Transfer Switch Controls and Operations for Mission Critical Applications

PowerHour webinar series for consulting engineers

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October 28th, 2021

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Participants are encouraged to refer to the entire text of all referenced documents. In addition, when it doubt, reach out to the Authority Having Jurisdiction.

Meet your panelists

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Course Objectives

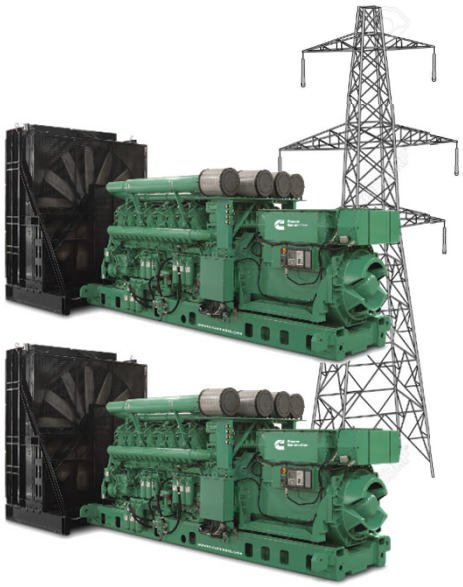
Transfer Switch Controls and Operations for Mission Critical Applications

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

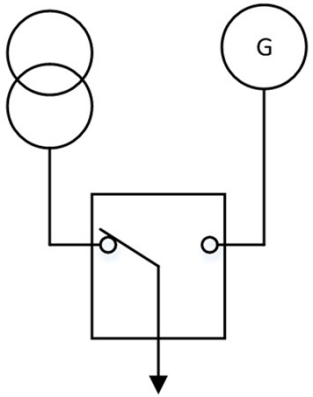


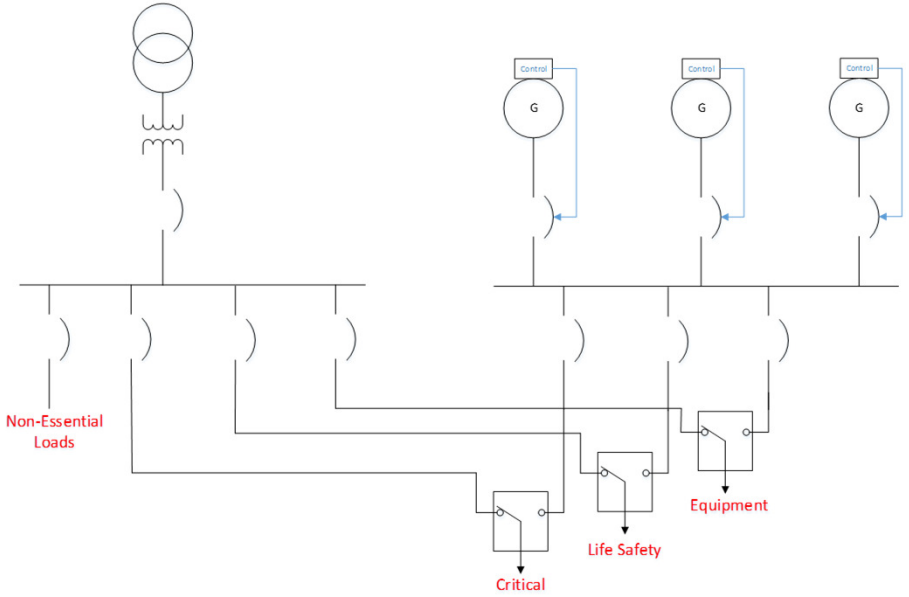
Sources	Source Switching	Distribution Boards & Control	Remote Monitoring
Utility Generator sets	Transfer switches	Switchgear UL1558 Switchboard UL891 System level control	Diagnostics Compliance reports Push notifications

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

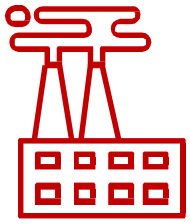




Transfer Switch Control by Segment

Home & Small Business

Commercial & Light Industrial



Mission Critical

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

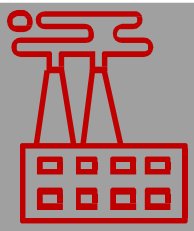
Advanced Controls

- 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

Home & Small Business

Commercial & Light Industrial



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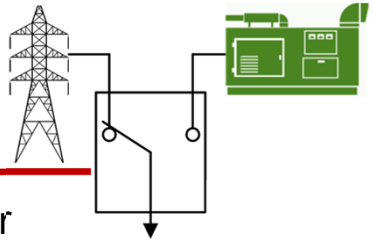
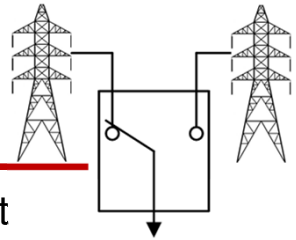
Common Transfer Switch Applications

Utility To Generator



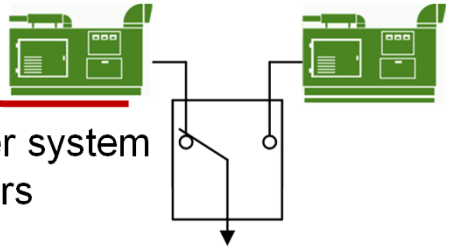
For facilities with a standby power system and a single utility feed

Utility To Utility



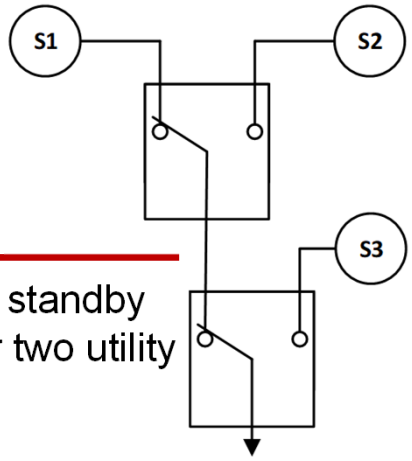
For use in facilities with redundant utility feeds but no standby generator

Generator To Generator



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

Three Source System



For facilities with one or two standby power system(s) with one or two utility feed(s)

