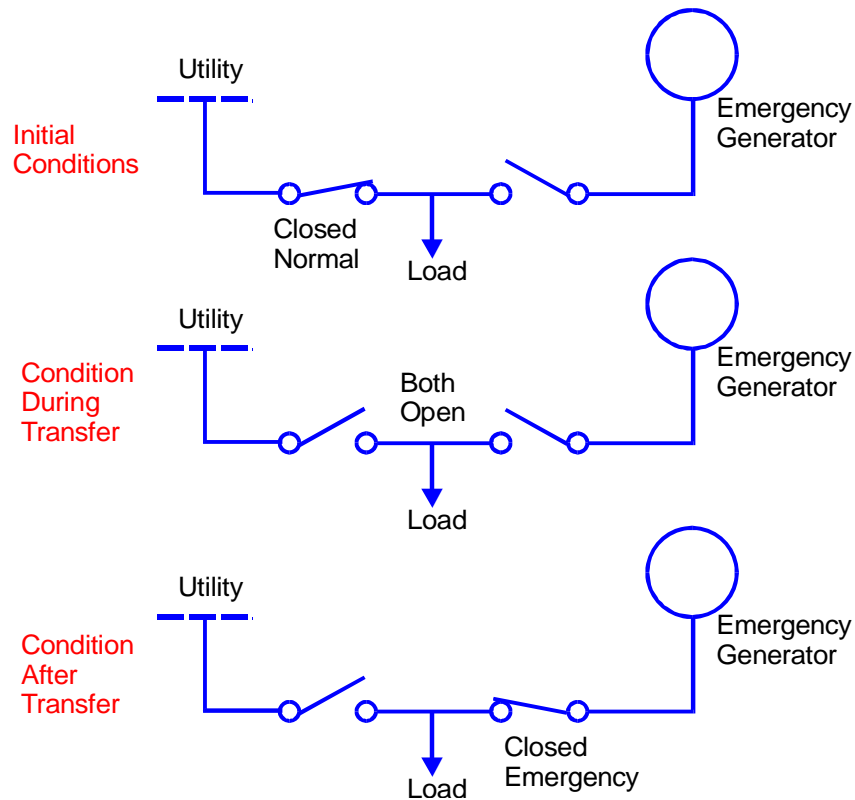
Considering that the ATS can control the entire process of power transfer to the backup source and eventual retransfer to the normal source, the ATS is an important part of a backup power system. If the ATS fails for any reason, backup power cannot be transferred even if it is available, unless a manual option is included with the ATS or if a manual bypass is installed in parallel with the ATS.

Some of the design criteria provided in this section relate to ATS applications in which the choice of power is either the utility (commercial power) or an onsite emergency source. In many ATS applications, the potential for cross-connecting emergency power to the utility supply will not be a design concern because of the location of the ATS in the electrical distribution system.

TRANSFER METHODS.**Open Transition Transfer (Break Before Make).**

Open transition transfer is a break before make transfer in which the loads are momentarily deenergized during the transfer; the original connection to the source is opened followed by a connection to the alternate source (refer to Figure 1). The length of time that the loads are deenergized can vary from a few milliseconds to several seconds or more, depending on the transfer switch design and operating logic.

