

# Transfer switch 101

An introductory guide to picking the right transfer switch for your environment

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## Executive summary

Transfer switches play an essential role in keeping critical electrical loads functional during power outages. In an effort to help facilities managers and others select the most appropriate transfer switch for their specific environment, this white paper introduces readers to what transfer switches do and describes their most common applications, transition types, switching mechanisms, and operation modes.

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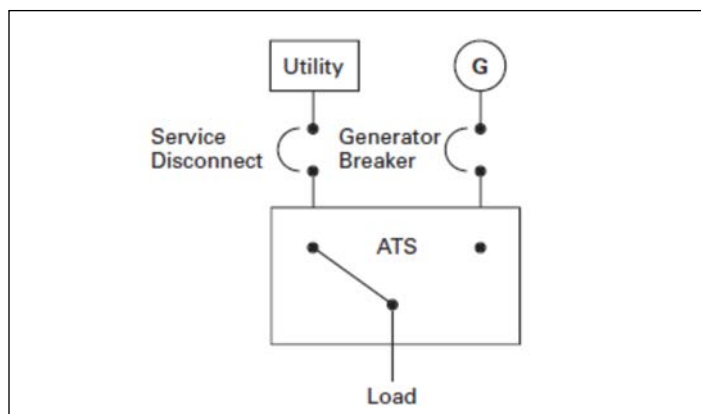


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## Transfer switch basics

Data centers, hospitals, factories, and a wide range of other commercial and institutional facilities that require continuous or near-continuous uptime typically utilize an emergency power source, such as a generator or a backup utility feed, when their normal power source is unavailable. Transfer switches are responsible for quickly and safely transitioning all electrical power consumed by the circuit, equipment, or systems connected to the transfer switch output between those normal and emergency power sources. All electrical power consumed by the circuit, equipment, or system connected to the transfer switch output is defined as the load. A typical transfer sequence includes these steps:

1. The normal power source fails.
2. When power from the generator or the backup utility feed is stable and within prescribed voltage and frequency tolerances, the transfer switch shifts the electrical load to the emergency power source. Depending on the facility's needs and preferences, that transfer either occurs automatically or is executed manually.
3. When utility power is restored, the transfer switch returns the load from the emergency power source to the normal one. Again, this can happen automatically or manually, depending on the type of switch being used and its operation mode.



**Figure 1. One-line drawing of the basic elements of a transfer switch**

## Common system installation types

Transfer switches are employed in a variety of applications that typically fall into one of four categories defined by the National Electrical Code® (NFPA 70): emergency systems, legally required systems, critical operations power systems, and optional standby systems. Understanding those categories is important, as they play a critical role in determining what kind of transfer switch you require.

### Emergency systems

Emergency systems supply, automatically distribute, and control electricity used by systems essential to life safety during fires and other disasters. They include fire detectors, alarms, emergency lights, elevators, fire pumps, public safety communication systems, and ventilation systems, and are commonly found in hotels, theaters, sports arenas, and hospitals.

Emergency systems are regulated by a municipal, state, federal, or other government agency. Transfer from the normal power source to the emergency source must complete within 10 seconds and meet the requirements of Article 700 of the National Electrical Code (NFPA 70). In addition, overcurrent devices must be selectively coordinated with all supply-side overcurrent protective devices.

### Legally required systems

Legally required systems automatically supply power to a selected set of regulated loads not classified as emergency systems when normal power is unavailable. They serve critical heating, refrigeration, communication, ventilation, smoke removal, sewage disposal, and lighting functions that could create hazards or hamper rescue or fire-fighting operations if denied electrical power.

As with emergency systems, legally required systems are regulated by municipal, state, federal, and other governmental agencies. Transfer from the normal power source to the emergency source must complete within 60 seconds and meet the requirements of Article 701 of the National Electrical Code (NFPA 70). Overcurrent devices must be selectively coordinated with all supply-side overcurrent protective devices.

