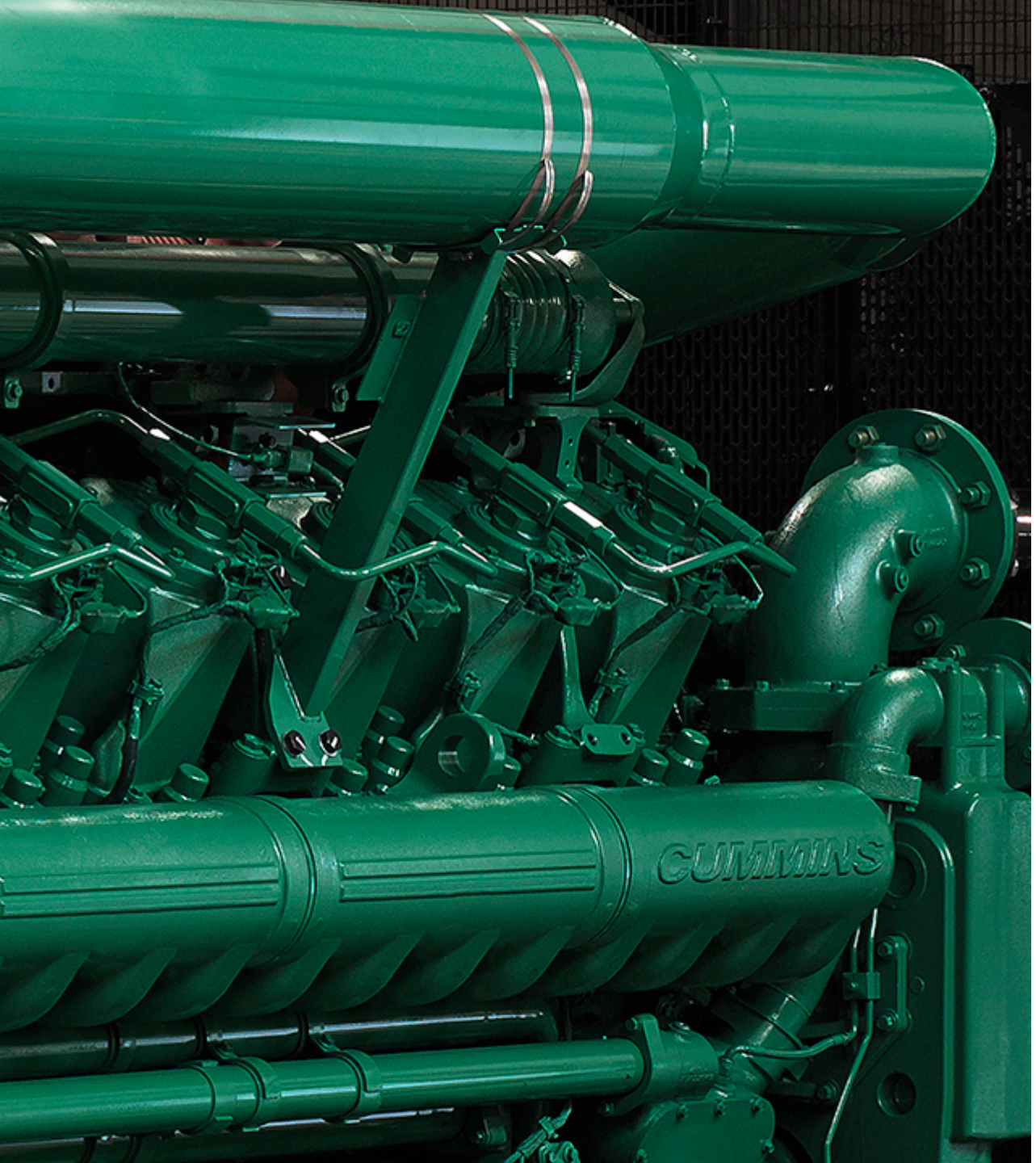


# Transfer Switch Operation and Application

**PowerHour** webinar series for consulting engineers

**Experts you trust. Excellence you count on.**

7/25/2019 11:00 PDT / 13:00 CDT

*(1PDH issued by Cummins)*

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# Meet your panelists

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Divya Mahabal
Technical Specialist-Application Engineering
Cummins Inc.

## Cummins facilitator:

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Global Sales Training Manager
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The views and opinions expressed in this course shall not be considered the official position of any regulatory organization and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

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.

# Course Objectives

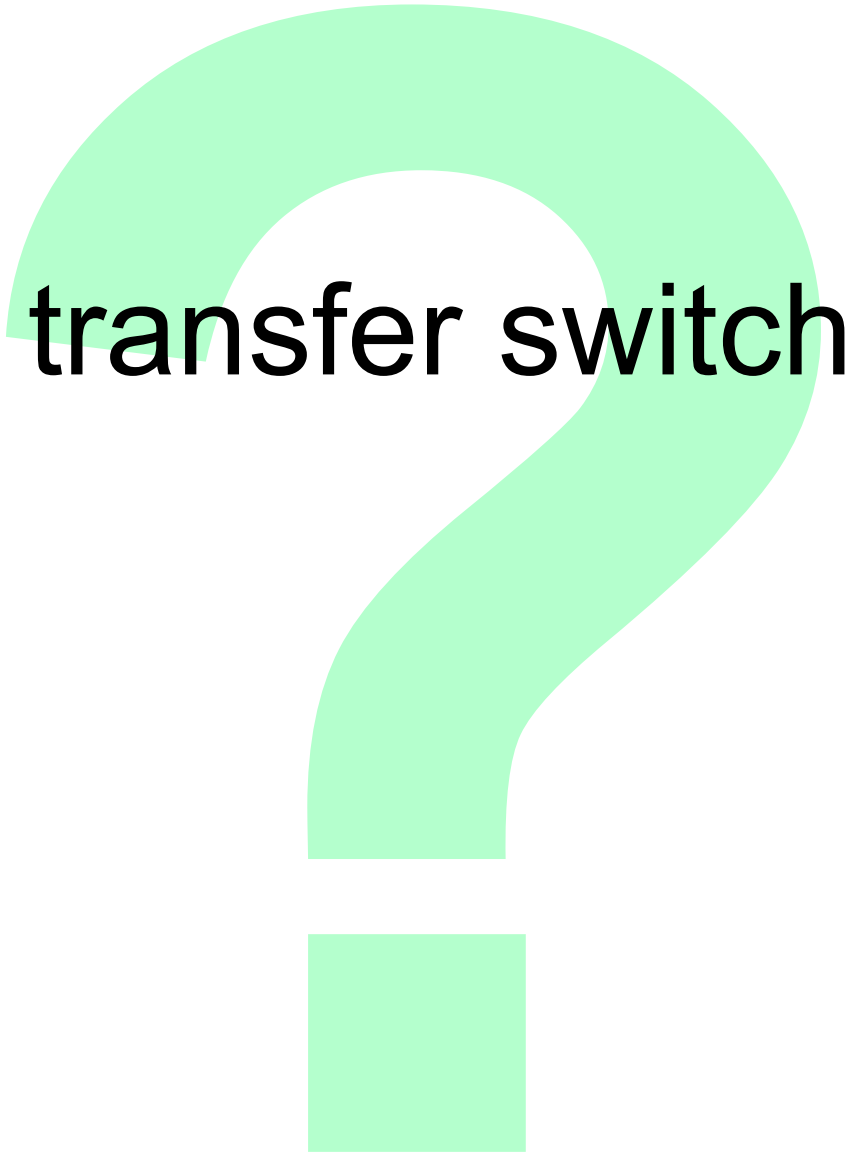
**Transfer Switch Operation and Application**

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:

- Discuss the basic operation of transfer switches and transition types to aid in the selection of equipment
- Describe the operation modes of bypass switches and isolation methods.
- Identify when it is appropriate to use a 4 pole switch as compared to 3 pole switch

# What does a transfer switch do?



# Transfer Switch Functionality

Load transfer between power sources

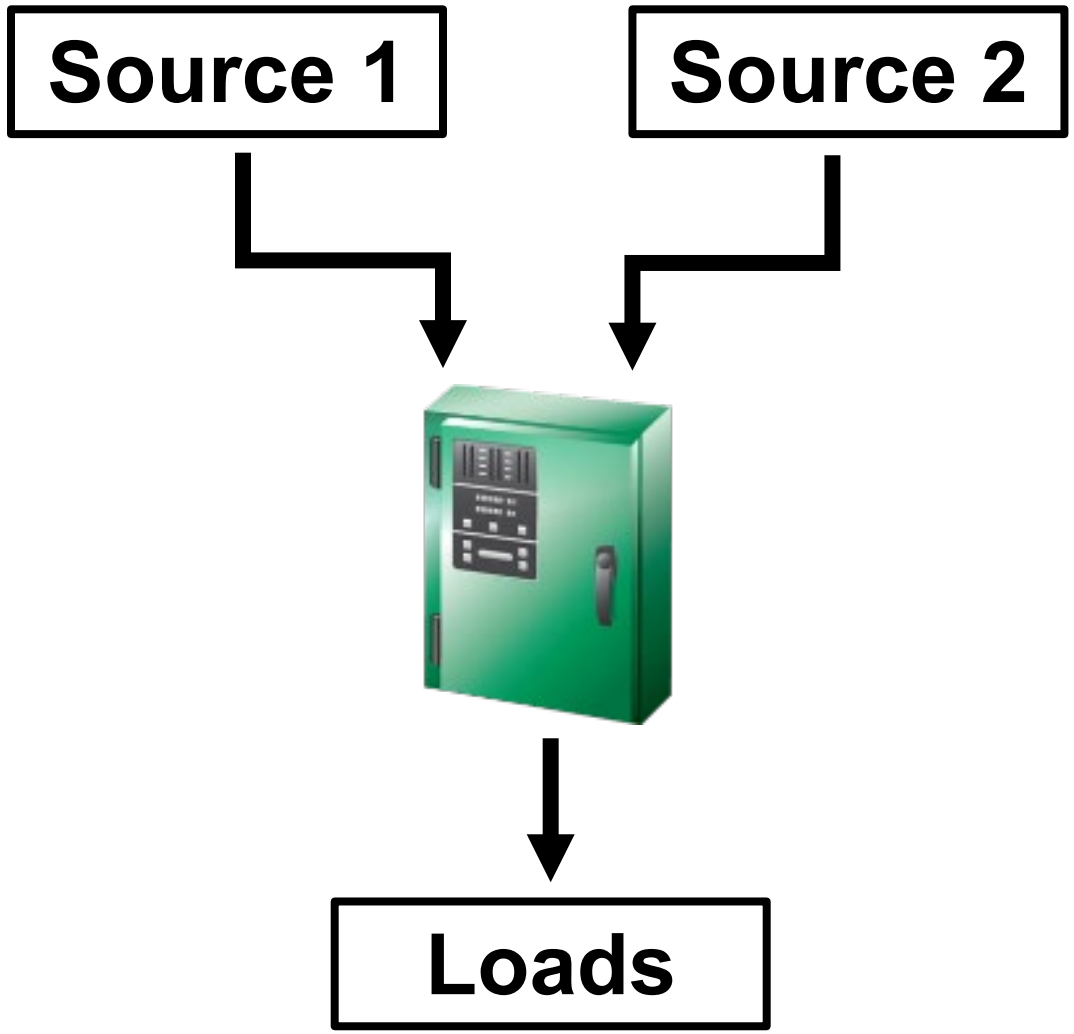
- ATS control monitors quality of both sources
  - Voltage, Frequency, Phase Rotation, Phase Loss

Load shed

- 3 Position ATS is recommended for load shedding
- Emergency systems [NEC 2017 700.4 (B)] may require load shed functionality