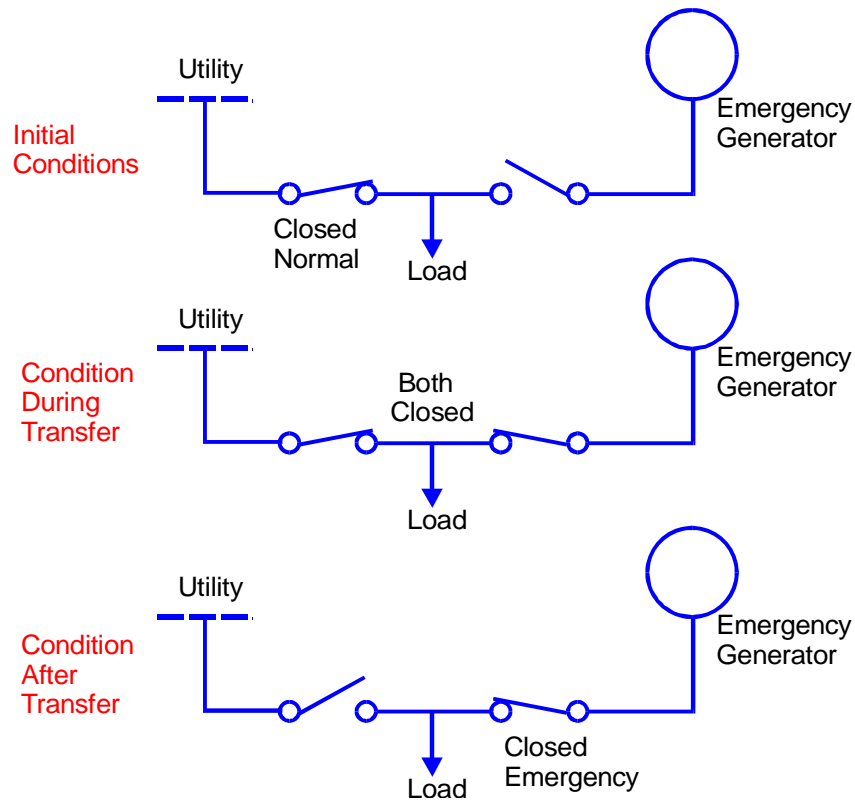
Figure 1 Open Transition Transfer



Open transition transfer is usually used for transfers from normal commercial power to an emergency generator, and back. In this case, open transition transfer avoids issues arising with possibly paralleling, even momentarily, an emergency generator with commercial power.

Closed Transition Transfer (Make Before Break).

Closed transition transfer is a make before break transfer in which the normal source is momentarily paralleled with the alternate source (refer to Figure 2). Closed transition transfer is often used on UPS systems to transfer to and from its bypass, and it is also a standard feature on high end rotary UPS systems. Closed transition can be used between an energized normal source and an energized alternate source, including two emergency generators. Note that closed transition transfer is only possible when both the normal and alternate sources are available. Upon loss of the normal source, the transfer switch must operate in open transition transfer mode to the alternate source.

Figure 2 Closed Transition Transfer

Closed transition transfer must be used with care on any transfer scheme that includes commercial power. Because of the problems that can be caused by inappropriate closed transition transfer, the following subsections provide additional information and design criteria if commercial power is involved.

Closed transition transfer between commercial power and an emergency generator means that the two sources are momentarily operating in parallel. In this case, install all controls and protective functions necessary to operate a generator in parallel with commercial power. Do not use an in-phase monitor to accomplish the transfer. Instead, include synchronization equipment with the transfer switch to actively control the speed and phase angle of the generator relative to the utility. The generator must be properly designed for parallel operation with commercial power, including provisions for load control and power factor control. Note that even with the above features, closed transition transfer will still place the full load on an unloaded generator as an instantaneous load. This block loading of the generator will cause a voltage and frequency excursion that still might exceed the intended power disturbance limits.

Utility permission is required for all systems paralleled with the utility system. Even if the utility grants permission, it will probably impose additional protective relaying requirements to protect the utility system from transfer switch problems. Some utilities do not allow closed transition transfer with the emergency system under any conditions.

Regularly scheduled testing of a system with closed transition transfer will usually only transfer the load from an energized source to another energized source. This configuration does not represent the actual system configuration when normal power is lost. When normal power fails, the transfer switch must transfer the deenergized load to the energized emergency side, and all equipment must be capable of handling the subsequent inrush currents. This capability cannot be tested without actually deenergizing the loads and requiring the emergency system to then pick up the loads.

NEC Article 700.6 (2005 Edition) requires that transfer equipment be designed and installed to prevent the inadvertent interconnection of normal and emergency sources of supply in any operation of the transfer equipment. For closed transition transfer, a switch failure could cause both sources to remain connected to the load.