### Critical operations power systems (COPS)

COPS supply, distribute, and control electricity in designated critical areas when a normal power source fails. They include HVAC, fire alarm, security, communication, signaling, and other services in facilities that a government agency has deemed important to national security, the economy, or public health and safety. All COPS must meet the requirements of Article 708 of the National Electrical Code (NFPA 70), and their overcurrent devices must be selectively coordinated with all supply-side overcurrent protective devices.

### Optional standby systems

Optional standby systems supply power to loads with no direct bearing on health or life safety, and are not required to function automatically during power failures. They are typically found in commercial buildings, farms, and even residences, and must meet the requirements of Article 702 of the National Electrical Code (NFPA 70).

## Understanding transition types

Transfer switches can transition loads between normal and emergency power sources in two basic ways: open or closed. The specific functions performed by a given load and the importance of those functions to safety or security play an important role in determining which kind of transition is required.

### Open transition

An open transition is a “break before make” transfer. That is, the transfer switch breaks its connection to one power source before making a connection to the other. For some period of time between disconnection and connection, neither the normal power source nor the emergency source is providing electricity to downstream loads.

There are two kinds of open transition: open delayed and open in-phase.

### Open delayed transition

In an open delayed transition, the transfer switch pauses in-between disconnecting from one power source and connecting to the other. That delay typically lasts either a specific, pre-set amount of time or however long it takes the load voltage to drop below a pre-specified level.

#### Advantages

- Building a delay into the transition process can prevent higher than normal electrical current (also known as “inrush current”) from developing. Inrush current can occur when an inductive load is rapidly reconnected to a non-synchronized power source. It can be an issue in applications where a residual voltage is briefly maintained at the load due to the generator effect created by a rotating motor or by the stored energy released from a transformer’s windings or core
- Operation is independent of electrical synchronization between both sources of power
- A transfer between power sources can be initiated automatically or manually

#### Disadvantages

- Unless some type of stored energy system, such as an uninterruptible power supply (UPS), is located downstream of the transfer switch, loads will experience a brief interruption in power during the transition delay period

### Open in-phase transition

With open in-phase transitions, an automatic controller uses built-in intelligence to execute an open transition at the precise moment it expects the normal and emergency power sources to be synchronized in phase, voltage, and frequency. In-phase transitions are typically completed in 150 milliseconds or less to ensure that inrush current is equal to or less than the normal starting current of the inductive load(s). If synchronization doesn’t occur within that time span, some transfer switches have the ability to default automatically to a delayed transition that serves as a failsafe.

#### Advantages

- The rapid transfer time means that a transfer is accomplished without an appreciable power interruption to the load, provided that the system is properly adjusted

#### Disadvantages

- In-phase transitions must be executed by an automatic controller. Manual operation is not possible as microprocessor logic is needed to manage source synchronization
- If both sources of power are available but unable to meet pre-set synchronization criteria, and the transfer switch isn’t capable of defaulting to a delayed transition, a transfer will not occur

### Closed transition

A closed transition is a “make before break” transfer, in that the transfer switch makes a connection to the new power source before breaking its connection to the old one. As there’s no gap between disconnection and connection, downstream loads receive continuous power throughout the transfer process.

Switches configured for closed transitions usually transfer power automatically as soon as both power sources are closely synchronized in phase, voltage, and frequency. The overlap period during which both sources are simultaneously connected, or “paralleled,” usually lasts no more than 100 milliseconds to comply with local utility interconnect requirements.

#### Advantages

- Critical loads can continue to operate, without an interruption in power, during loaded generator engine testing
- Energy costs can be reduced through “peak shaving,” which is the ability to control usage from a utility during intervals of high demand in order to limit or reduce demand penalties during a given billing period
- Depending on the application, may eliminate the need for a UPS to be located downstream

#### Disadvantages

- Transfer switches sophisticated enough to execute a closed transition tend to cost more
- Some utilities require closed transitions to comply with interconnect requirements aimed at preserving power quality and protecting utility service personnel and equipment. In some cases, this can require the inclusion of protective relays in the electrical circuit
- Closed transitions must be executed by an automatic controller. Manual operation is not possible as microprocessor logic is needed to manage source synchronization
- Closed transitions can produce higher fault current, due to the 100 millisecond period when both power sources are paralleled. As a result, the consulting engineer may specify a higher withstand close-on rating (WCR), which could require oversizing the transfer switch amperage rating

## Understanding switching mechanisms

The switching mechanism is the part of a transfer switch that is physically responsible for carrying the rated electrical current and shifting the connection from one power source to another.