Load sequencing

- Multiple ATS with different time delays: e.g. motor loads



# Transfer Switch Functionality

## Source Transfer

### Load transfer between power sources

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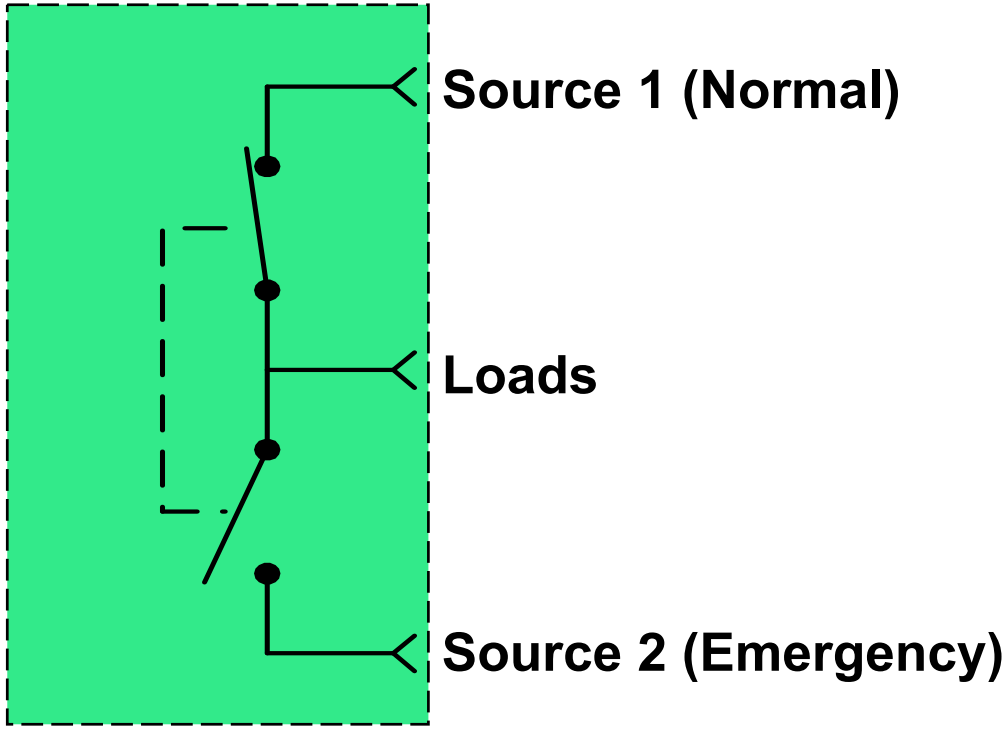

# Transfer Switch Functionality

## Load Shed

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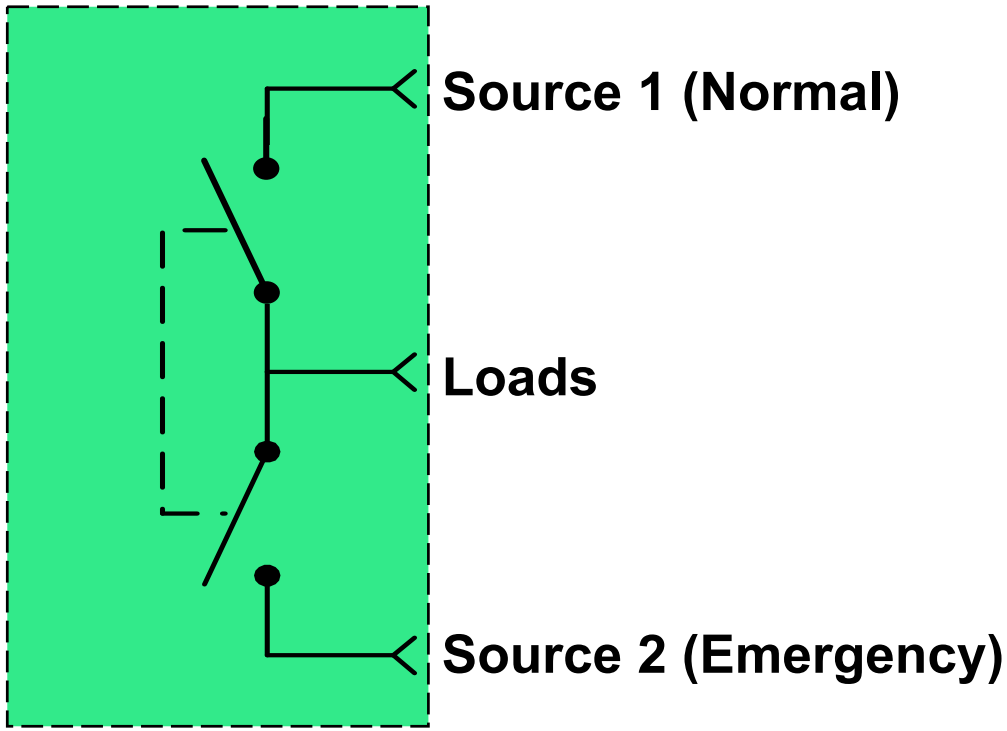

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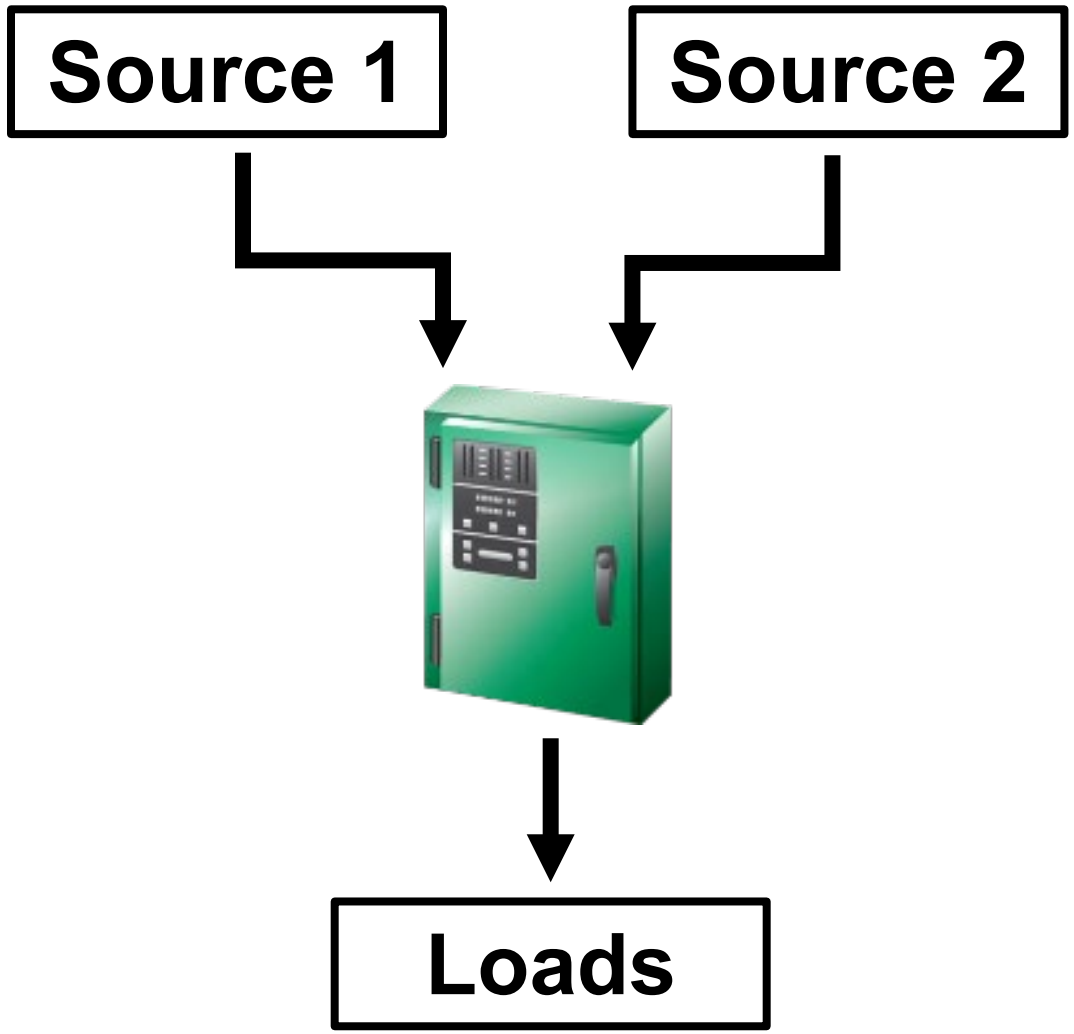
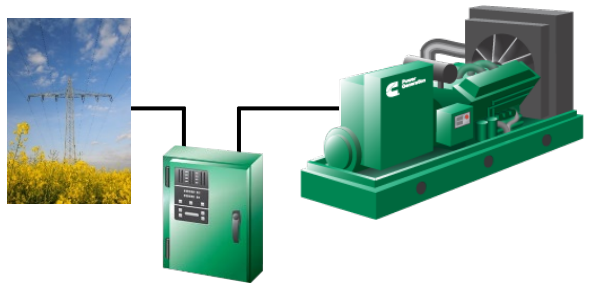


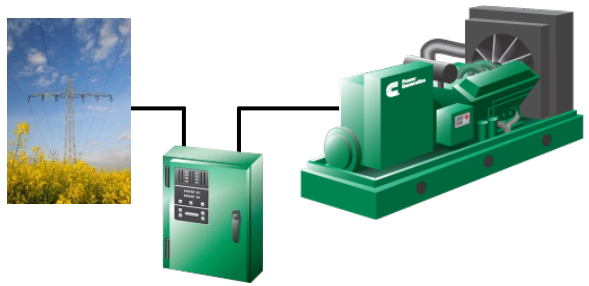
# Application Types



**Utility to Generator**

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

# Application Types



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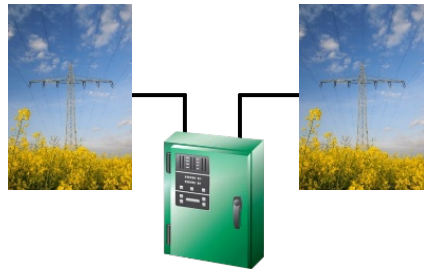
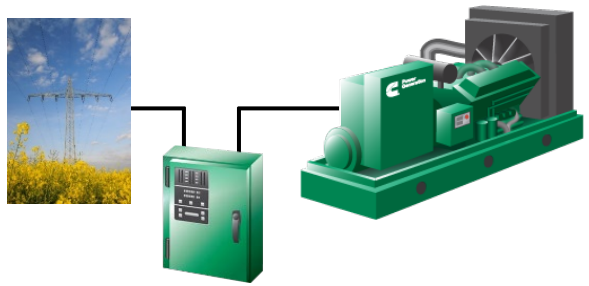


**Utility to Utility**
For use in facilities with redundant feeds but no standby generator

# Application Types



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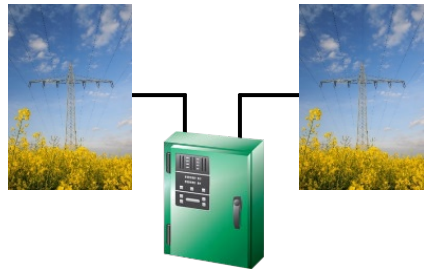
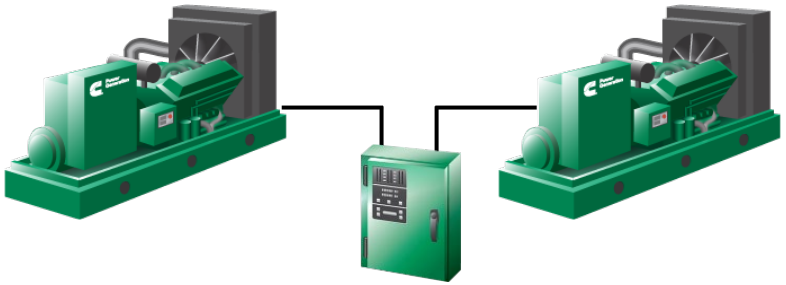
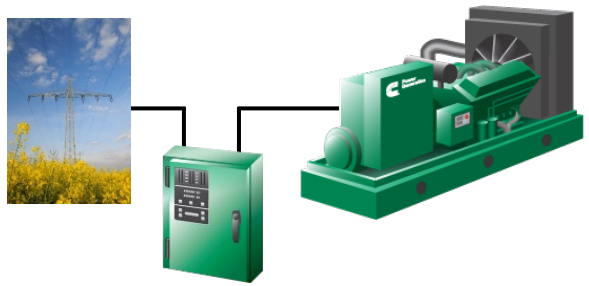