The above cautions have been provided because closed transition transfer requires careful design and still might not be accepted by the local utility if commercial power is involved. Instead, a UPS system should be used for those loads that require uninterrupted power. In the case of a UPS, closed transition transfer to and from the bypass is appropriate because the ac power source to the UPS is the same in each case.

Fast Transfer (Break Before Make). Fast transfer schemes accomplish a transfer within a few cycles. Typically, an in-phase monitor is used to keep the transfer within some degree of synchronization. This approach has been used as one method of transferring motor loads. Under loss of normal power conditions, even a fast transfer scheme can cause significant stress on electrical equipment; an in-phase monitor cannot fully anticipate or compensate for the complex rate of change of frequency. Fast transfer schemes require careful evaluation.

DESIGN CONSIDERATIONS.

Continuous Current Rating.

An ATS is usually installed upstream of branch circuits because it is supplying power to a variety of loads. Thus, the ATS must be capable of maintaining power to continuous loads and withstanding different types of abnormal loading or short circuit conditions. An ATS is continuously exposed to system full-load current. During normal operation, current flows through the ATS to supply the operating loads. Upon loss of power, the ATS transfers to a backup source of power, such as an engine generator. This load requirement is different than for other backup power supplies that only have to provide power during the period that normal power is lost.

The ATS has to do more than provide power 24 hours a day for its expected service life. During this period, load switching, periodic short circuits, or abnormal environmental conditions must not degrade its performance below acceptable levels. Finally, as an ongoing maintenance consideration, the ATS continuous duty capability should be achievable with minimal maintenance.

To meet the above continuous duty requirements, the ATS contact temperature rise must be well below that established for an 8-hour rated device. Select an ATS capable

of carrying the maximum continuous load current. Momentary inrushes need not be included in the continuous load requirement, provided that the ATS is rated for the inrush. Table 1 shows typical ATS continuous current ratings:

Table 1 Typical ATS Continuous Current Ratings

Current Ratings (amperes)	
30	600
40	800
70	1000
80	1200
100	1600
150	2000
225	3000
260	4000
400	

Consider oversizing the ATS to be as large in current carrying capability as its upstream protective device. Although oversizing an ATS will add to the system cost, it ensures that the ATS does not become the limiting component if loads are added to the system.

Fault Current Withstand Rating.

An ATS has to be capable of withstanding the stresses and dissipate the heat energy generated during short circuit currents. ATS withstand current ratings vary with switch size and type as shown in Table 2. An ATS has to be rated for 1) the available fault current at its location in the electrical system and 2) the expected duration that the fault current will be present before an upstream overcurrent device (or the ATS if it has integral overcurrent protection) clears the fault; both design features are important.

Table 2 Typical ATS Fault Current Ratings

Available Symmetrical Amperes RMS Ratings at 480 Volts						
ATS Rating (Amperes)	Long-Time Withstand With Any Overcurrent Protective Device		Rating When Applied With a Rated MCCB	Rating When Applied With Current Limiting Fuses		
	Symmetrical Amperes RMS at 480 Volts	Time (Cycles)	Symmetrical Amperes RMS at 480 Volts	Symmetrical Amperes RMS at 480 Volts	Fuse Size Maximum	Fuse Type
30	10,000	1.5	22,000	100,000	60	J
70, 100	10,000	1.5	22,000	200,000	200	J
150	10,000	1.5	22,000	200,000	200	J
260	35,000	3	42,000	200,000	600	J
400	35,000	3	42,000	200,000	600	J
600, 800	50,000	3	65,000	200,000	1200	L
1000, 2000	65,000	3	85,000	200,000	2000	L
1600, 2000	100,000	3	100,000	200,000	3000	L
3000, 4000	100,000	3	100,000	200,000	6000	L

An ATS is rated in terms of the available RMS symmetrical current at a specified power factor. The system short circuit study must consider the X/R ratio at the ATS location. Higher than rated X/R ratios allow the fault current to peak higher and be sustained longer than was certified during ATS certification testing. If the system X/R ratio exceeds that of the ATS certification, discuss the available options with the manufacturer. Higher withstand and X/R ratio ATS designs are available.

