Transfer Switch Controls and Operations for Mission Critical Applications

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October 28th, 2021
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Meet your panelists

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Course Objectives

Transfer Switch Controls and Operations for Mission Critical Applications

A critical component of a transfer switch is the control. This course dives into the features that a transfer switch control must include to meet the demands and complexities of today’s applications. And since transfer switch equipment is available in a variety of types with a wide array of features, selecting the appropriate transfer switch for a specific application requires a clear understanding of site needs and application restraints.

After completing this course, participants will be able to:

- Describe the basic components of transfer power equipment
- Discuss transfer switch controls and features to best meet application needs and requirements
- Learn about the basic operation of transfer switches and transition types to aid in the selection of equipment for a particular application
## Integrated Power System Components

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<th>Source Switching</th>
<th>Distribution Boards &amp; Control</th>
<th>Remote Monitoring</th>
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<td>Transfer switches</td>
<td>Switchgear UL1558</td>
<td>Diagnostics</td>
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<td>Switchboard UL891</td>
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<td>System level control</td>
<td>Push notifications</td>
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</table>
What to Consider When Specifying A Transfer Switch

- Application (Utility-Gen, Gen-Gen, Utility-Utility)
- Service-entrance or non-service-entrance
- Switch type (Transfer Switch, Bypass Isolation Switch)
- Transition type (Open, Closed, Non-Automatic)
- Number of poles (3-Pole or 4-Pole)
- Switch positions (2-Positions, 3-Positions)
- Cable sizes and entry requirements (Top Entry, Bottom Entry)
- Enclosures (NEMA Type 1, 3R, 4, 4x, 12)
- Voltage/Frequency (600VAC, 480VAC / 50Hz, 60Hz)
- Current rating (40A – 3000A)
- Fault current capability (WCR: 30kA – 200kA)
- Selective coordination (WCR & Listed OCPD)
- Codes/standards (UL, CSA, NFPA, NEMA, IBC, OSHPD, ISO, EN)
Mission Critical Applications
Transfer Switch Control by Segment

- **Basic Control**
  - Generator start/stop
  - Basic LCD display
  - Delayed transition
  - Basic event log
  - Time delays
  - Basic test scheduler
  - Some level of protection

- **Midrange Control**
  - Generator start/stop
  - Larger LCD display
  - Delayed and in-phase transitions
  - Rich event log
  - Time delays
  - Flexible test scheduler
  - Higher level of protection
  - Communication

- **Advanced Controls**
  - Generator start/stop
  - Sophisticated colored LCD display
  - Closed, delayed & in-phase transitions
  - Detailed event log and diagnostics
  - Load metering
  - Load shedding and load sequencing
  - System statistics
  - Time delays
  - Advanced test scheduler
  - Advanced level of protection
  - More communication options
  - Advanced digital I/Os
## Transfer Switch Control by Segment

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### Home & Small Business
- Generator start/stop
- Basic LCD display
- Delayed transition
- Basic event log
- Time delays
- Basic test scheduler
- Some level of protection

### Commercial & Light Industrial
- Generator start/stop
- Larger LCD display
- Delayed and in-phase transitions
- Rich event log
- Time delays
- Flexible test scheduler
- Higher level of protection
- Communication

### Mission Critical
- Generator start/stop
- Sophisticated colored LCD display
- Closed, delayed & in-phase transitions
- Detailed event log and diagnostics
- Load metering
- Load shedding and load sequencing
- System statistics
- Time delays
- Advanced test scheduler
- Advanced level of protection
- More communication options
- Advanced digital I/Os
Common Transfer Switch Applications

**Utility To Generator**
For facilities with a standby power system and a single utility feed

**Generator To Generator**
For facilities with a prime power system using multiple on-site generators

**Utility To Utility**
For use in facilities with redundant utility feeds but no standby generator

**Three Source System**
For facilities with one or two standby power system(s) with one or two utility feed(s)
Common System Installation Types

- Transfer switches are applied in a variety of applications that typically fall into one of four categories defined by the National Electrical Code® (NFPA 70):
  - **Emergency systems (Article 700):**
    - Automatically supply, 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
  - **Legally required systems (Article 701):**
    - 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, and smoke removal
  - **Optional standby systems (Article 702)**
    - Supply power to loads with no direct bearing on health or life safety, and are not required to function automatically during power failures
  - **Critical operations power systems (Article 708):**
    - 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
Transfer Switch Components

- Switching mechanism
- Control
- Enclosure
- Accessories
Switching Mechanism

- Critical component of a transfer switch
  - Electrical contacts
  - Solenoid driven operators
  - Arc chutes
  - Connection terminals
Enclosures