**Utility to Utility**
For use in facilities with redundant feeds but no standby generator

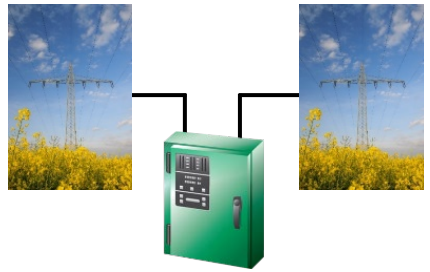
**Generator to Generator**
For facilities with a prime power system using multiple on-site generators



# Application Types



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



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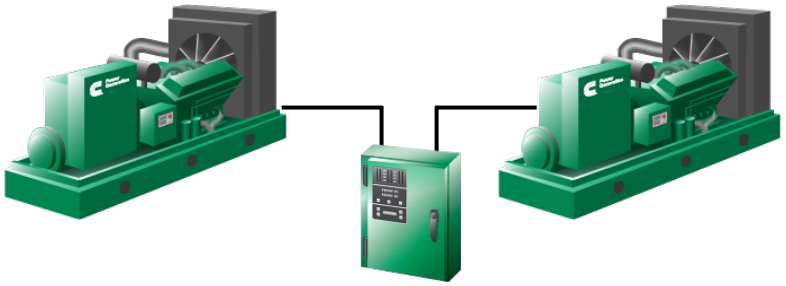
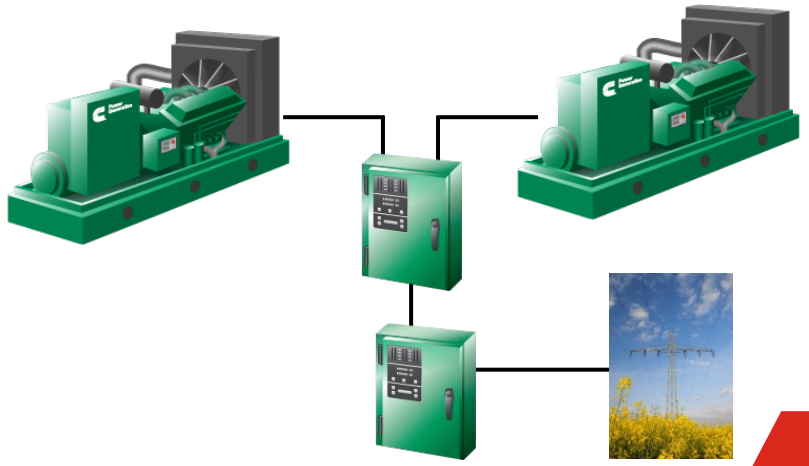
For facilities with a prime power system using multiple on-site generators



**Three-Source System**
Two generator sets backup a utility service



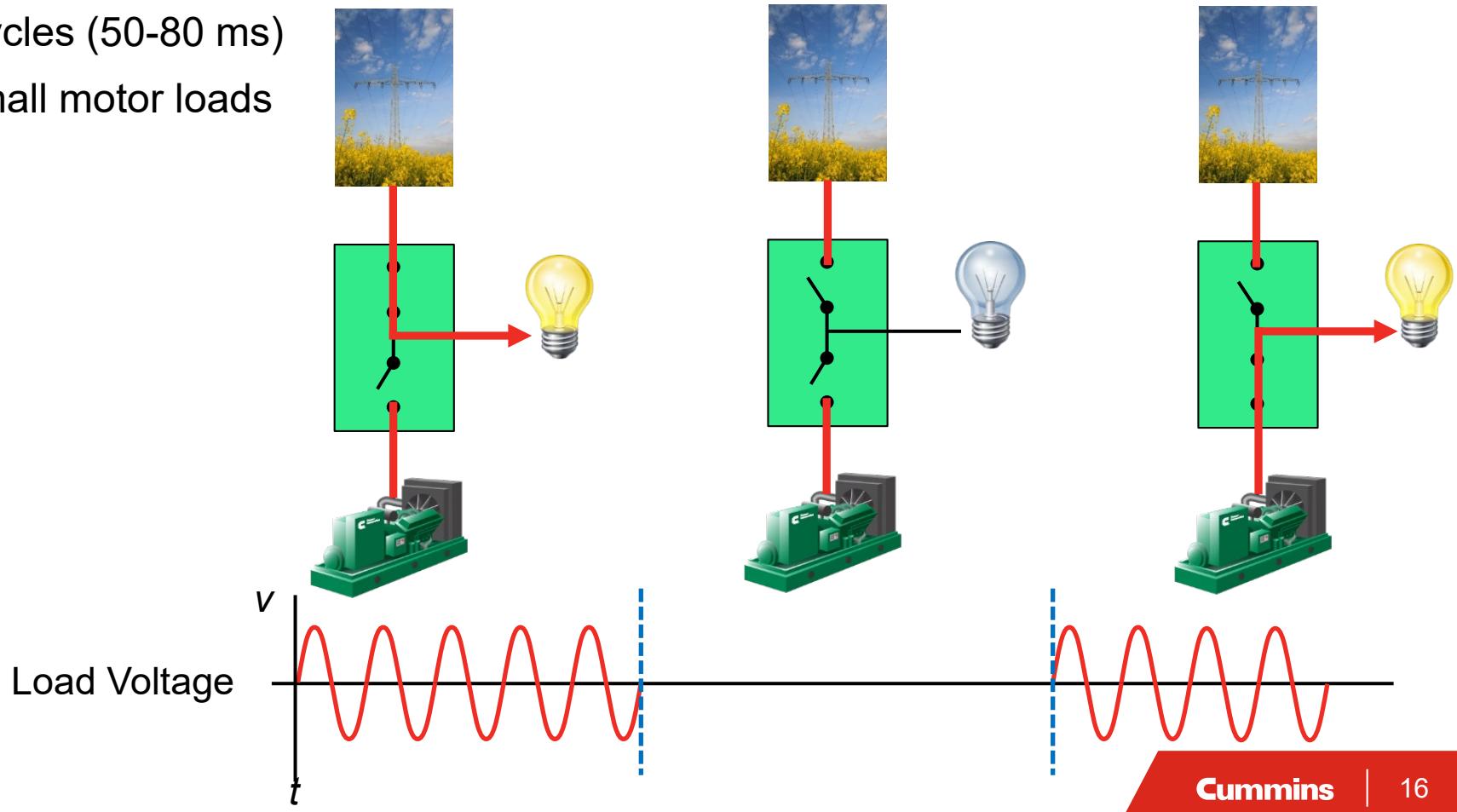
# Transition Types

- Open Transition (In Phase)
- Open Transition (Time Delayed / Programmed Transfer)
- Closed Transition

# Open Transition

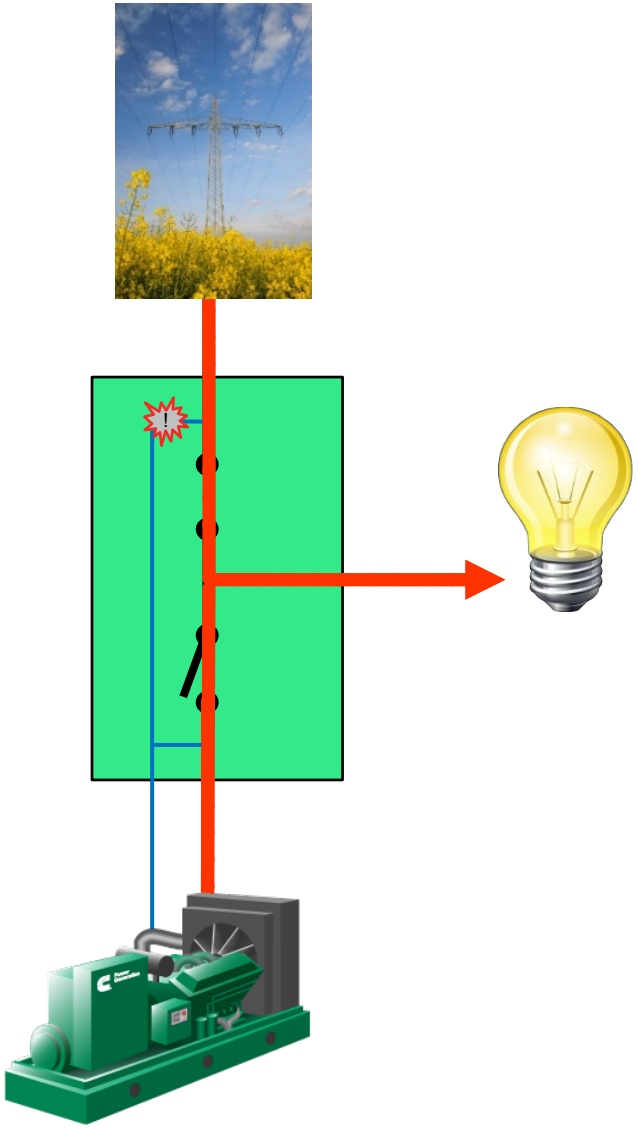
## In Phase Transfer

- Break-before-make switching action
- Power interruption of 3-5 Cycles (50-80 ms)
- Suitable for resistive and small motor loads (<20hp)