Arc Interrupt Capability.

When a set of contacts open that are carrying power, an arc will be drawn as the contacts separate. The duration of the arc increases with higher voltages and lower power factors. In an ATS, the arc between the opening contacts must be extinguished before the other contacts close. Otherwise, a short circuit can occur between the two sources.

When an ATS transfers from the normal source to the emergency source, an arc might not occur because the normal source voltage might be zero. But, when the switch retransfers back to the normal source, it will have to interrupt the full voltage of the emergency source. During testing, the switch might have to interrupt full voltage between both sources.

When evaluating an ATS application, review the manufacturer's test documentation to ensure the ATS is capable of repeated arc interruption during transfer.

Inrush Current Capability.

When an ATS transfers to its alternate source, its contacts must be capable of withstanding a substantial inrush current. The amount of current depends on the type of load. Regardless of the load type, the ATS contacts must not weld when closing on loads with high inrush currents. UL 1008, *Standard for Automatic Transfer Switches*, requires that an ATS be capable of withstanding inrush currents of 20 times the

continuous current rating. Verify the selected ATS has contacts rated for heavy duty use.

An ATS is rated for different types of loads, such as the following UL 1008 classifications:

- Resistive load consisting of heating and other noninductive loads.
- Electric discharge lamp load consisting entirely of electric discharge lamps, including fluorescent lamps.
- Incandescent lamp load consisting entirely of incandescent lamps.
- Motor loads.
- Total system load consisting of any combination of motors, electric discharge lamps, resistive heating, and incandescent lamp loads. The incandescent lamp loads cannot exceed 30 percent of the ATS continuous current rating.

Simultaneous Closure of Both ATS Power Sources.

An ATS must be designed to prevent the normal source and the alternate source from being inadvertently connected to the load at the same time. The operating mechanism should be simple, yet ensure that the two sources are interlocked from ever being simultaneously closed.

ATS Power Source.

An ATS should receive its power to transfer from the source to which it is transferring the loads. For example, upon loss of normal power, the power to the ATS must come from the emergency power source to which it transfers. The controls used for ATS operation should ensure reliable switching operation and not allow the transfers to cross through an off position.

Maintainable Design.

In order to accomplish periodic maintenance, the ATS design must be maintainable. Most components should be accessible from the front of the ATS. Also, the ATS must be in a location that allows interior access. A parallel bypass feature should be provided if power to the load cannot be interrupted or if outages cannot be easily scheduled.

Static Transfer Switches.

Static transfer switches provide digital switching without the use of electromechanical components. This allows very fast transfer times compared to conventional ATS designs. Static transfer switches are commonly provided with UPS systems and are usually provided with an independent certification based on UL 1008. The ATS design

criteria apply also to static transfer switches. In particular, inrush and overload capability must be confirmed during the design process.

Sizing.

Most ATS designs are capable of carrying 100 percent of rated current at an ambient temperature of 40 °C (104 °F). Some designs, including those incorporating integral overcurrent protective devices, might be limited to a continuous load of 80 percent of the ATS rating. Confirm the continuous load rating as part of the sizing and selection process.

When sizing an ATS, specify a switch capable of carrying the total current load, including anticipated future load additions. The required ATS rating is calculated by adding the amperes required by all loads. Apply the following guidelines when determining the total load.

- Only a motor's continuous load current has to be considered. Motor inrush current need not be included, provided that the ATS or static transfer switch is rated for inrush capability.
- Resistive loads and incandescent lamp loads are determined from the total wattage.
- Fluorescent, mercury vapor, and sodium vapor lamp currents must be based on the current that each ballast or autotransformer draws, not the total watts of the lamps.

In ambient temperatures above 40 °C (104 °F), the ATS might require derating. Consult with the manufacturer for sizing requirements for operation above this temperature.

Effect of Motor Loads.