Common System Installation Types

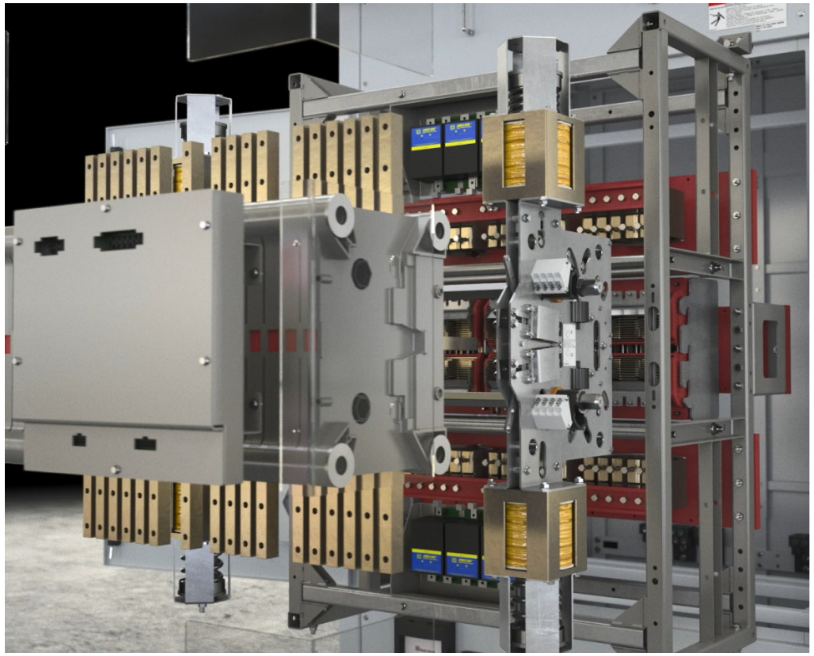
- Transfer switches are applied in a variety of applications that typically fall into one of four categories defined by the National Electrical Code® (NFPA 70):
  - Emergency systems (Article 700):
    - Automatically supply, distribute, and control electricity used by systems essential to life safety 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

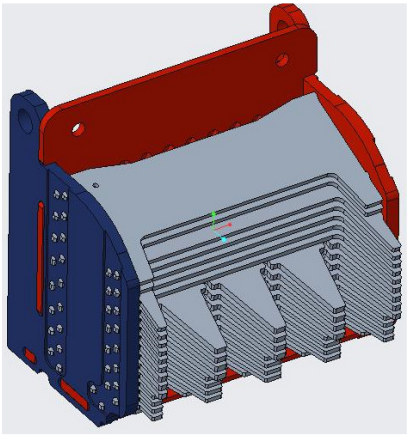
Transfer Switch Components

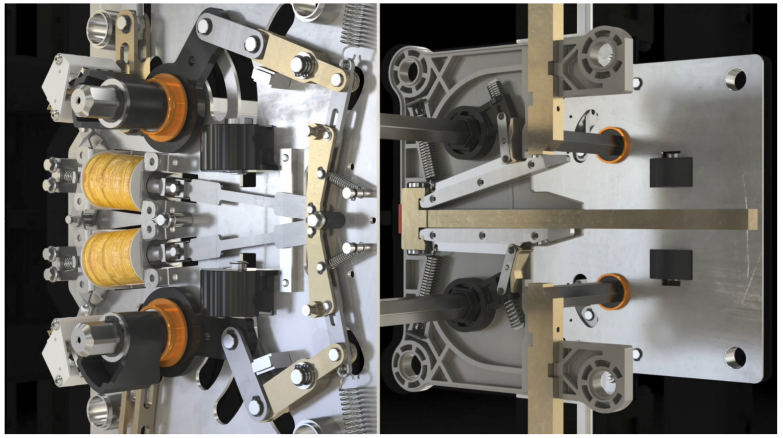
- Switching mechanism
- Control
- Enclosure
- Accessories

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

32R

SPDs

86LOR

Power Supply

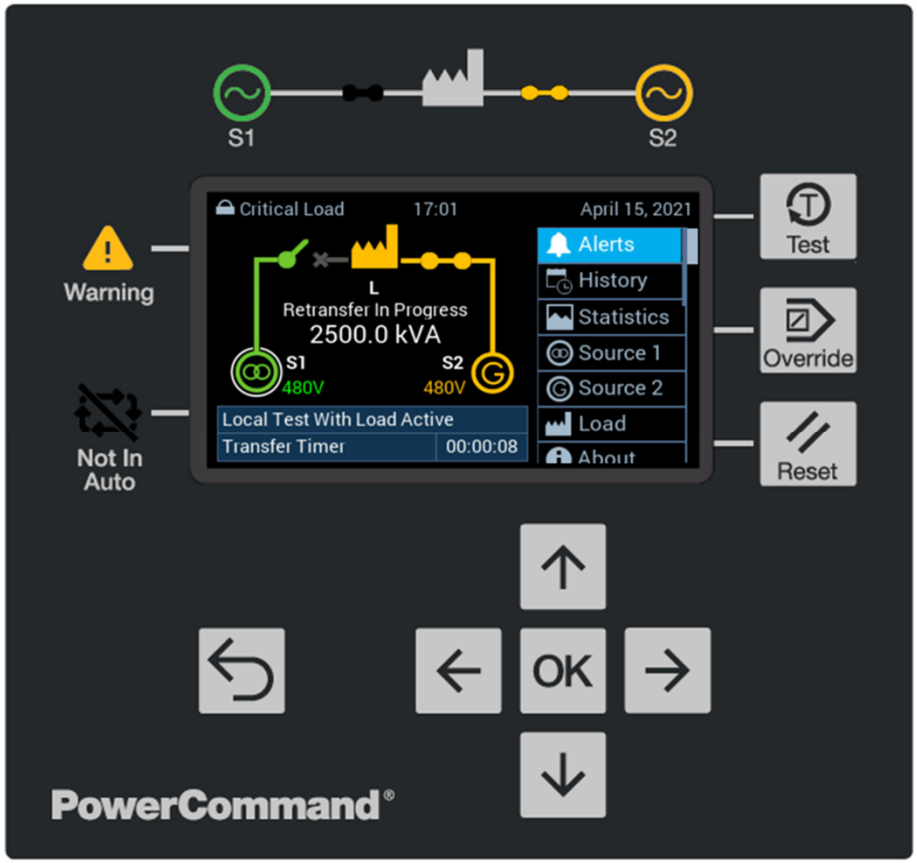
Utility Grade Meter

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

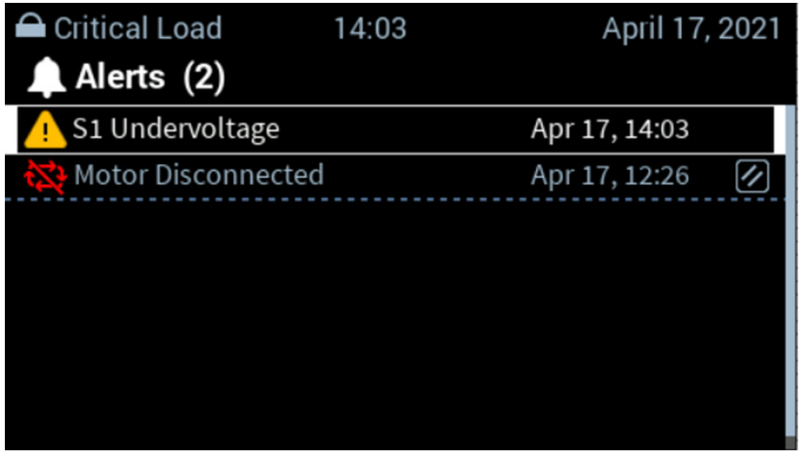
Human Machine Interface (HMI)