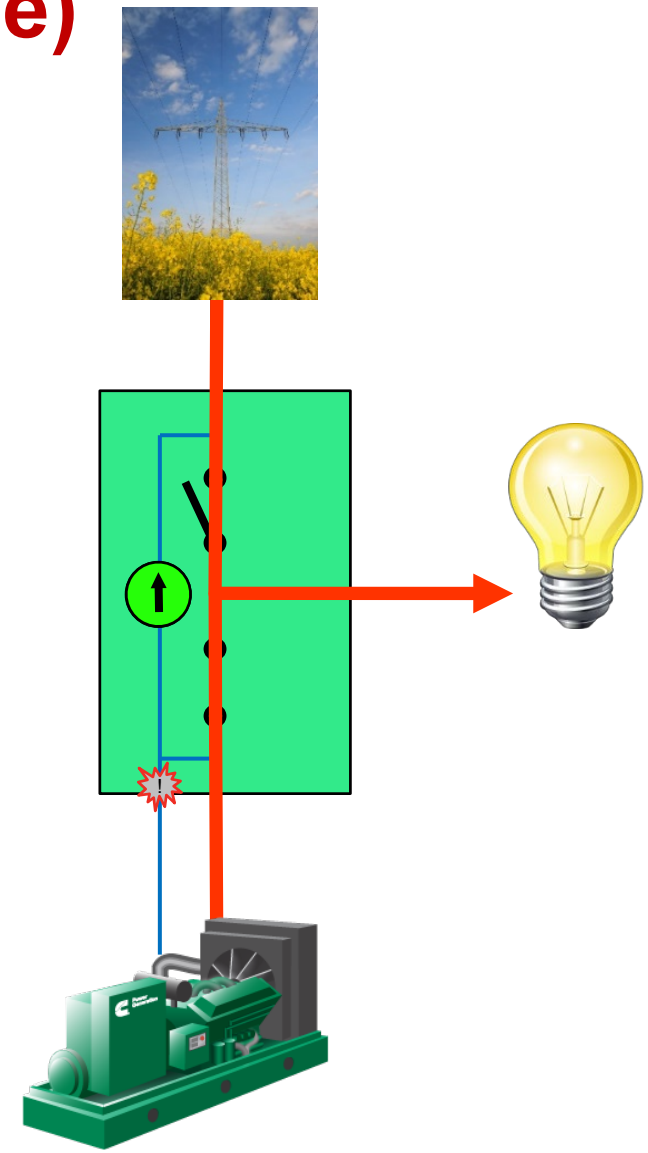
# Open Transition

## In Phase Transfer



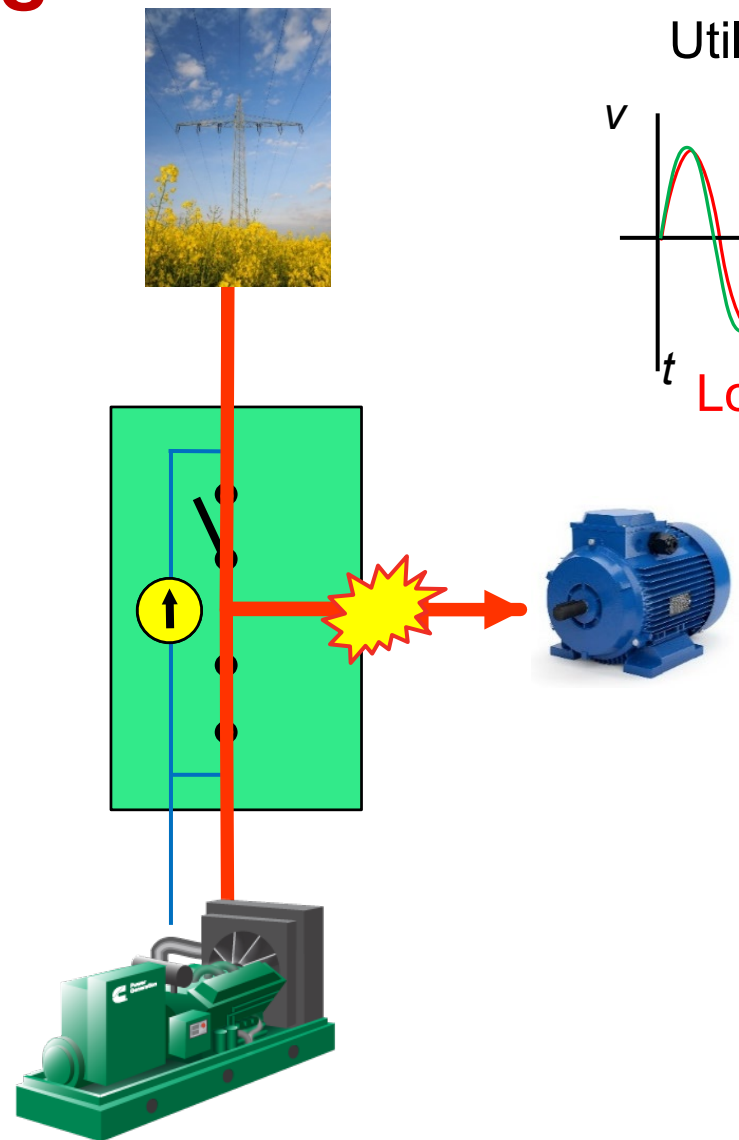
# Open Transition

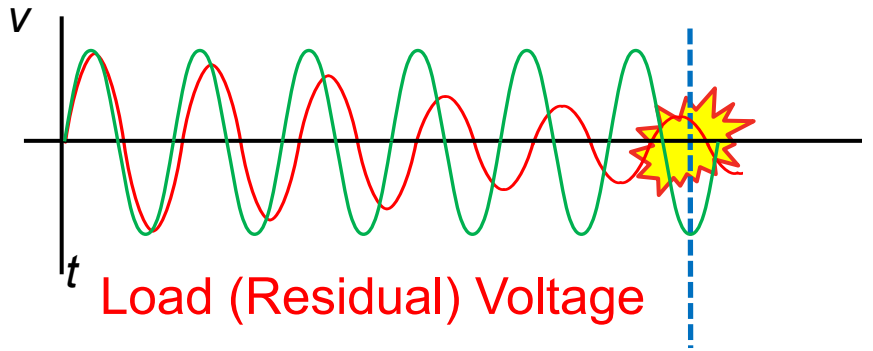
## Retransfer (In Phase)