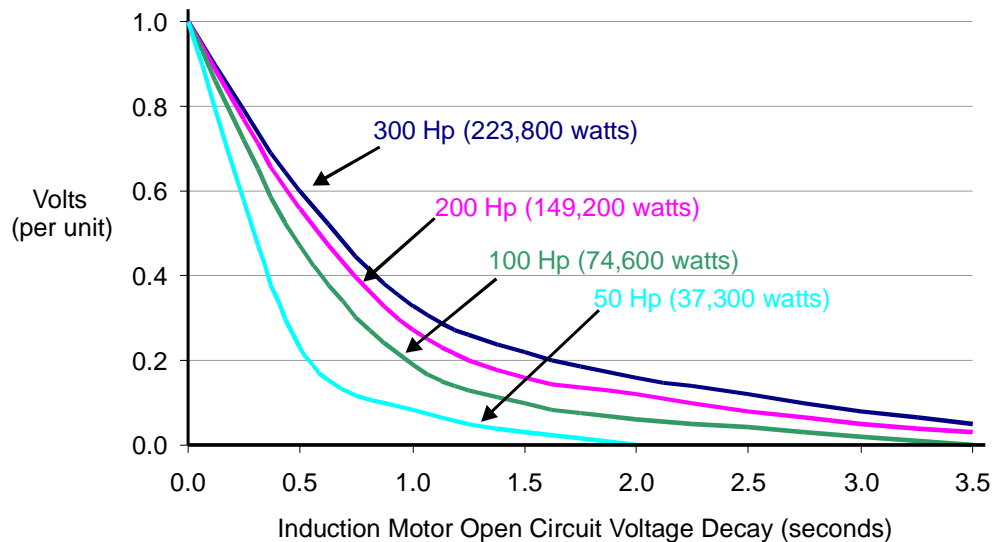
Motor loads require two considerations with regard to transferring their power source by an ATS during open transition transfer:

- How to avoid nuisance breaker tripping and possible motor damage when the motor is switched between two unsynchronized energized sources. Motors and related equipment can be damaged when switched between two energized power sources. During a retransfer back to normal power or during a system test, both power sources are at full voltage, which can result in abnormal inrush currents in large motors causing damage to motor windings, insulation, or couplings.
- How to shed motor loads prior to transfer to prevent overloading of the alternate power source. Engine generators are often used as the alternate power source to an ATS. When substantial motor load is present, the resulting inrush current can overload the generator. Engine generators that are intended as an emergency power source are often sized for the expected

full-load current plus a limited margin for motor starting. The engine-generator can be overloaded if several motors simultaneously have high inrush currents. In these cases, the loads must be sequenced onto the generator. Time delays are usually used on less critical loads to assure that the most important loads are connected first. Load shedding ASDs with subsequent restart might be necessary to avoid damaging the ASD during the period of ATS power transfer.

The standard method used to avoid the potential problems with motor loads is to include a time delay in the transfer circuit to allow the residual motor voltage to decay to a safe level before allowing connection to the alternate source. When a running induction motor is disconnected from its power source, the motor generates residual internal voltage until the stored residual magnetism dissipates due to losses in the iron and as the motor loses speed. Figure 3 shows the typical voltage decay rate for different size motors.

Figure 3 Induction Motor Open Circuit Voltage Decay



The motor voltage should be below 0.25 per unit to allow a safe connection to the transferred source. Although only 1 to 2 seconds is necessary for voltage to decay to this level, the transfer should be delayed by 5 to 10 seconds to be conservative. This provides adequate margin for several motors operating from a common source. If this long of a time delay is not desired because of other loads, the motor loads should be separately disconnected by the automatic transfer equipment and then restarted in a sequenced manner after the transfer has been made.

Some transfer switches use a phase angle monitor in an attempt to avoid the motor voltage decay problem. The rate of change of frequency associated with motor loads is complex and varying during transfer. Phase angle monitors should not be used because they are not guaranteed to achieve an in-phase transfer.

Maintaining Ground Fault Protection.

Ground fault protection requires special consideration with an ATS. Specify four-pole ATS designs to ensure that the neutral is switched with the circuit.