Low voltage switching mechanism technology comes in two basic varieties, commonly referred to as “contactor type” and “circuit breaker type.” Circuit breaker switching mechanisms can be further divided into two sub-types: molded case and power case.

### Contactor switching mechanisms

This is the most common and affordable switching mechanism type. In most cases, contactors are constructed as a double-throw switch where a single operator opens one set of power contacts while closing a second set. In an open transition design, a mechanical interlock is often employed to prevent simultaneous closure of both contact sets. In a closed transition design, the mechanical interlock is absent.

### Advantages

- Contactor switching mechanisms support all three transition types: open delayed, open in-phase, and closed
- Transfer switches equipped with a contactor switching mechanism are generally the most economical

### Disadvantages

- Contactor switching mechanisms don't include integral overcurrent protection, so the power contacts are not self-protecting. In the event of a fault, the contacts will typically remain closed and future viability is dependent on other protective devices in the electrical circuit, eliminating the condition
- At rated amperage, WCR may be lower when compared to a circuit breaker switching mechanism



**Figure 2. Contactor switching mechanisms are fast and flexible, but don't offer overcurrent protection**

### Molded case switching mechanisms

Routinely used for closing and interrupting a circuit between separable contacts under both normal and abnormal conditions, molded case switches feature simple designs and are capable of supporting either a mechanically operated, over-center toggle or a motor operator. They are typically assembled in an enclosed housing constructed of insulating material.

When configured for use in a transfer switch, a pair of molded case switches are operated via a common, interlocking mechanical linkage. The linkage can be driven manually or automatically. When overcurrent protection is needed, molded case circuit breakers equipped with a thermal-magnetic trip element are used.

Molded case switching mechanisms provide a compact, cost-effective and service entrance-rated solution, as they eliminate the need for additional upstream protective devices. Each molded case mechanism individually complies with industry standard UL<sup>®</sup> 489, which covers low voltage molded case switches and circuit breakers.

### Advantages

- Contacts are self-protecting at high fault currents due to integral magnetic sensing
- Molded case switching mechanisms can be configured with integral overcurrent protection that provides “lock-out” functionality and eliminates automatic transfers into a fault condition
- Users can manually operate them under load due to “quick make/quick break,” over-center toggle switching action
- Molded case switching mechanisms provide high WCR at lower amperages, eliminating the need to oversize transfer switch frame size to meet specification requirements

### Disadvantages

- Molded case switching mechanisms are generally more expensive than contactor switching mechanisms
- Molded case switching mechanisms don't support closed or in-phase transitions



**Figure 3. Molded case switching mechanisms are ideal for loads up to 1000 A that require a compact, high-capacity transfer switch with built-in fault protection**

### Power case switching mechanisms

Power case mechanisms are larger, faster and more powerful than molded case mechanisms, and capable of handling up to 5,000 amps. The two-step stored energy technology they utilize can be operated both mechanically and electrically, and some models feature integral overcurrent protection similar to what's typically found in molded case designs. Their high, interrupt rating also makes power case mechanisms a good fit for applications vulnerable to large fault currents. Each power case mechanism individually complies with industry standard UL 1066, which covers low voltage power case breakers.