# In Phase Transition

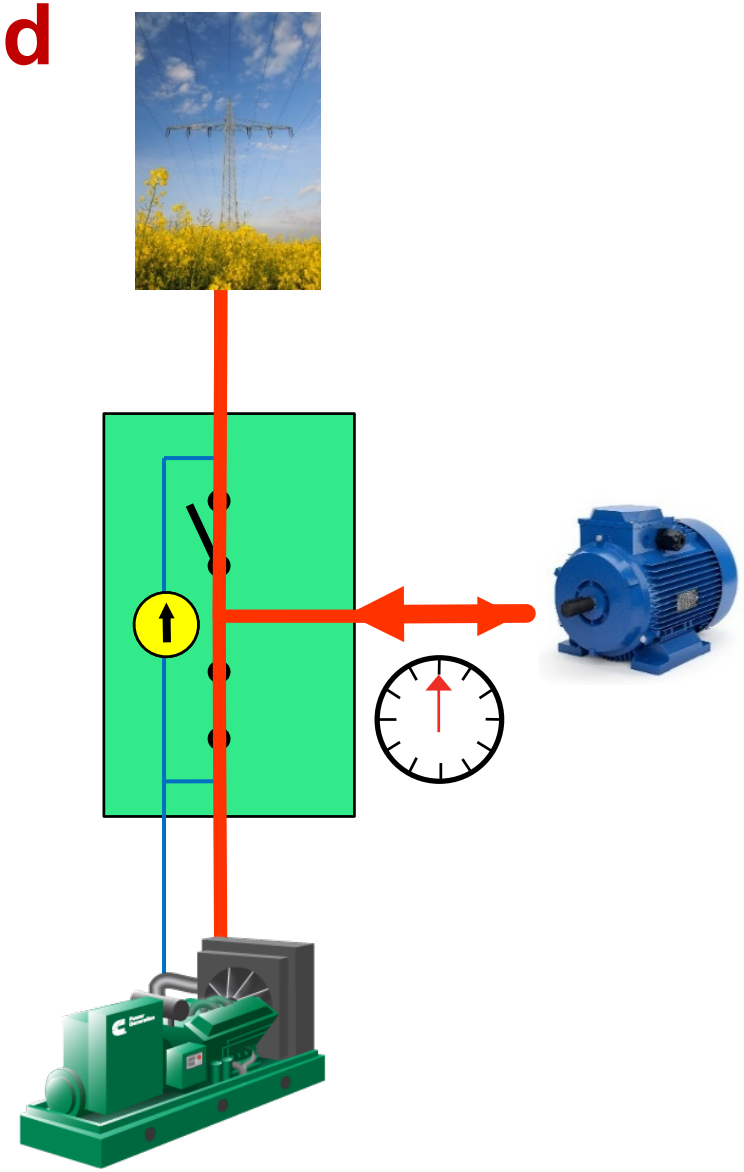
## Inductive Loads

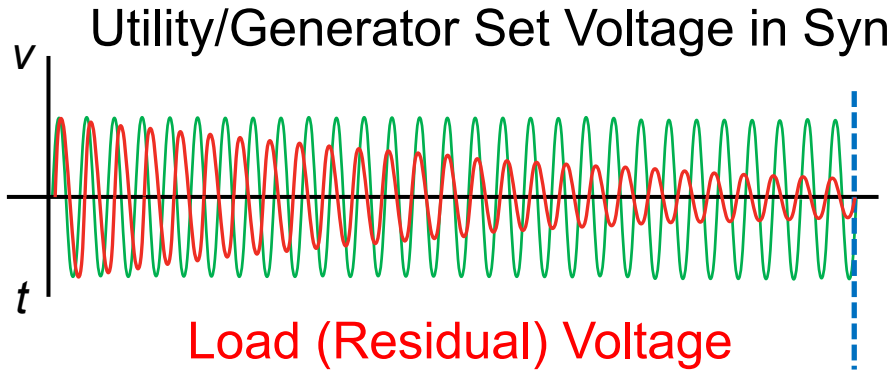




# Open Transition

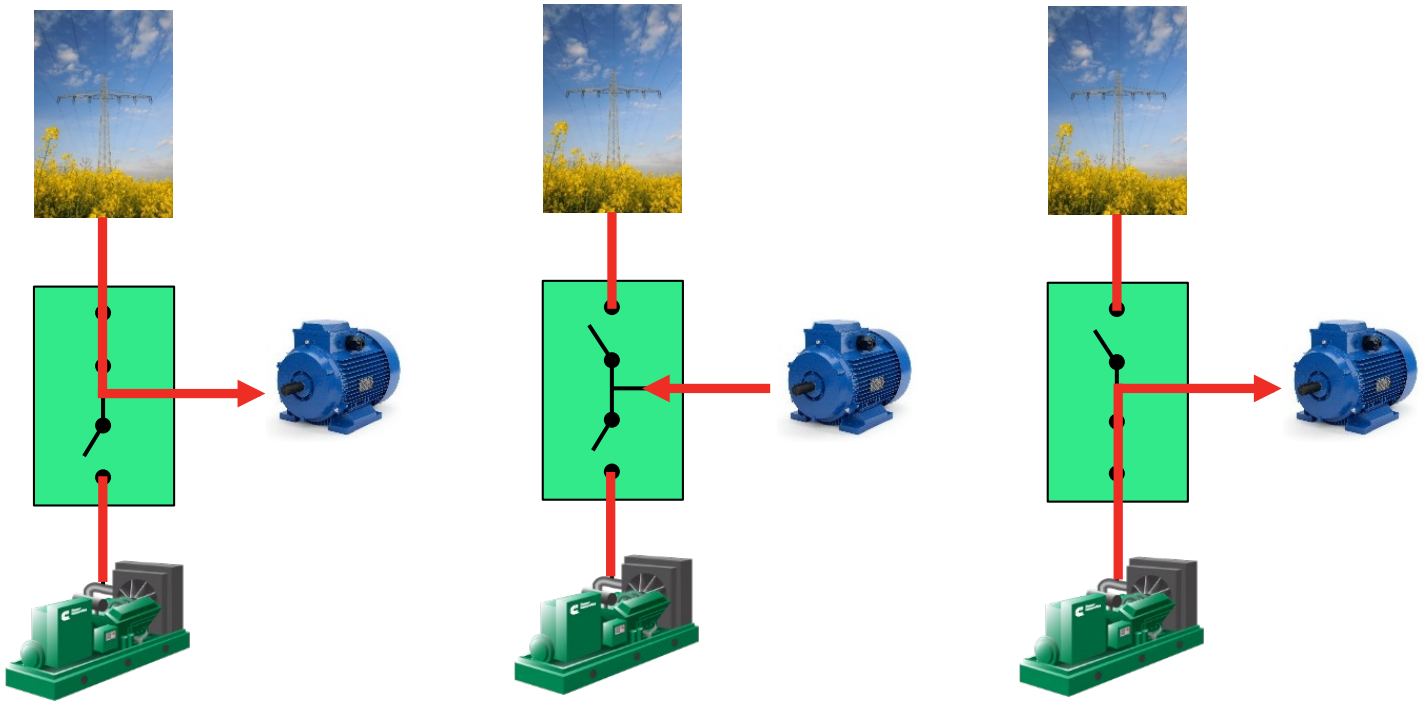
## Time Delayed

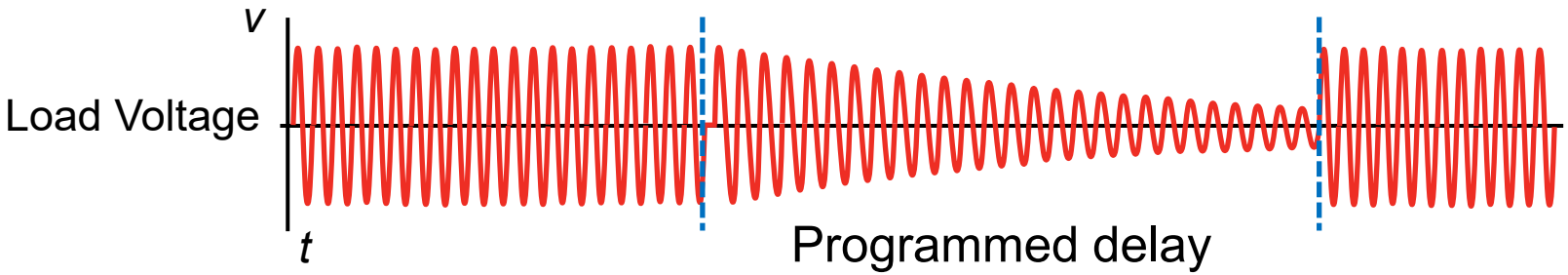




# Open Transition

## Time Delayed

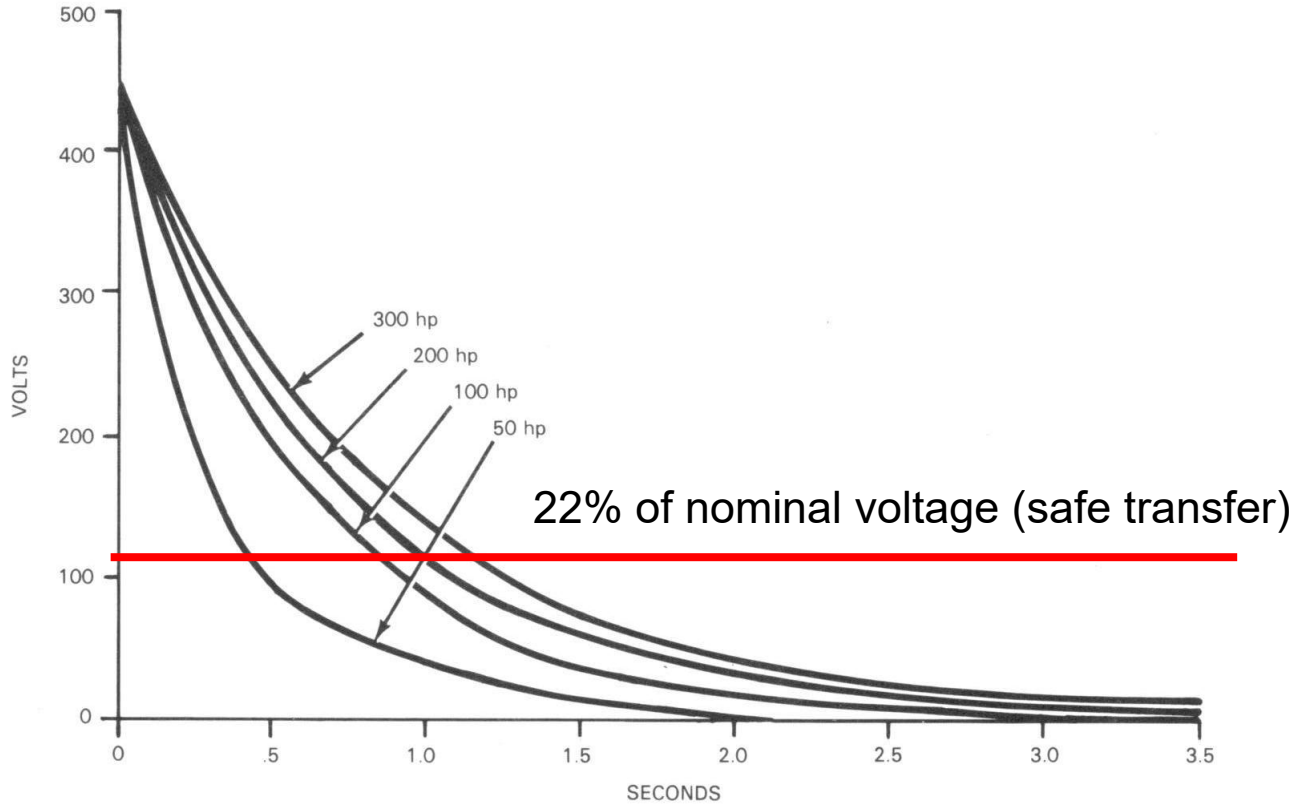




# Time Delayed Transition

## Residual Voltage Decay

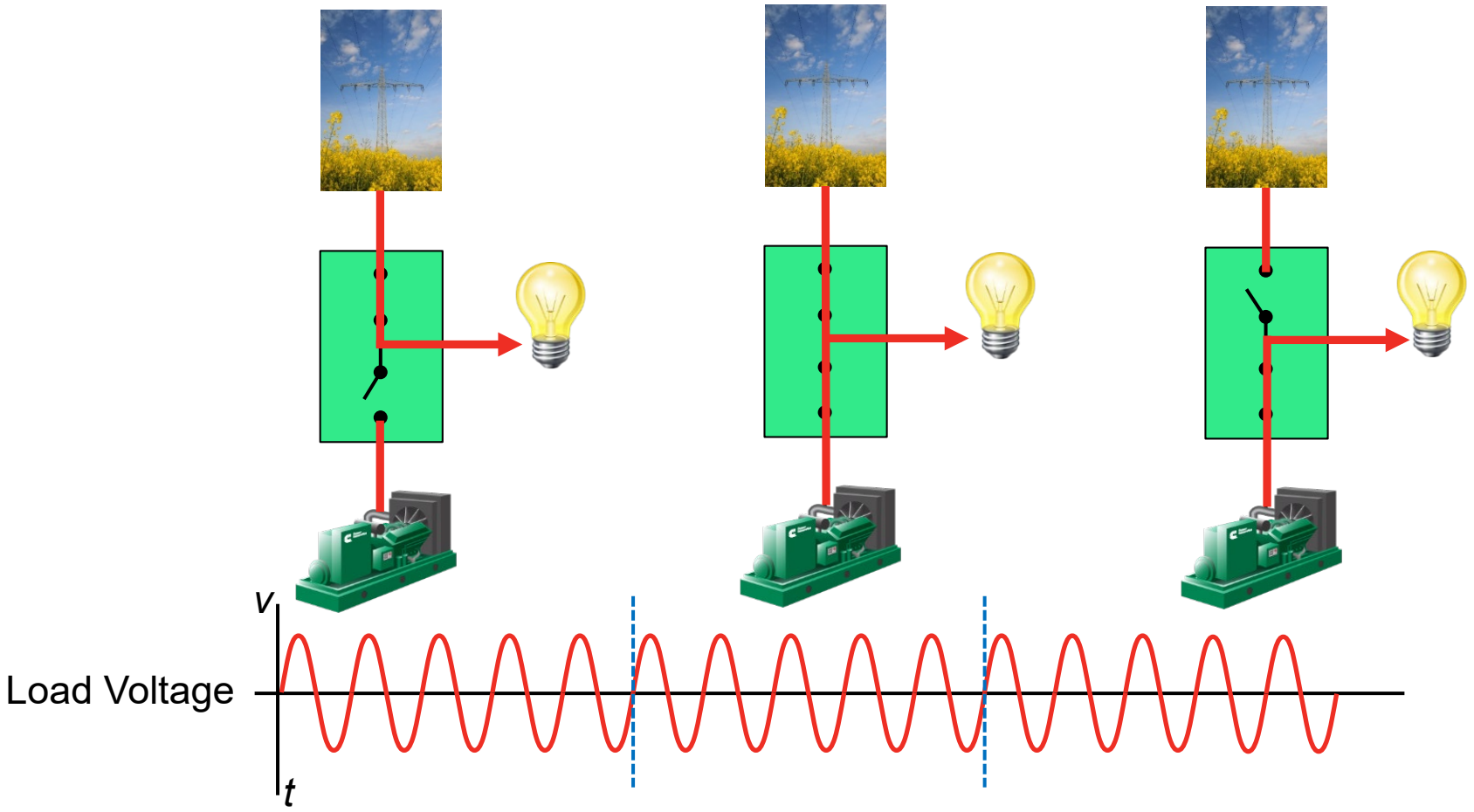
- Voltage decays exponentially (independent of motor speed)
- NEMA MG-1 recommends a delay of 1.5 Motor Open Circuit Time Constants
  - Voltage will be at 22% of nominal
- For multiple motors, use the time delay for the largest motor




Residual Voltage Decrement
Source: IEEE Orange Book

**Spec Note** Open transition and delayed transition switches shall be supplied with a 3 position mechanism .The switch control will move to the center off position when there is a load shed signal from Generator set controller or a supervisory controller. The switch will also move to the center off position during delayed transition for a pre programmed amount of time, and aid in residual voltage dissipation

# Closed Transition

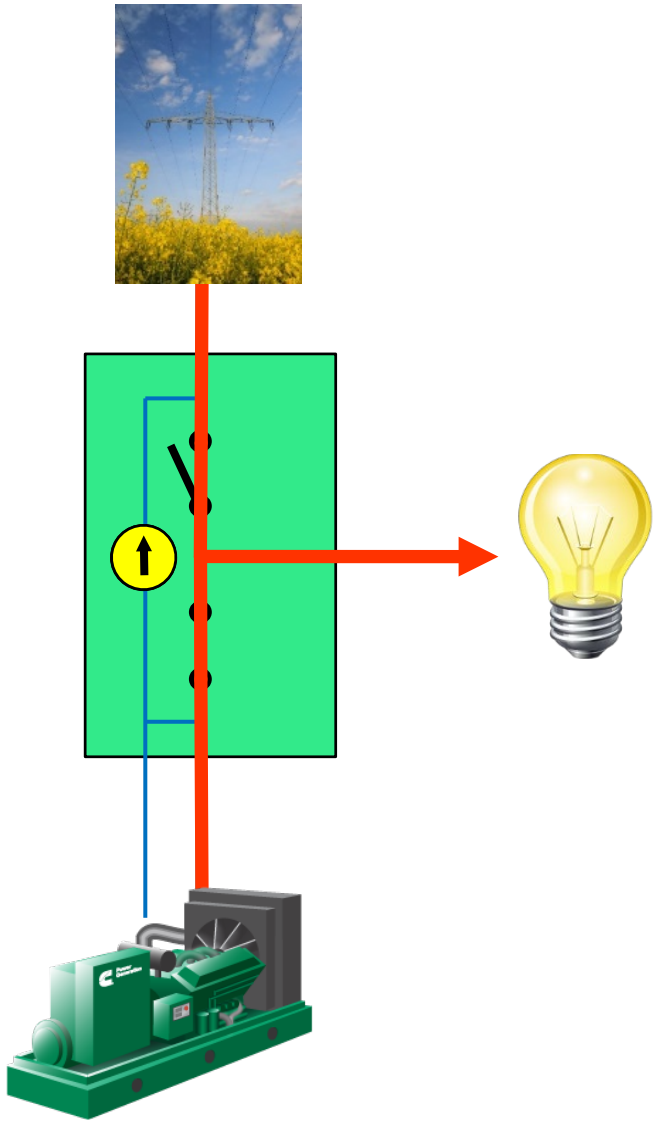



- Make-before-break - uninterrupted power transfer when both sources are available
- Seamless transfer of the load by momentarily paralleling both sources (<100 milliseconds)

# Closed Transition

## Retransfer

Reference Cummins PowerHour “Guidelines for ATS selection: How to choose the right transfer solution for your power application.” for more details!

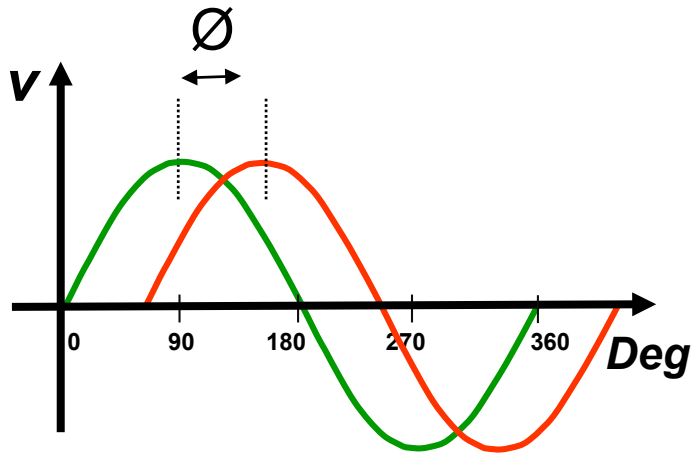


# Synchronizing

Reference Cummins PowerHour “Features of Generator Set Control Based Paralleling” for more details!