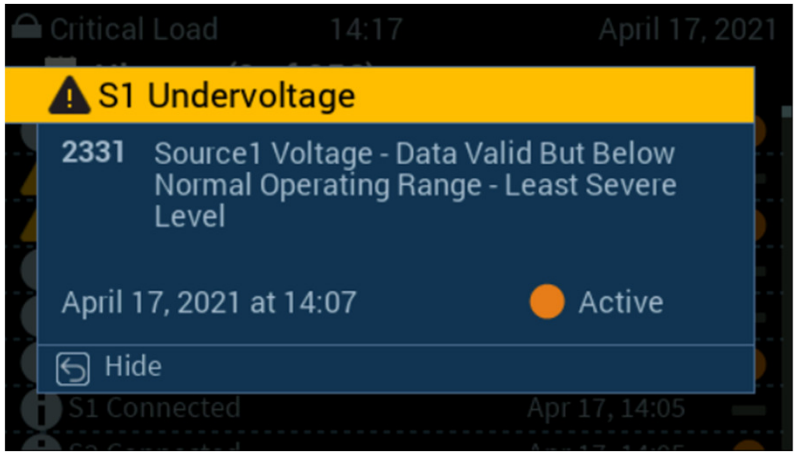
- Readily Available Data
  - Source availability
  - Load connection
  - Date and time
  - Source 1/Source 2 voltage
  - Load KVA
  - Transfer switch name
  - Password protection status
  - Preferred source indication
  - Active banner that shows time delays, inhibits and test statuses



Active Alerts

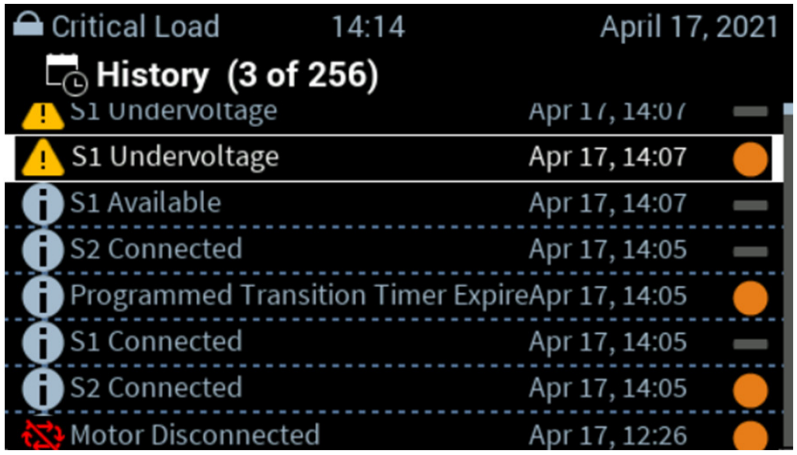
- Event information to include the following:
  - Alert type
    - Not in auto
    - Warning
    - Information
  - Fault code name
  - Fault code description
  - Date and time of occurrence
  - Fault code number





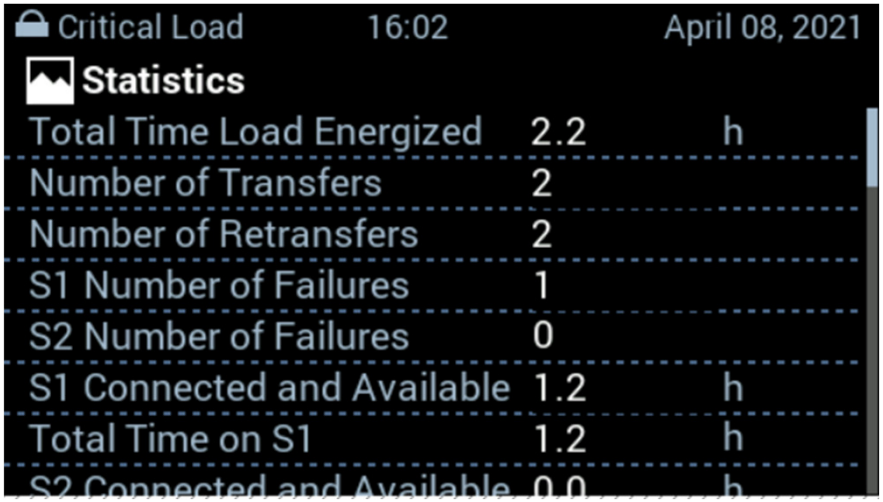
History of Events

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



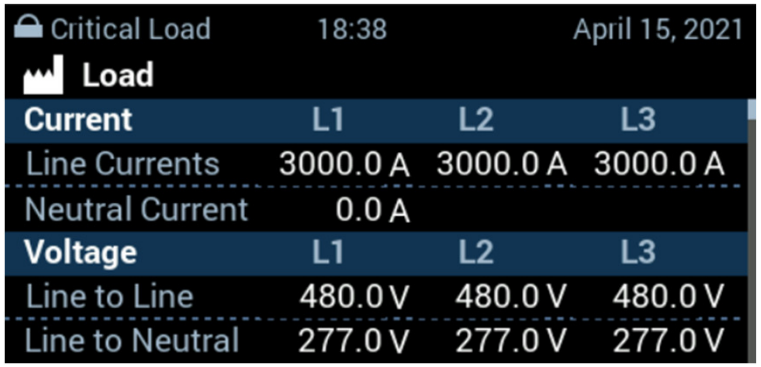
Source Statistics

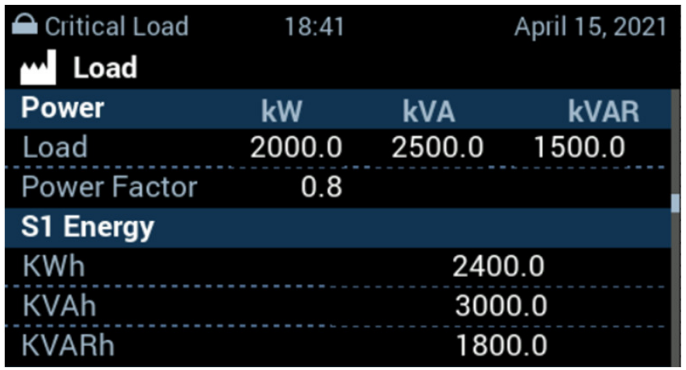
- Total Time Load Energized
- Number of Transfers
- Number of Retransfers
- S1 Number of Failures
- S2 Number of Failures
- S1 Connected and Available
- Total Time on S1
- S2 Connected and Available
- Total Time on S2
- Transfer Time
- Last Transfer Due to Failure