#### Advantages

- Power case switching mechanisms can be configured with a variety of trip unit types that provide integral, programmable overcurrent protection, ground fault sensing, power quality metering, and diagnostics
- Power case switching mechanisms offer the highest withstand and amperage ratings of any switching mechanism design
- Rapid closing speed facilitates in-phase and closed transitions in addition to delayed transitions
- Unlike both contactor and molded case mechanisms, power case switching mechanisms can be configured for "selective coordination," allowing the protective device located immediately upstream of an electrical fault to open first, leaving the rest of the power distribution system operational. For many applications, including emergency, COPS and legally required systems, use of selective coordination is mandatory

#### Disadvantages

- Power case switching mechanisms are larger than contactor and molded case designs
- Power case switching mechanisms are typically the most expensive of the three switching mechanism types



**Figure 4. Power case switching mechanisms are available up to 5000 A and offer the highest withstand close-on rating of any switching mechanism type**

### Understanding operation modes

Power transfers involve two processes: initiation and operation. Initiation is what starts the transfer. Operation is what completes it. Most transfer switches can support multiple operation modes through the addition of configurable options.

#### Manual mode

In manual mode, both initiation and operation are performed manually, typically by pushing a button or moving a handle.

#### Advantages

- With molded case or power case designs, transfers can occur under load as a failsafe if the automatic controller and/or control circuitry sustain damage or become inoperable
- Human operator has maximum control over the transfer process
- Transfer is independent of the automatic controller

#### Disadvantages

- An operator must be physically present to initiate a transfer—even overnight and on weekends
- Transition delay time is dependent on the operator and therefore may increase when compared to automatic mode transfers, which are described below
- Limited to open delayed transitions, as open in-phase and closed transitions require microprocessor logic to manage source synchronization
- On some transfer switch designs, operators must open an outer safety door to access the switching mechanism, exposing them to energized electrical equipment and potentially requiring them to wear personal protective equipment
- Facilities with emergency and legally required installations are usually prohibited by law from using manual mode unless their transfer switch is capable of performing an automatic transfer in certain especially urgent situations

#### Non-automatic mode

In non-automatic mode, the operator manually initiates a transfer by pressing a button or rotating a switch that causes an internal electromechanical device to electrically operate the switching mechanism.

#### Advantages

- As with manual mode, operators are in complete command of transfer initiation
- Transitions complete more rapidly than with manual mode because of the electromechanical device that electrically operates the switching mechanism
- Non-automatic transfer switches tend to cost less than an automatic type

#### Disadvantages

- As with manual mode, a human operator must be present to initiate a transfer, and there's no support for open in-phase or closed transitions

### Automatic mode

In automatic mode, the transfer switch controller completely manages both initiation and operation. Initiation is triggered when the automatic controller senses an unavailability or loss of source power and operation is typically performed by an electric solenoid or motor.

### Advantages

- Transfers and re-transfers can be completed in the shortest time possible
- As the transfer switch executes the entire transition process itself, there's no dependence on a human operator
- Users enjoy greater flexibility, as they can select from automatic, non-automatic, and manual operation modes using programmable set points and/or an integral control panel
- Automatic mode meets NEC requirements applicable to emergency and legally required systems

### Disadvantages

- Automatic transfer switches tend to cost more than devices that operate only in manual or non-automatic mode

### Bypass isolation mode

Traditional transfer switches feature a single switching mechanism. In contrast, bypass isolation transfer switches include dual switching mechanisms that provide redundancy for critical applications. The primary switching mechanism handles day-to-day distribution of electrical power to the load, while the secondary switching mechanism serves as a backup. During repair or maintenance procedures, a technician can bypass power around the primary mechanism through the secondary mechanism to ensure that critical loads remain powered without interruption.

### Advantages

- Operating in bypass isolation mode allows users to service transfer switches safely without compromising availability
- The secondary switching mechanism provides built-in redundancy if the primary mechanism malfunctions or requires routine inspection

### Disadvantages

- Transfer switches with bypass isolation mode are usually more expensive, as they require dual switching mechanisms
- Dual switching mechanisms also make switches with bypass isolation mode larger than traditional transfer switch types

## Conclusion

Transfer switches support multiple operation modes and transition types, and feature a range of different switching mechanisms. With the help of the information in this white paper, however, facilities managers can sort through their options and choose the right switch for their specific requirements.

## About Eaton

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