- Enclosures are typically third-party certified for compliance to NEMA 250 and UL 50E
  - Enclosure must accommodate wire bend space in accordance with NFPA 70, regardless of direction of conduit entry
  - Exterior cabinet doors must provide complete protection for the system's internal components. Doors must have permanently mounted key-type latches
- Enclosure Types:
  - Type 1 Indoor – general purpose
  - Type 12 Indoor – dust tight
  - Type 3R Outdoor – rainproof
  - Type 4 Outdoor – watertight
  - Type 4x Outdoor – watertight & stainless steel
Accessories

- Surge protection devices (SPDs)
  - Installed on the line side
- Protective relays for closed transition operations
  - 62PL Parallel Timer
  - 32R Reverse Power
  - 86LOR Lockout relay
- Utility grade meter
- Redundant DC power supplies for diode-isolated inputs on the control
- Thermostat controlled anti-condensation cabinet heater
- Additional auxiliary contacts
- Digital inputs/outputs (I/Os)
  - User configured to meet various application needs
Transfer Switch Control

- An essential component of a transfer switch
  - Human Machine Interface (HMI)
  - Normal operational data
  - Alerts
  - Source data
  - Load transfer
  - Power sensing
  - Load metering
  - Automatic downstream load sequencing
  - Protection
  - Communication

- With today’s technology, controls are becoming more integrated without the need for additional add-on modules
Human Machine Interface (HMI)

- Readily Available Data
  - Source availability
  - Load connection
  - Date and time
  - Source 1/Source 2 voltage
  - Load KVA
  - Transfer switch name
  - Password protection status
  - Preferred source indication
  - Active banner that shows time delays, inhibits and test statuses
Active Alerts

- Event information to include the following:
  - Alert type
    - Not in auto
    - Warning
    - Information
  - Fault code name
  - Fault code description
  - Date and time of occurrence
  - Fault code number
History of Events

- Fault codes
- Active time delays
- Power system changes
- Tests and exercises
- User-driven inputs (e.g., override, transfer inhibit)
Source Statistics

- Total Time Load Energized
- Number of Transfers
- Number of Retransfers
- S1 Number of Failures
- S2 Number of Failures
- S1 Connected and Available
- Total Time on S1
- S2 Connected and Available
- Total Time on S2
- Transfer Time
- Last Transfer Due to Failure
Load Data

- Current (L-L & L-N)
- Voltage (L-L & L-N)
- Load (kW, kVA, & kVAR)
- Power factor
- Source 1 & 2 energy (kWh, kVAh, kVARh)
High Accuracy Power Quality Metering

- Current (A)
- Total Power (kW)
- Reactive Power (kVAR)
- Apparent Power (kVA)
- Power Factor (PF)
- Energy (kWH)
- Reactive Energy (kVARH)
- Apparent Energy (kVAH)
- Harmonics (V-THD & I-THD)
Exerciser Function

- Different independent schedules with exceptions
- Test Type:
  - Test without load
  - Test with load
  - Transfer to standby: Transfers and keeps the load connected to the generator set (standby source) for a specified duration, regardless of the preferred source availability
Adjustable Time Delays

- **Time Delay Engine Start (0 to 3,600s)**
  - Prevents nuisance start of the generator
- **Time Delay Engine Cooldown (0 to 3,600s)**
  - Allows the engine to cooldown after load is removed
- **Normal to Emergency (0 to 15,549s)**
  - Allows the emergency source to stabilize before transferring
- **Retransfer Time Delay (0 to 15,549s)**
  - Allows the normal source to be stable before transferring
- **Programmed Transition Time Delay (0 to 600s)**
  - Allows the switch stay is in the neutral position before transferring
- **Elevator Pre-Transfer Time Delay (0 to 600s)**
  - Allows an elevator to attempt to reach the nearest floor and open its doors, prior to a loss of power
- **Elevator Post-Transfer Time Delay (0 to 600s)**
  - Energizes elevator pre-transfer output for an additional period after connecting to destination source
Security Protection

- Three levels of password security designed to restrict user access, and display will display visually if password is enabled:
  - User Level: Modifiable password that prevents unauthorized users from accessing setup screen and initiating tests using the test button on operator panel
  - Advanced: Password that allows users access to advanced parameters
  - Service: Password that allows users (authorized services technicians only) access to advanced and service screens
- End-to-end encryption: from the transfer switch control to Cloud platforms
Voltage Sensing and Protection