Load Data

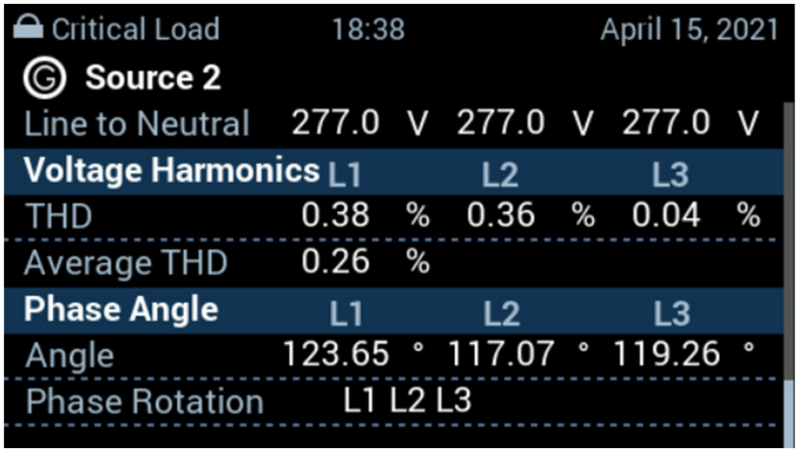
- Current (L-L & L-N)
- Voltage (L-L & L-N
- Load (kW, kVA, & kVAR)
- Power factor
- Source 1 & 2 energy (kWh, kVAh, kVARh)

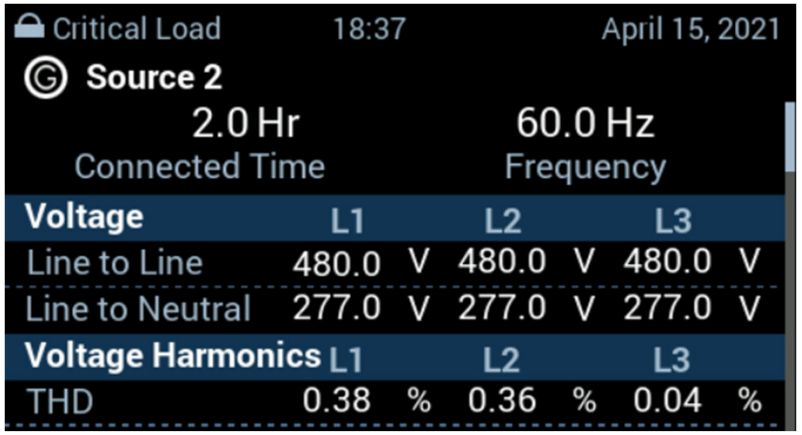




High Accuracy Power Quality Metering

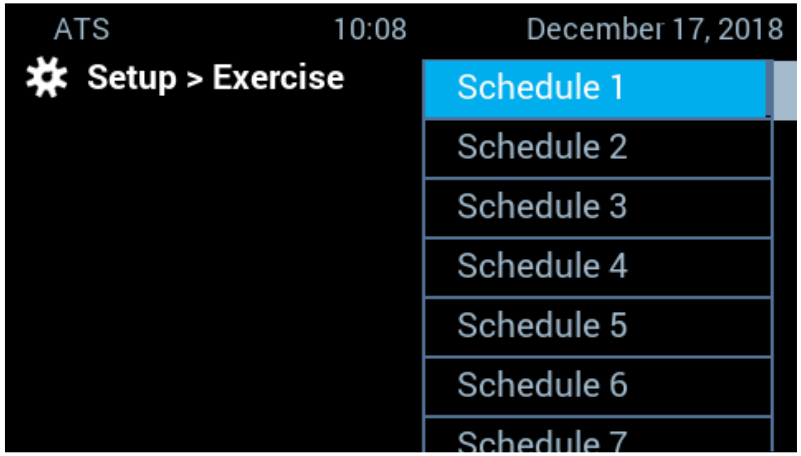
- Current (A)
- Total Power (kW)
- Reactive Power (kVAR)
- Apparent Power (kVA)
- Power Factor (PF)
- Energy (kWH)
- Reactive Energy (kVARH)
- Apparent Energy (kVAH)
- Harmonics (V-THD & I-THD)

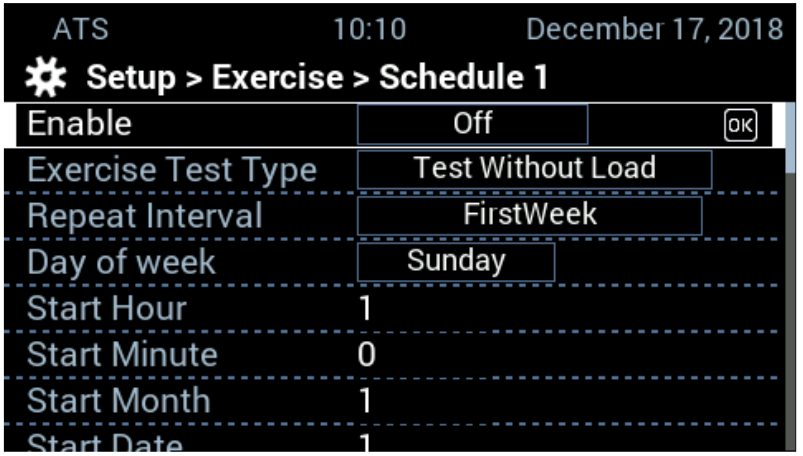




Exerciser Function

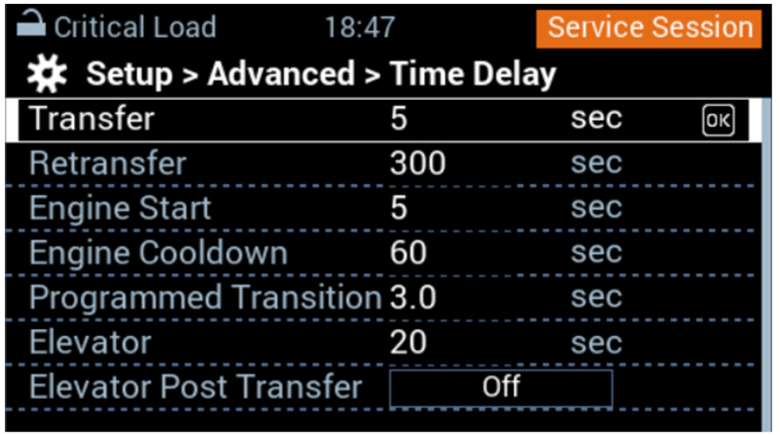
- Different independent schedules with exceptions
- Test Type:
  - Test without load
  - Test with load
  - Transfer to standby: Transfers and keeps the load connected to the generator set (standby source) for a specified duration, regardless of the preferred source availability