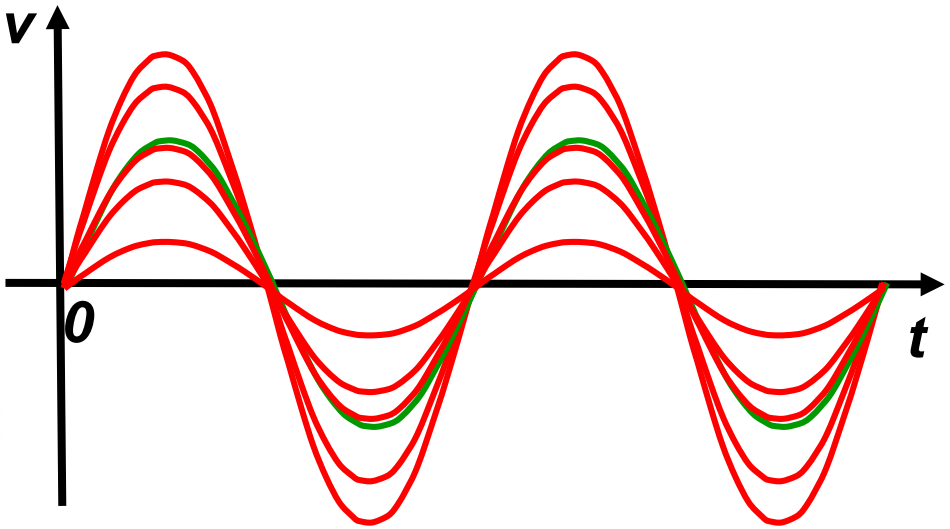
- Synchronization is the mechanism of matching frequency, phase and voltage of AC power sources
  - Phase and Frequency: engine governor fuel
  - Voltage: alternator field excitation

**Phase**



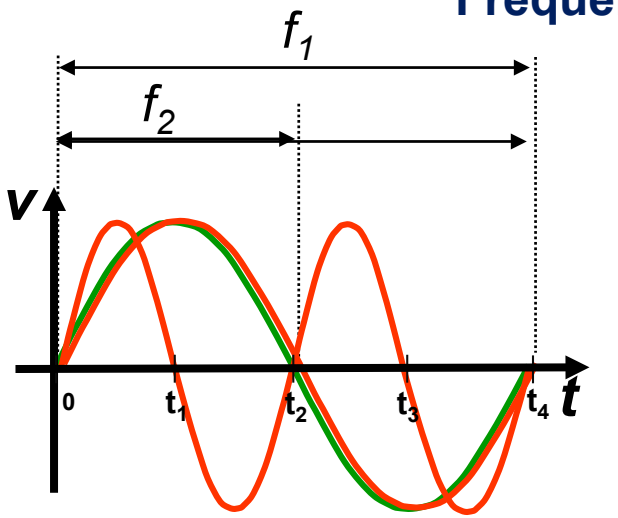

**ECM**

**Voltage**




**AVR**

**Frequency**




Generator output

Utility output

# Closed Transition

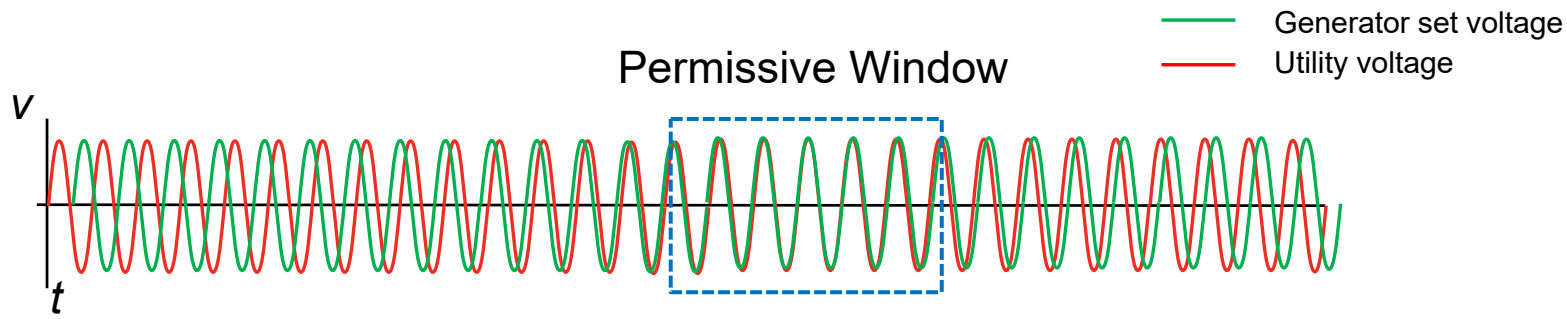
## Synchronizing Methods

- Passive synchronizing - sync check
  - Wait for sources to drift into permissive window
- Sync by slip frequency
  - Drive sources through permissive window
- Active sync
  - Relies on generator set control to match utility waveform

# Synchronization Methods

## Passive Synchronization (Sync Check)

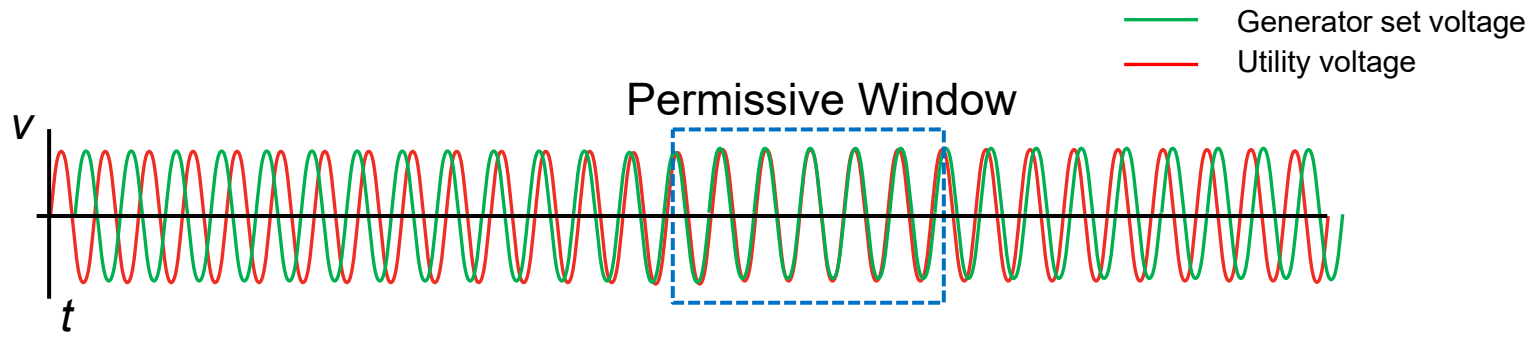
- Wait for sources to drift into sync
  - Does not drive sources to come into phase
- Depends on sources running at slightly different frequency
  - Sources with same frequency will not drift into sync
  - If frequency is too different, permissive window might be too short



# Synchronization Methods

## Sync by Slip

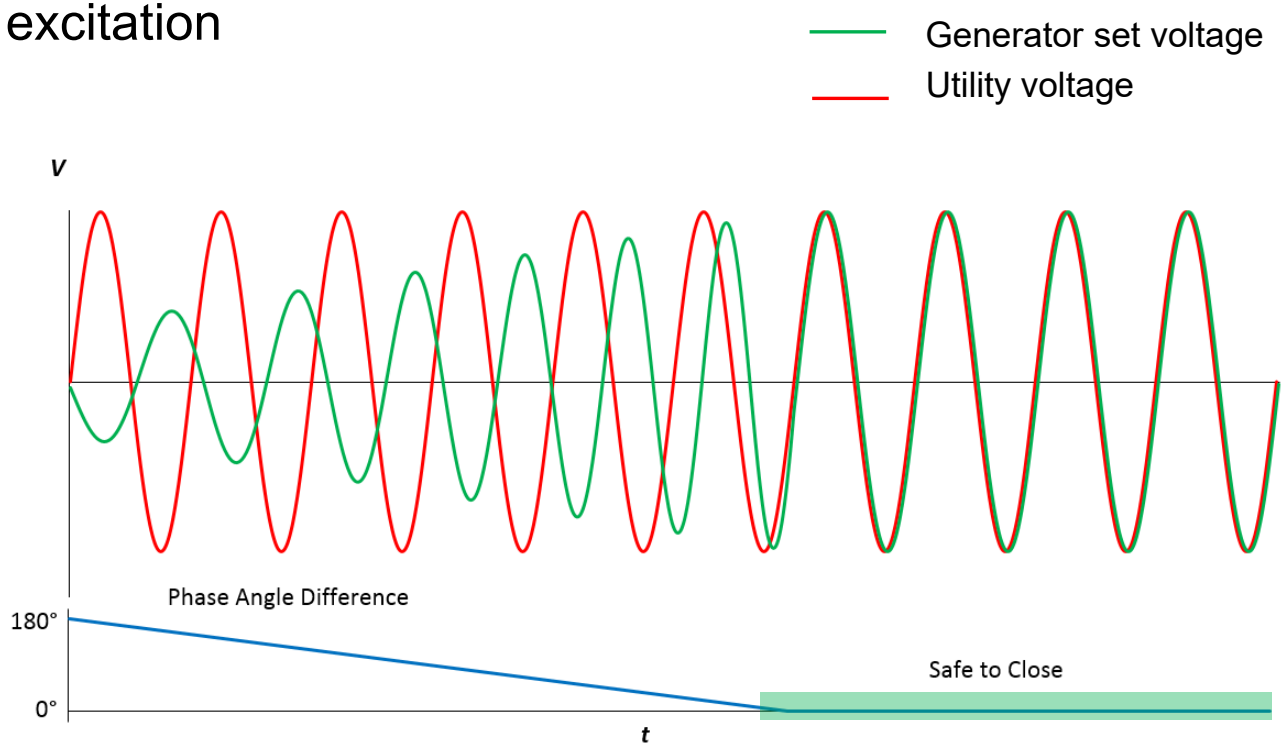
- Generator set frequency is set to a slightly different value compared to utility frequency
- Drive sources through permissive window



# Synchronization Methods

## Active Sync

- Actively adjust generator set governor and voltage regulator control loops to match the utility waveform
  - Transfer switch sends “sync” command to generator controller
  - Generator set control adjusts fueling and excitation

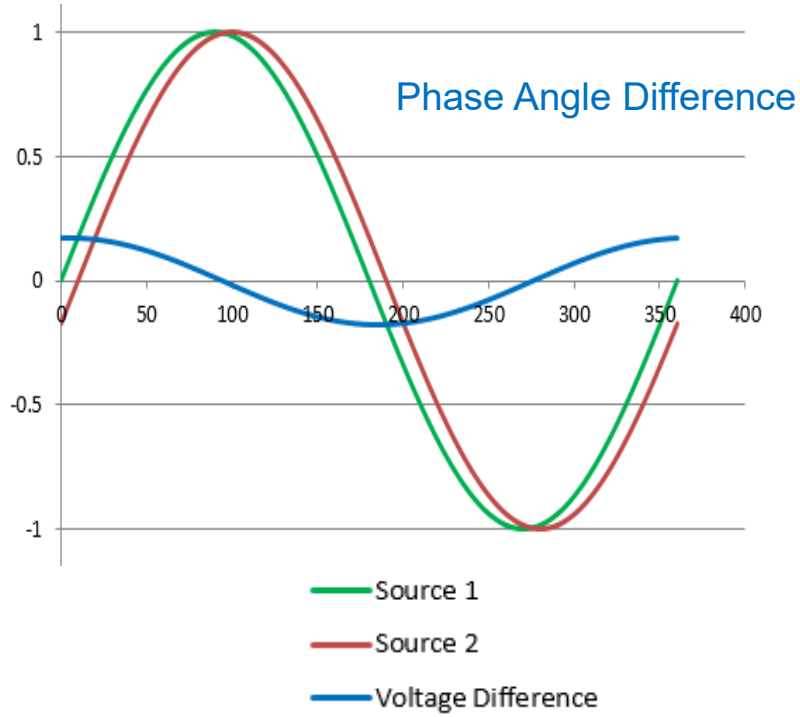


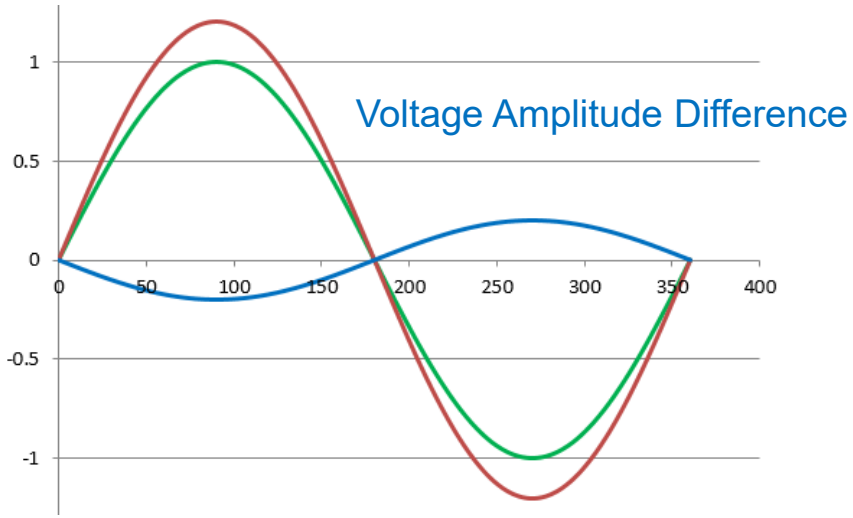

**Spec Note** The transfer switch controller shall be capable of providing a synchronization signal to the generator set controller when both sources are available during a transfer. This signal shall drive active voltage, frequency and phase matching to enable fast synchronization between sources, hold synchronization during the transfer process so transient current spikes are minimized.