- Integrated true RMS voltage sensing on **all three phases on both sources** (S1, S2)
  - No additional external power transformers
- Monitors and compares the phase rotation of each source against the system phase rotation
- Monitor both sources and detect when a neutral current exceeds the current threshold
- Sync check function with the ability to determine when both sources are within specified tolerances of frequency, voltage, and relative phase difference before transferring load
- Loss of phase detection on all three phases
Transfer Switch Transition Types

- Transfer switches transition loads between two sources. The way the transition takes place is known as the transition type.
- Three transition types:
  - Automatic open transition
    - Delayed transition
    - Fast transition sync
    - Fast transition no sync
  - Automatic hard-closed transition
  - Non-automatic transition
Automatic **Open-Delayed Transition**

- Requires a 3-position transfer switch
- Fully automatic break-before-make operation with center off position
- Switch pauses or stops in intermediate position to momentarily disconnect both sources
- Sources must be mechanically and electrically interlocked to prevent closing both sources on the load at the same time
- Application: stored energy loads such as inductive loads and MRI machines
- Time delay up to 600s
  - Set the delay so the voltage generated by the load is 22% of nominal

3 positions transfer switch: connected to S1 or S2, or in center off

![Diagram of Open-Delayed Transition](image-url)
Stored Energy Loads Power Transfer

- Voltage decays exponentially (independent of motor speed)
- NEMA MG-1 recommends a delay of 1.5 Motor Open Circuit Time Constant
  - Voltage will be at 22% of nominal
- 3-position transfer switch should be specified

Residual Voltage Decrement
Source: IEEE Orange Book (Std 446)

22% of nominal voltage (safe transfer)

Figure 4-14—Induction motor open-circuit voltage decay (based on constant speed)
Transfer Switch Add/Shed

- Transfer switch add/shed is adding and shedding the switch through an external independent load management system such as load controller or system level controller.
- The National Electrical Code (NEC) allows the alternate power source to supply emergency, legally required, and optional system loads where the source has adequate capacity or where automatic selective load shed is provided as needed to ensure adequate power.
- 3-position transfer switch should be specified.
Automatic **Open-Fast Transition Sync**

- Fully automatic break-before-make operation
- Sources must be mechanically and electrically interlocked to prevent closing both sources on the load at the same time
- No intentional time delays but waits for sources to be synchronized: Phase, voltage, and frequency
- The only delay is the time it takes the switch to move from one source to another (40ms-80ms)
- This transition mode is also known as **In-Phase** transition
- Application: small inductive loads and resistive loads
- **Note:** If synchronization doesn’t occur within that time span, some transfer switches can default automatically to a delayed transition
Automatic **Open-Fast Transition No Sync**

- Fully automatic break-before-make operation
- Sources must be mechanically and electrically interlocked to prevent closing both sources on the load at the same time
- No intentional time delays and no need to wait for sources to be synchronized before transferring
- Application: resistive loads
Automatic **Hard-Closed Transition**

- Fully automatic make-before-break operation
- Load transfer occurs by momentarily *paralleling both sources* before transferring between sources
- Both sources must be synchronized *(phase, voltage, and frequency)* and connected to load for as short a time as possible *(less than 100ms)*
- Application: seamless load transfer *(stored energy loads and resistive loads)*

![Diagram showing Hard-Closed Transition with Source 1 and Source 2, synchronized within less than 100ms]
Hard-Closed Transition
Utility Interconnect

- 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:
  - 62PL Parallel Timer
  - 32R Reverse Power
  - 86LO Lockout

- For added redundancy and maybe required by some utilities: shunt trip breaker on the normal source through the lockout relay.
Non-Automatic Transition

- Fully break-before-make operation
- Similar to delayed transition; however, the transfer is manually initiated by an operator
- All the time delays (transfer, retransfer, elevator, program transition) are active
- Control continues to monitor sources and displays source availability but requires user action to operate transfer switch using manual selector switches.
- Note: Non-automatic is not the same as Manual Transfer Switch (MTS)
  - NEC requires automatic transfer switches for life-safety and legally required loads
Downstream Automatic Load Sequencing

- Integral load control (on/off) for two independent loads to prevent overloading the generator set source while continuing to power higher priority loads.
- The control monitors the generator set frequency
- Capable of performing the following:
  - Add Load:
    - Block Load (Load 1 and Load 2 simultaneously).
    - Sequential time dependent load add (Load 1 then Load 2) with adjustable time delay
  - Shed Load:
    - Source frequency and time-delay dependent.
    - Sheds lowest priority first.
- Capable of automatically re-adding load(s) after an overload occurs
Integrated communication capabilities:
- Modbus RTU RS485
- Modbus Ethernet TCP/IP (isolated)
- USB B-Type service-tool port with dust cover