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



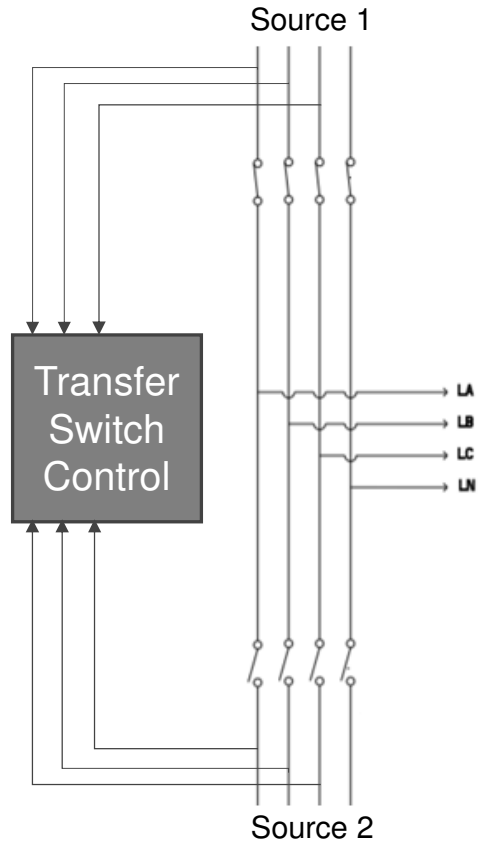
- Programmed Transition Time Delay (0 to 600s)
  - Allows the switch stay is in the neutral position before transferring
- Elevator Pre-Transfer Time Delay (0 to 600s)
  - Allows an elevator to attempt to reach the nearest floor and open its doors, prior to a loss of power
- Elevator Post-Transfer Time 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

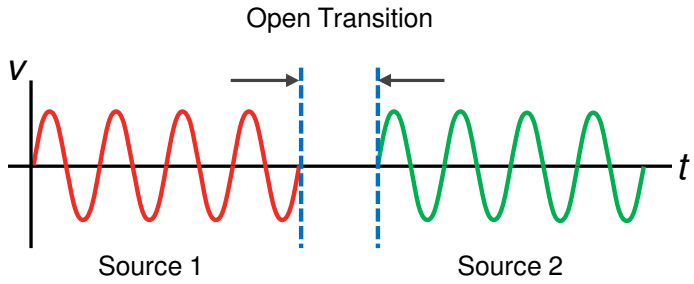
Voltage Sensing and Protection

- 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

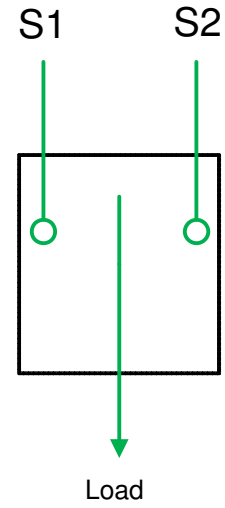
- Transfer switches transition loads between two sources. The way the transition takes place is known as the transition type
- Three transition types:
  - Automatic open transition
    - Delayed transition
    - Fast transition sync
    - Fast transition no sync
  - Automatic hard-closed transition
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



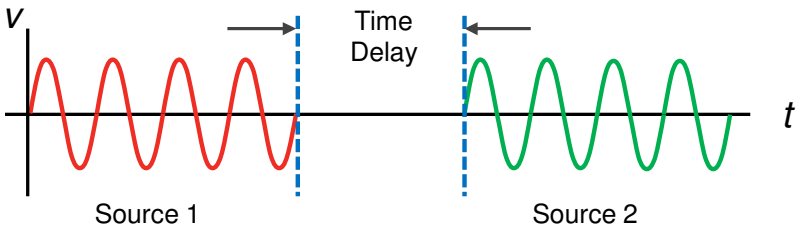
Automatic Open-Delayed Transition

- 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



Open-Delayed Transition



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)

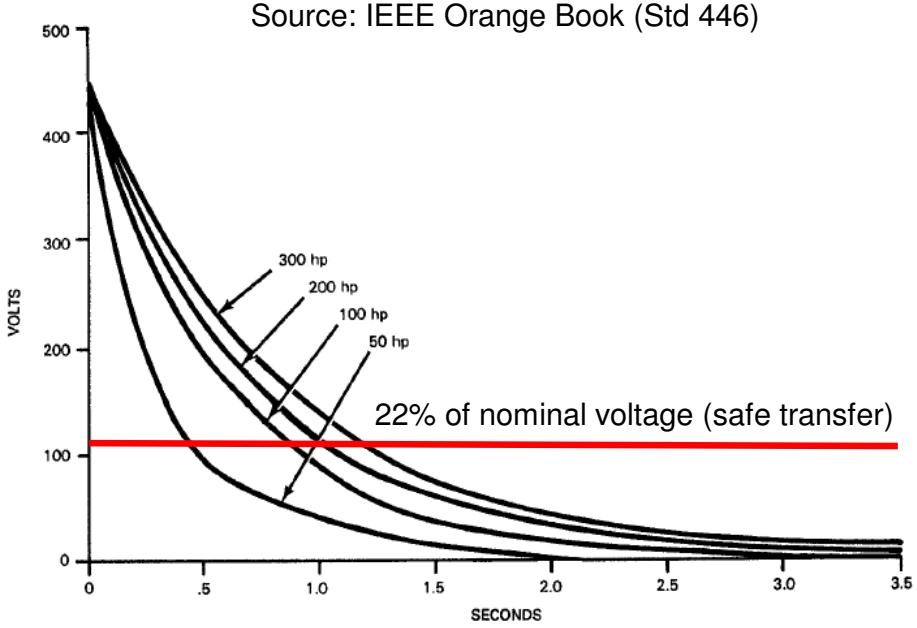
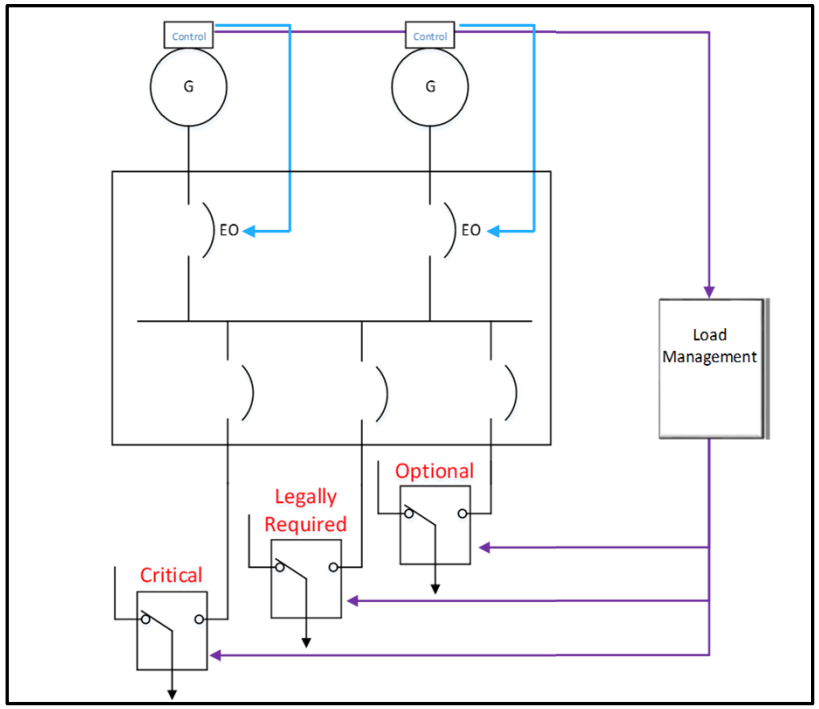