# Closed Transition

## Risks

- Why do breakers trip during closed transition transfer?
  - Current flows between sources caused by a difference in instantaneous voltage between sources at the instant of closure



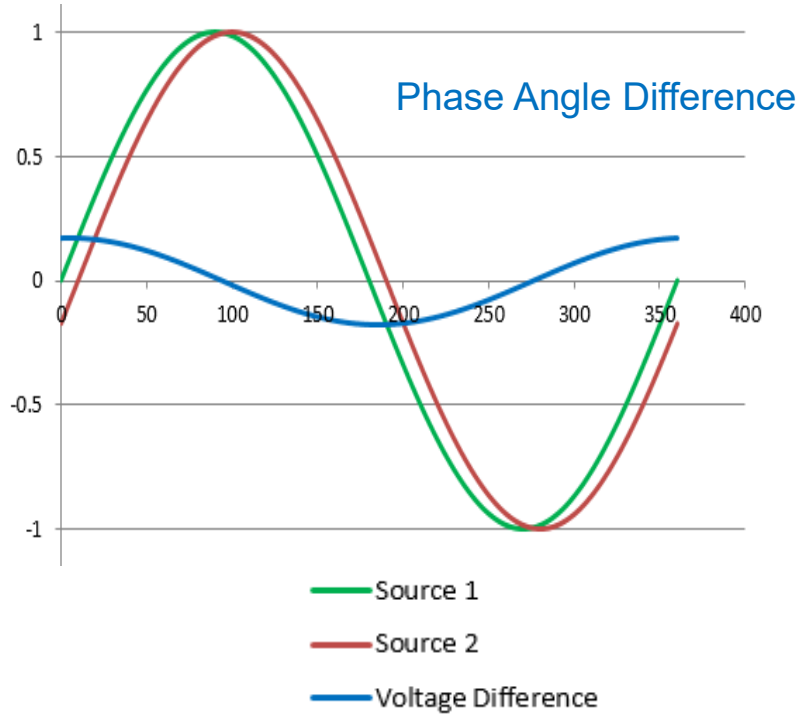



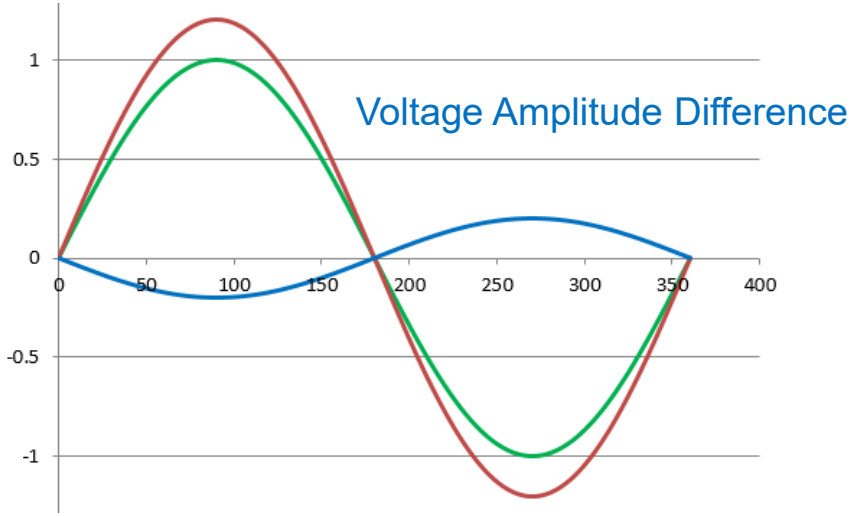
# Closed Transition

## Risks

- Why do breakers trip during closed transition transfer?
  - Current flows between sources caused by a difference in instantaneous voltage between sources at the instant of closure

- What causes the difference in voltage?
  - Phase angle difference between sources
    - Use active synchronizing
  - Difference in RMS voltage between sources
    - Use synchronizer with voltage match
  - Transient condition on one of the sources
    - Allow only one switch to transfer at a time

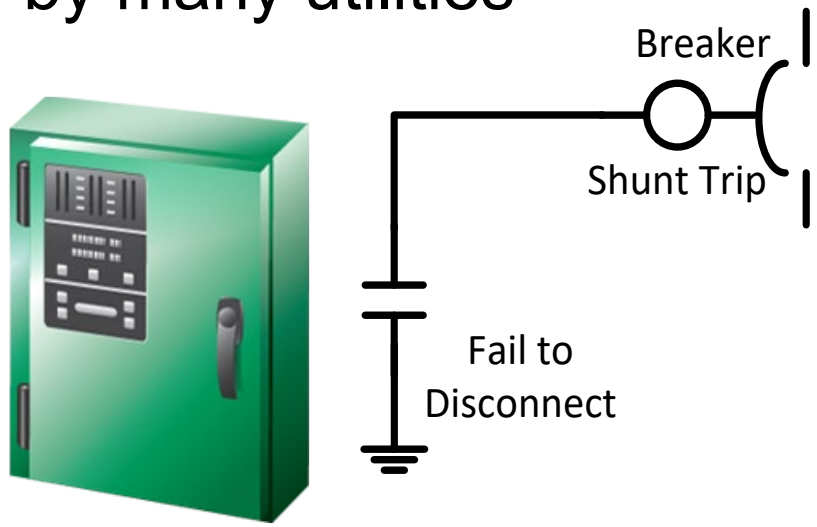


# Closed Transition

## Preventing Extended Paralleling

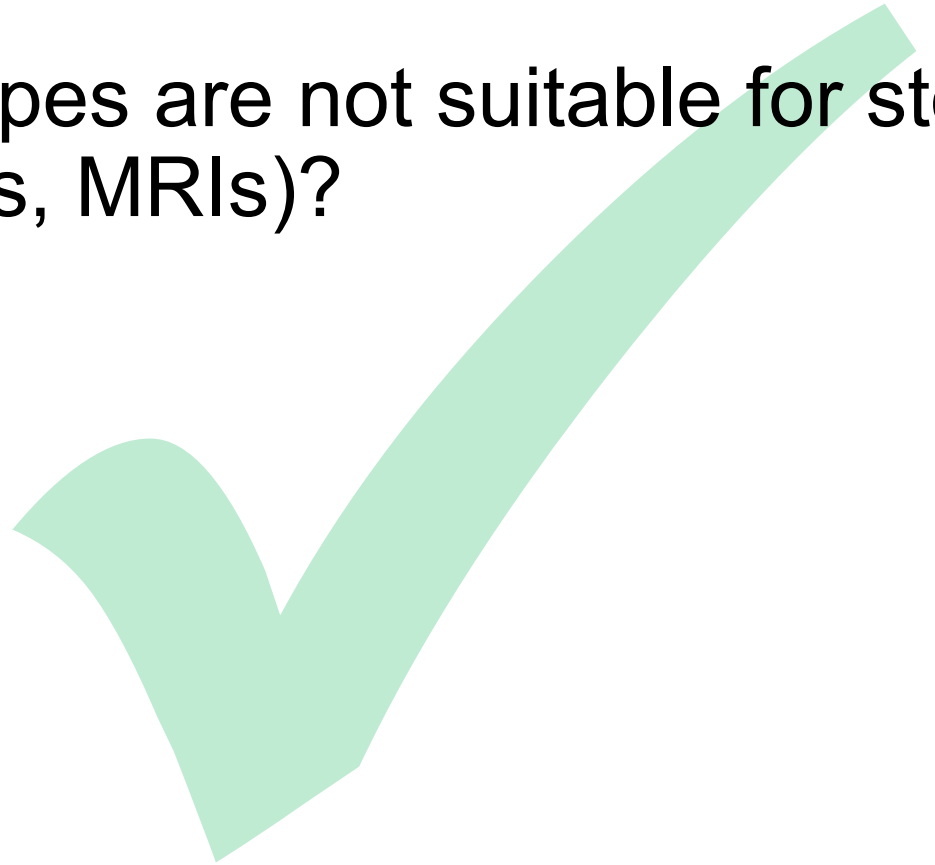
- Shunt trip breaker on normal or emergency source in the event of a failure of ATS to disconnect
  - Use Fail to disconnect signal from ATS control or
  - Use External parallel timer and lockout relay
- Function is required by many utilities



# Concept Check

Which transition types are not suitable for stored energy loads (large motors, MRIs)?

a) Open (In Phase)
b) Open (Delayed)
c) Closed
d) Both b) and c)



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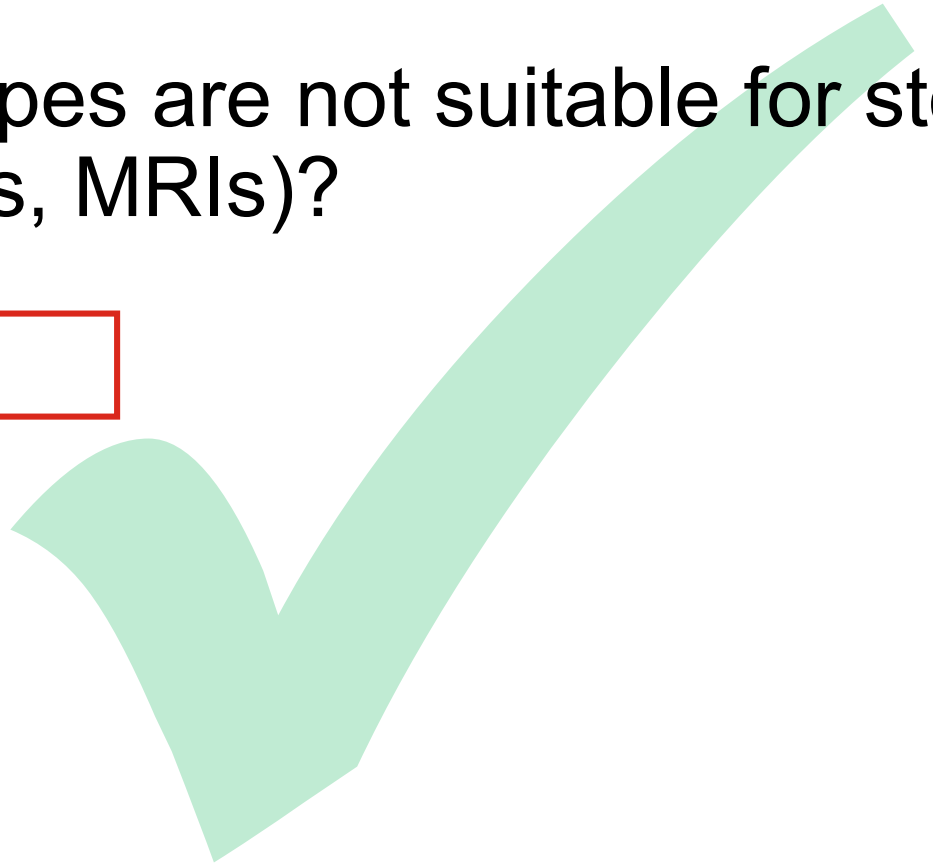
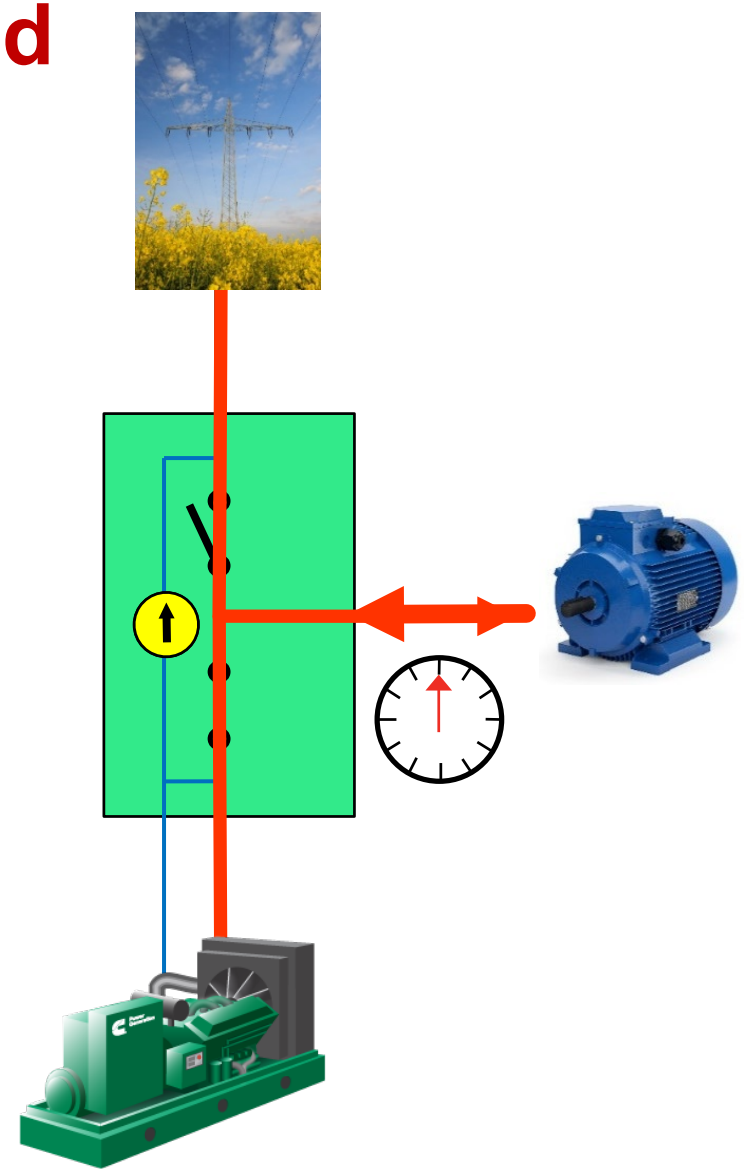
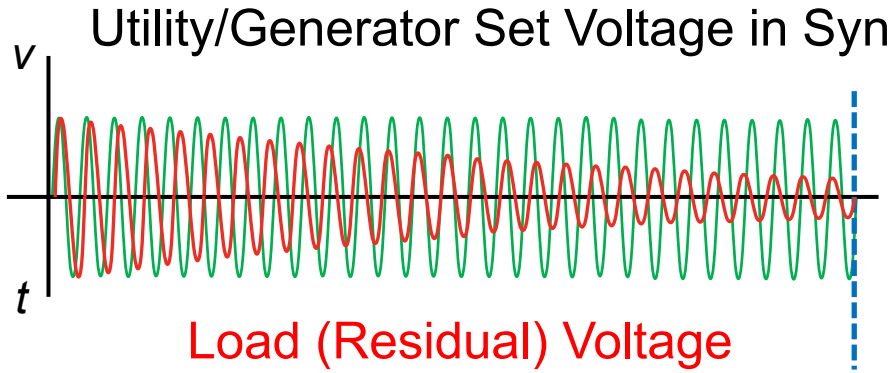