End-to-end encryption

PowerCommand® Cloud

SCADA Network
Typical Interconnect

- Remote start
- Start signal integrity per NFPA® 70 (NEC)
- Ground
- DC power
- Inhibit signals (transfer/re-transfer)
- Elevator signals
- Remote test
- Load shed
- Communication (Modbus)
- Additional wiring depending on the applying:
  - Configurable I/Os
  - Sync enable
  - Load sequencing (on/off) controls
Transfer Switch Control by Segment

**Home & Small Business**
- Basic Control
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  - Basic LCD display
  - Delayed transition
  - Basic event log
  - Time delays
  - Basic test scheduler
  - Some level of protection

**Commercial & Light Industrial**
- Advanced Controls
  - Generator start/stop
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**Mission Critical**
- Advanced Controls
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All these features and capabilities can be integrated into a single control for enhanced reliability, connectivity, and serviceability.
# Transfer Switch Short-Circuit Ratings

## Short-Circuit Withstand/Closing Ratings

When protected by a circuit breaker, this transfer switch is suitable for use in a circuit capable of delivering the short-circuit current for the maximum time duration and voltage listed below.

The circuit breaker must include an instantaneous trip response unless the available short-circuit current is less than or equal to the short-time rating of the transfer switch and the circuit breaker includes a short-time response.

The maximum clearing time of the instantaneous trip response must be equal to or less than the time duration shown for the listed short-circuit current.

When protected by a circuit breaker with a short-time trip response, the short-time response of the circuit breaker must be coordinated with the short-time current rating of the transfer switch as listed below.

<table>
<thead>
<tr>
<th>Short-Circuit Current (RMS Symmetrical Amperes)</th>
<th>AC Voltage (Maximum)</th>
<th>Time Duration (Maximum Seconds)</th>
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<tbody>
<tr>
<td>150000</td>
<td>600</td>
<td>0.050</td>
</tr>
<tr>
<td>125000</td>
<td>600</td>
<td>0.500</td>
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</tbody>
</table>

## Fuse Rating

When protected by a fuse of the specific fuse class and up to the fuse amperes listed below, this transfer switch is suitable for use in a circuit capable of delivering up to the short circuit current and voltage listed below.

<table>
<thead>
<tr>
<th>Short-Circuit Current (RMS Symmetrical Amperes)</th>
<th>AC Voltage (Maximum)</th>
<th>Fuse Class</th>
<th>Fuse Amperes</th>
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<tbody>
<tr>
<td>200000</td>
<td>600</td>
<td>L</td>
<td>4000</td>
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</table>
Withstand/Closing Rating (WCR)

- Per UL 1008, transfer switches must:
  - Withstand the fault current
  - Close on the fault current
- Transfer switches have a short-circuit Withstand/Closing Rating (WCR)
- WCR is based on either:
  - A specific duration
    - OR
  - Until a specific overcurrent protection device (OCPD) trips
High WCR - Mission Critical Applications

- High time-based short-circuit withstand/closing ratings (WCR) simplifies breaker selection
- Short-Time demonstrates that the transfer switch can still carry rated current
- High Short-Time WCR simplifies selective coordination strategies and enables the switch to be used with UL1558 switchgear

### Short-Circuit Withstand/Closing Ratings

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Course Summary

Transfer Switch Controls and Operations for Mission Critical Applications

A critical component of a transfer switch is the control. This course dives into the features that a transfer switch control must include to meet the demands and complexities of today’s applications. And since transfer switch equipment is available in a variety of types with a wide array of features, selecting the appropriate transfer switch for a specific application requires a clear understanding of site needs and application restraints.

Conclusions:

- Transfer switch typical components are the switching mechanism, control, enclosure, and accessories
- The controls for transfer switches come in a wide range of features and capabilities
  - Mission critical, industrial, and "enhanced" commercial applications require sophisticated capable controls
- Control sensing, features, and capabilities can be integrated into a single control for higher reliability, connectivity, and serviceability
- Write specifications based on features and functions
Additional Resources

Cummins White Papers

• How to simplify electrical distribution designs and enable selective coordination strategies with transfer switch high Withstand and Closing Ratings (WCR)

• Considerations for Reliable Closed Transition Transfer Switches

• AIA MasterSpec® is the industry-standard product research and specification resource for the design professional and their firm

• PowerHour: Transfer Switches What to Specify and Why

• PowerHour: Applying Transfer Switch High WCR & Short-Time Rating To Simplify Electrical System Design
Q&A

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