Figure 4-14—Induction motor open-circuit voltage decay (based on constant speed)

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



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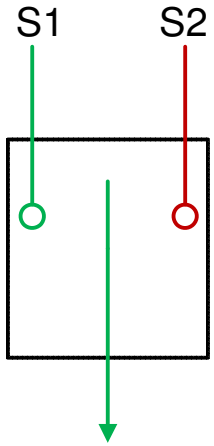
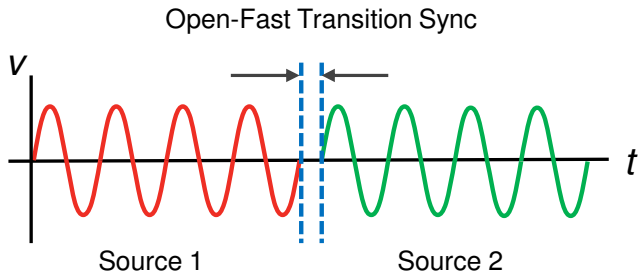


Automatic Open-Fast Transition Sync

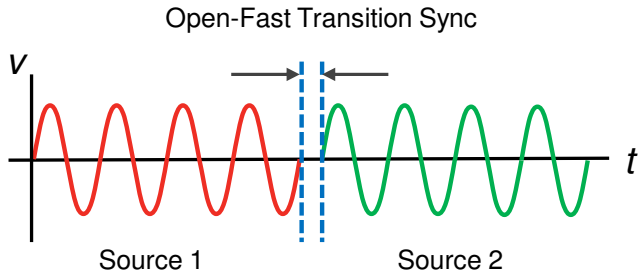
- Fully automatic break-before-make operation
- Sources must be mechanically and electrically interlocked to prevent closing both sources on the load at the same time
- No intentional time delays but waits for sources to be synchronized: Phase, voltage, and frequency
- The only delay is the time it takes the switch to move from one source to another (40ms-80ms)
- This transition mode is also known ad 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



Source 1 and 2 must be synchronized: phase, voltage and frequency before transfer

Automatic Open-Fast Transition No Sync

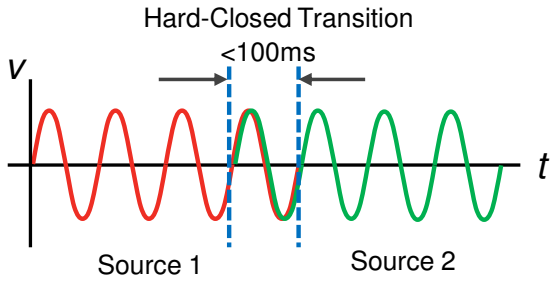
- Fully automatic break-before-make operation
- Sources must be mechanically and electrically interlocked to prevent closing both sources on the load at the same time
- No intentional time delays and no need to wait for sources to be synchronized before transferring
- Application: resistive loads



No synchronization between source 1 and 2

Automatic Hard-Closed Transition

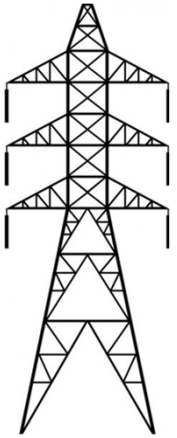
- Fully automatic make-before-break operation
- Load transfer occurs by momentarily paralleling both sources before transferring between sources
- Both sources must be synchronized (phase, voltage, and frequency) and connected to load for as short a time as possible (less than 100ms)
- Application: seamless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

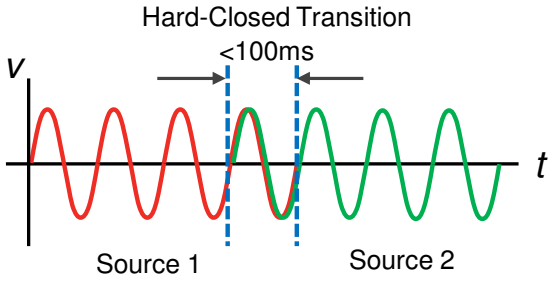


Source 1 and 2 must be synchronized: phase, voltage, and frequency

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





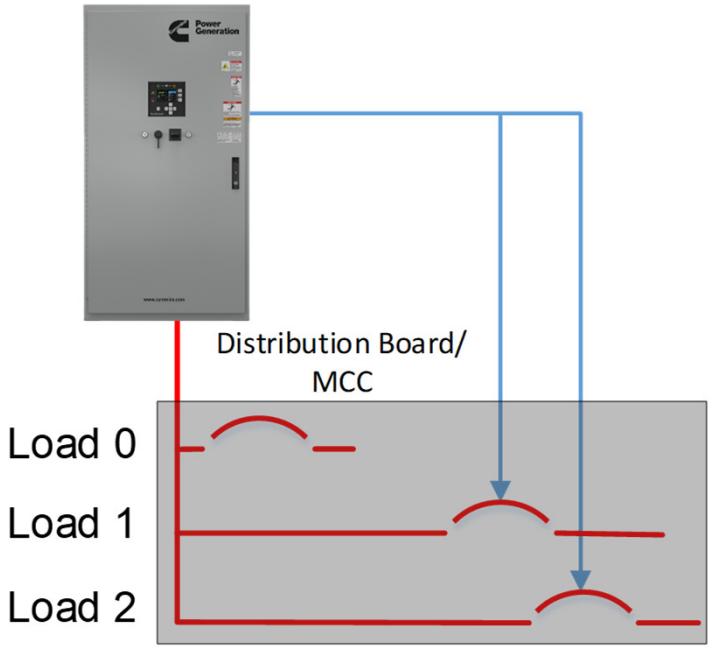
Source 1 and 1 must be synchronized: phase, voltage and frequency

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

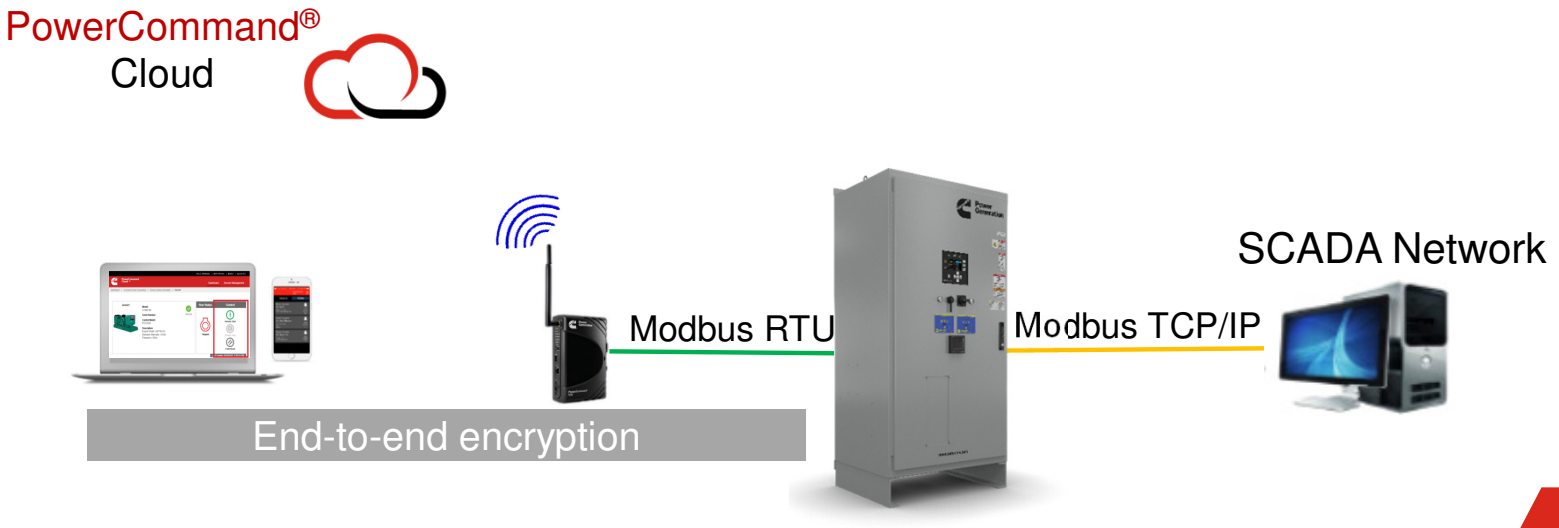
Downstream Automatic Load Sequencing

- 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



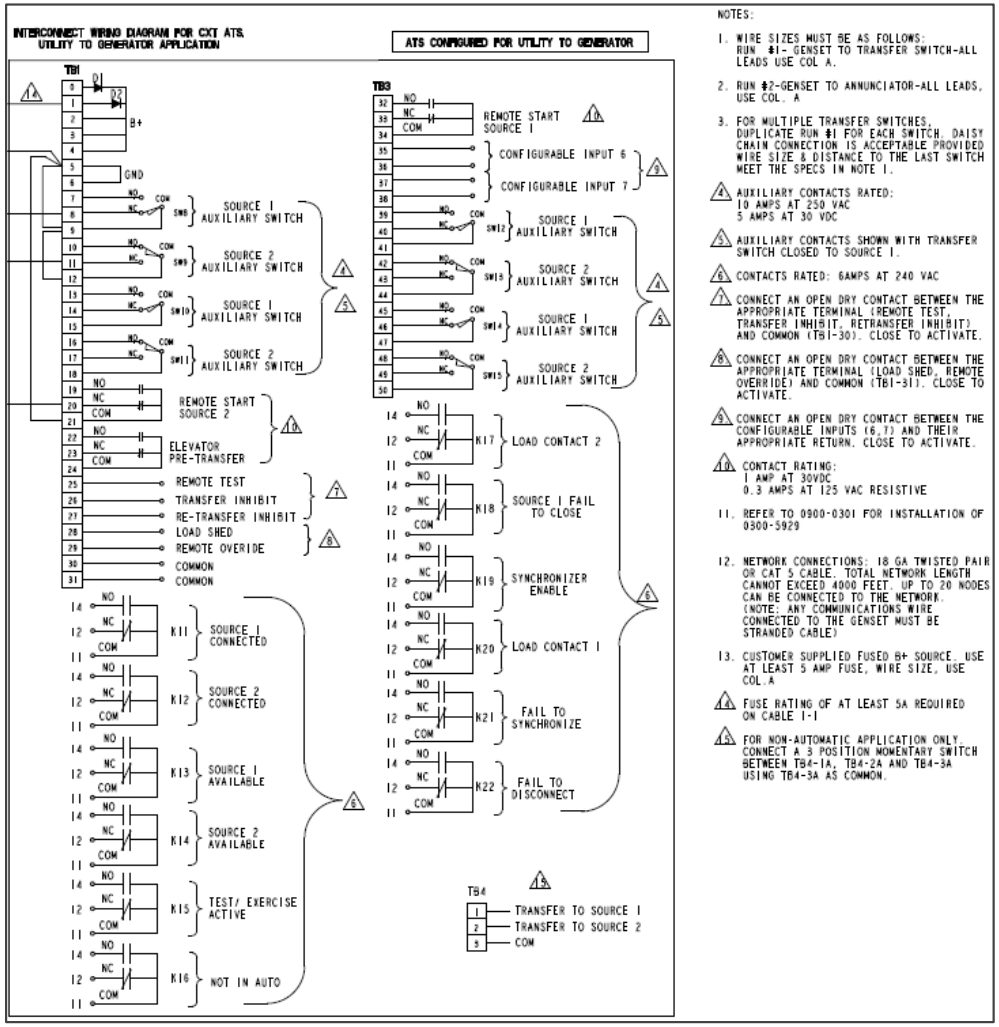
Network Communication Protocols

- Integrated communication capabilities:
  - Modbus RTU RS485
  - Modbus Ethernet TCP/IP (isolated)
  - USB B-Type service-tool port with dust cover



Typical Interconnect

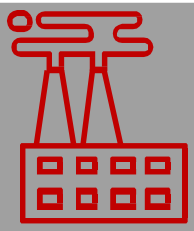
- Remote start
- Start signal integrity per NFPA® 70 (NEC)
- Ground
- DC power
- Inhibit signals (transfer/re-transfer)
- Elevator signals
- Remote test
- Load shed
- Communication (Modbus)
- Additional wiring depending on the applicating
  - Configurable I/Os
  - Sync enable
  - Load sequencing (on/off)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



Transfer Switch Control by Segment

Home & Small Business

Commercial & Light Industrial



Mission Critical

Basic Control

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

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

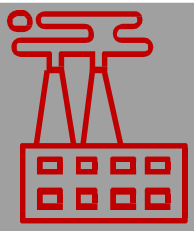
Transfer Switch Control by Segment

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 sched
- Higher level of pro
- Communication



Mission Critical

Basic Control

Advanced Controls

- Generator start/stop
- Sophisticated colored LCD Display
- Closed, delayed & in-phase transitions
- Detailed event log and diagnostics
- Load metering
- Sys
- Time delay
- Advanced test scheduler
- Advanced level of protection
- More communication options
- Advanced digital I/Os

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 AND SHORT-TIME CURRENT 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.

Short-Circuit Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
150000	600	0.050

Short-Time Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
125000	600	0.500

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.

Short-Circuit Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Fuse Class	Maximum Fuse Amperes
200000	600	L	4000

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 AND SHORT-TIME CURRENT 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.

Short-Circuit Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
150000	600	0.050

Short-Time Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
125000	600	0.500

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


HOW TO SIMPLIFY ELECTRICAL DISTRIBUTION DESIGNS AND ENABLE SELECTIVE COORDINATION STRATEGIES WITH TRANSFER SWITCH HIGH WITHSTAND AND CLOSING RATINGS (WCR)

White paper by Hassan Obeid, Global Technical Advisor

When designing a power system, sizing the electrical distribution to handle the available fault current is critical. A major challenge design engineers face when specifying transfer switches is that the available fault current and the overcurrent protection devices, specifically circuit breakers, are not known at the time specifications are written. This paper discusses how design engineers can take advantage of the high withstand and closing rating and short-time rating of transfer switches to simplify circuit breaker selection and enable effective selective coordination schemes.

Since transfer switches are applied in mission-critical and life-safety applications, superior reliability is paramount. Therefore, transfer switches are subjected to the most stringent testing requirements outlined by the leading standard in North America: UL 1008 "Standard for Safety – Transfer Switch Equipment" (UL 1008 is harmonized with Canadian standard CSA 22.2 178).

UL 1008 specifies robust testing requirements for verifying manufacturer ratings, including the Withstand and Closing Ratings (WCR).

The tests specified by UL 1008 are:

- Temperature rise test
- Dielectric voltage-withstand test
- Overload test
- Contact opening test
- Endurance test
- Short-circuit test
- Dielectric voltage-withstand test (following short-circuit withstand/closing test)
- Short-time current test (optional)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Considerations for reliable closed transition transfer switches

White Paper

By Rich Scroggins, Technical Specialist, Sales Application Engineering

Closed transition transfer switches are becoming more popular for transferring power for life safety and critical processing loads. The benefits are that the emergency power system can be tested without interrupting power to loads and power can be re-transferred to the utility after a failure without interrupting power to loads. There are risks associated with closed transition transfer as two live sources are connected together. This paper reviews best practices for minimizing these risks.

Problems with closed transition transfer originate from a difference in voltage between the two sources at the instant when the two sources are connected. The difference in voltage can be caused by several factors:

- A difference in root mean square (RMS) voltage between the sources.
- A phase angle difference between the two sources.
- A transient condition on one of the sources caused by a load switching on or off or instability of one of the sources.

The instantaneous voltage difference between the sources results in a current surge from the source with the higher voltage to the source with the lower voltage at the instant of interconnection of the sources. This current is limited only by the impedance of the sources and the cable or bus connecting the sources. It is this current surge that can result in tripping breakers or, in more extreme cases, damaging equipment.

Our recommendations for minimizing risks of out-of-phase closure include:

- Recognize that all sync check systems allow for sources to be a few degrees out-of-phase at closure resulting in some level of surge current between the sources. Breakers, transfer switches and cable must be sized accordingly.
- Consider active synchronizing with voltage matching to minimize the phase and voltage differences between sources
- Minimize the possibility of transient conditions at the moment of transfer by inhibiting multiple transfer switches from transferring at the same time and preventing other loads from cycling during the transition
- Use a transfer switch "fail to disconnect" or maximum parallel timer relay to shunt-trip an upstream breaker to prevent extended paralleling in the event that a transfer switch fails

- 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]

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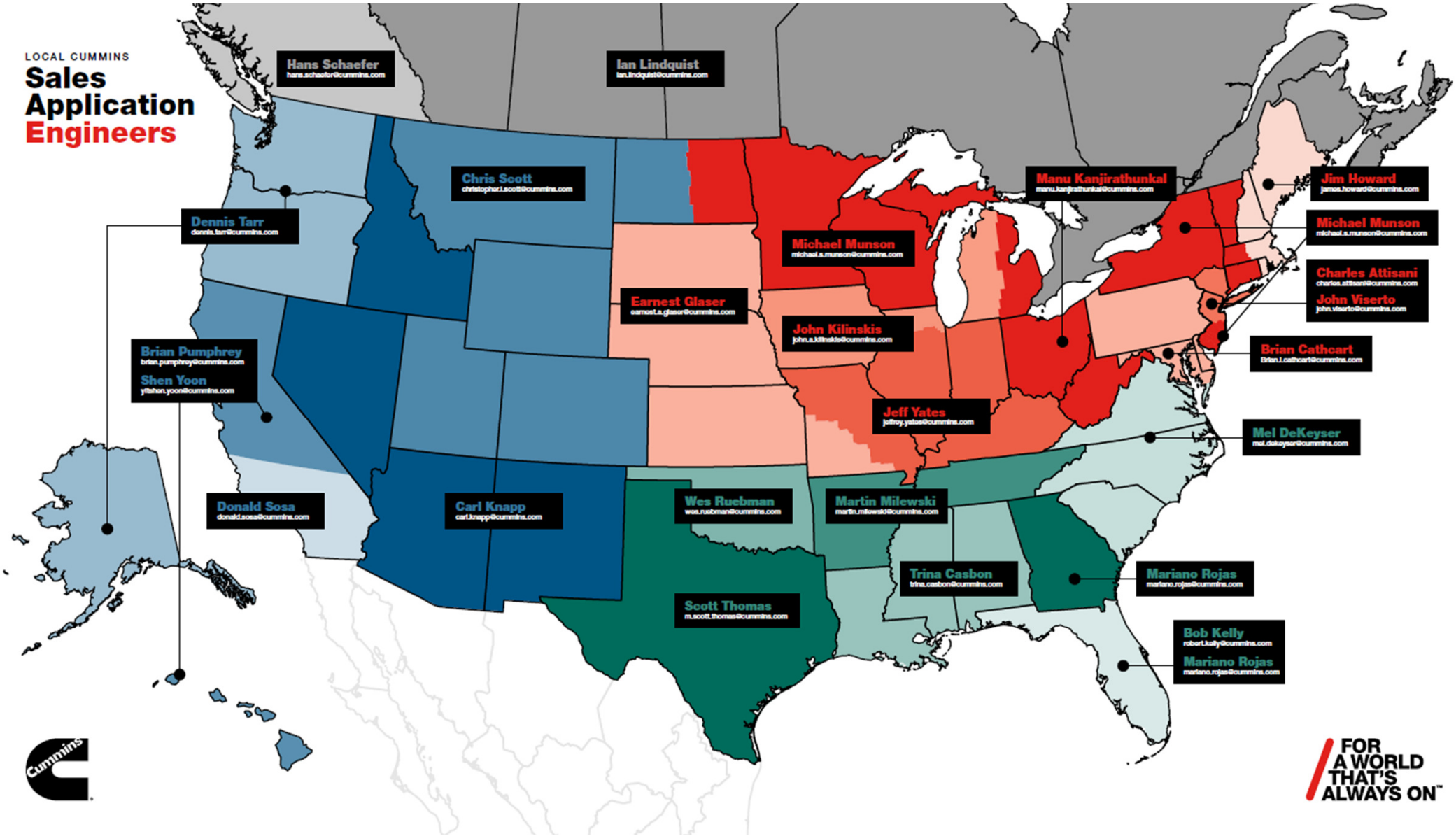

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