# Open Transition

## Time Delayed



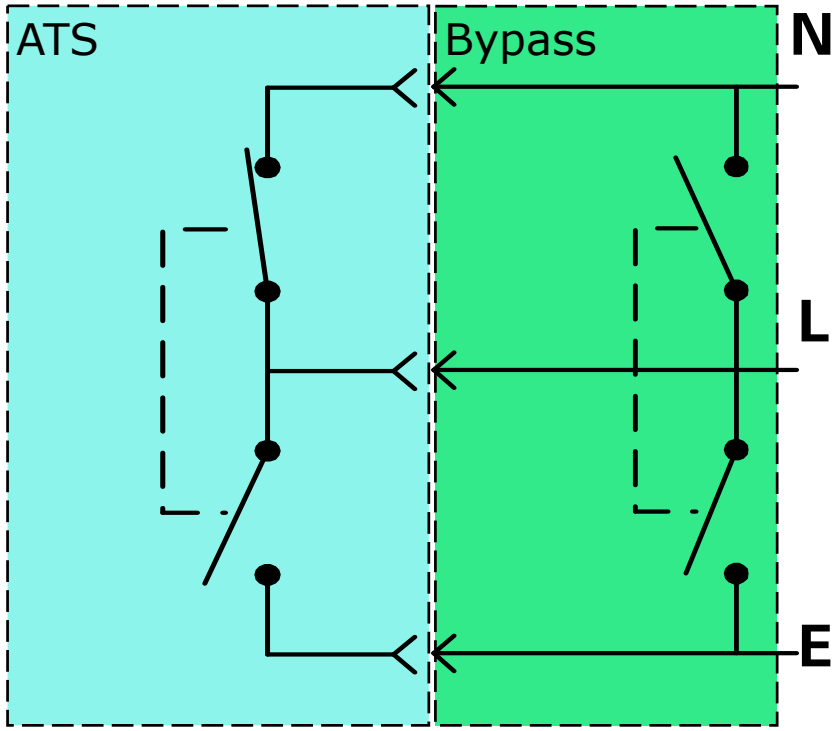


# Short Circuit Ratings

- UL 1008 defines test requirements for short circuit ratings
- Withstand and Close-On Rating (WCR)
  - Ability to withstand and close into a fault current (kA) until a protective device opens
  - Test sequence is as follows:
    - Specified fault current is applied for either
      - A specified period of time (e.g. 50 ms)
      - Until the specified overcurrent protective device clears the fault
      - After withstanding the fault current, the ATS must close into the fault using the same set of contacts
- Short Time Rating
  - Ability to carry rated current after a short circuit event

# Bypass Transfer Switch

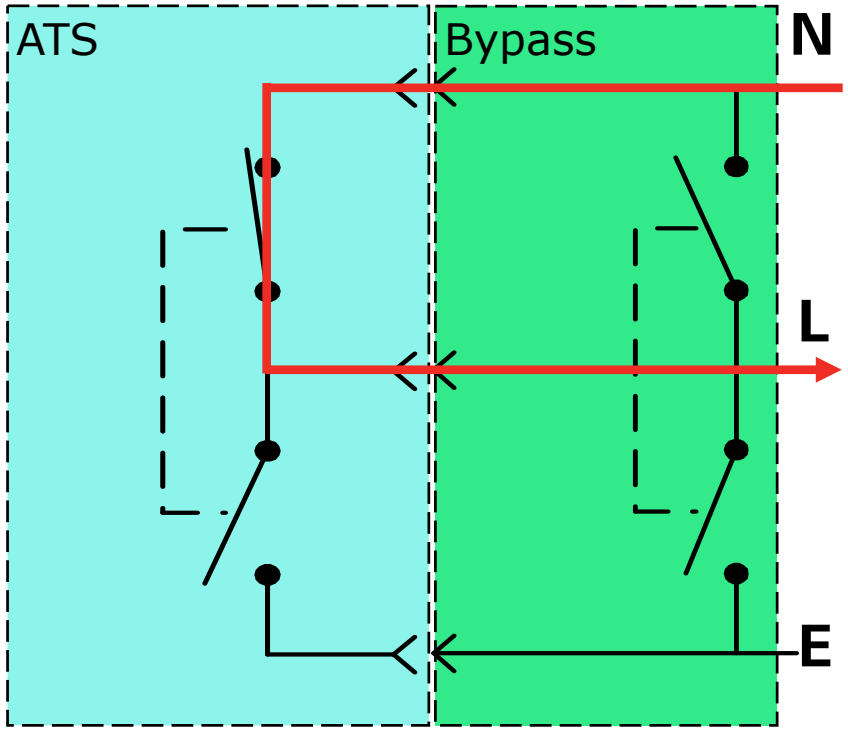
- Allows service of ATS without disrupting power to critical loads
- By having two transfer switches, the bypass transfer switch adds redundancy to the system
- Bypass Isolation: Bypass first and Isolate later (no power interruption to load)
- Watch out for term “Isolation Bypass”




# Bypass Transfer Switch

## Sequence of Operation – Normal Mode

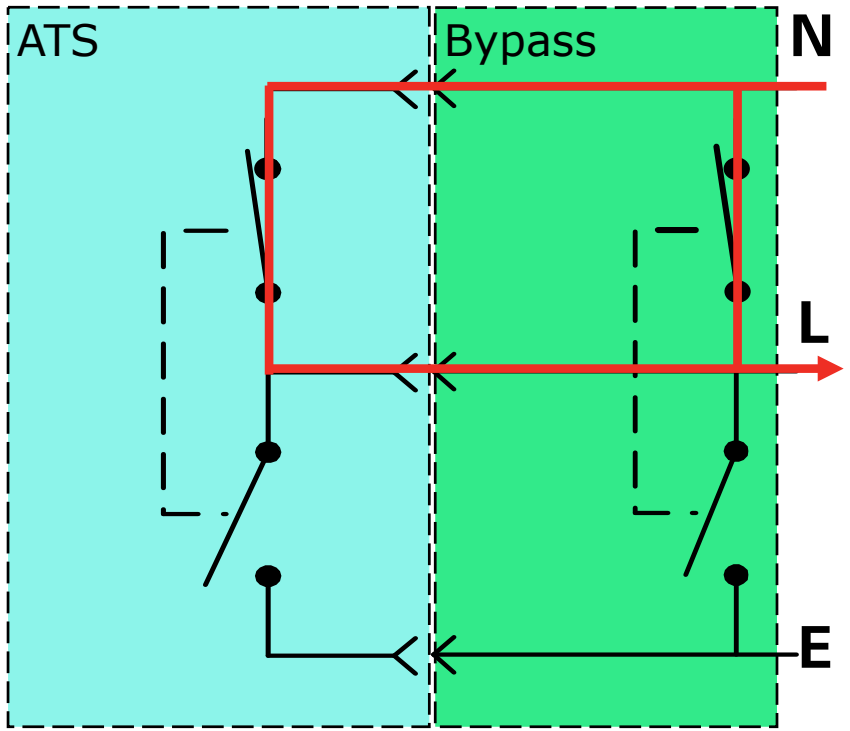
- Normal power flow through ATS
- Sequence of operation of ATS is unchanged
- Normal power does not flow through bypass transfer switch

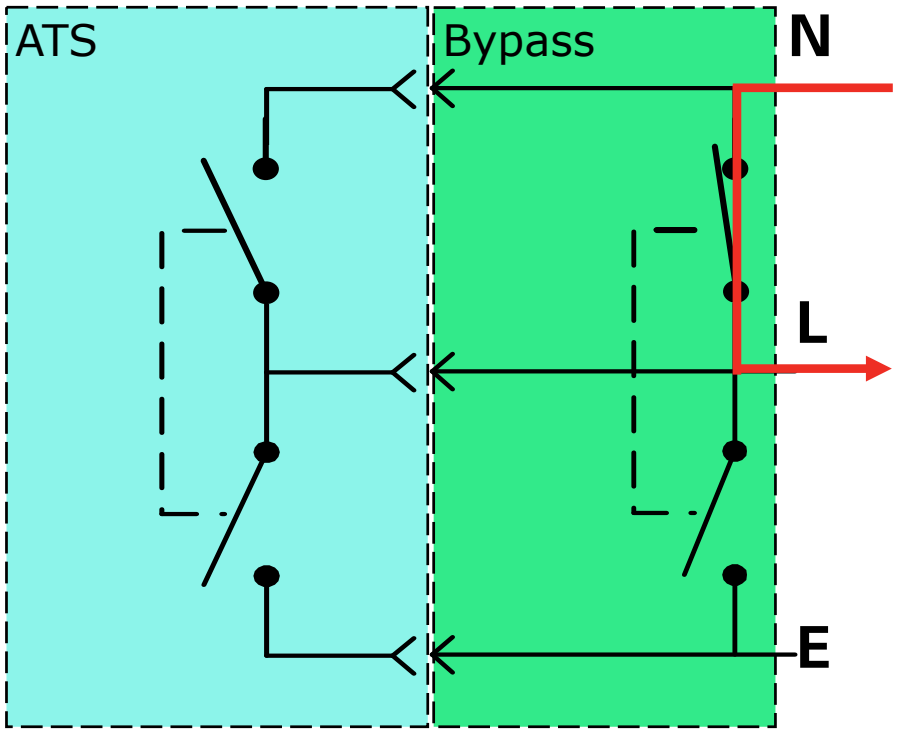


# Bypass Transfer Switch

## Sequence of Operation – Test Mode

- Bypass is connected to the same source as the ATS
- Dead source interlock
- Bypass to same source does not cause power interruption

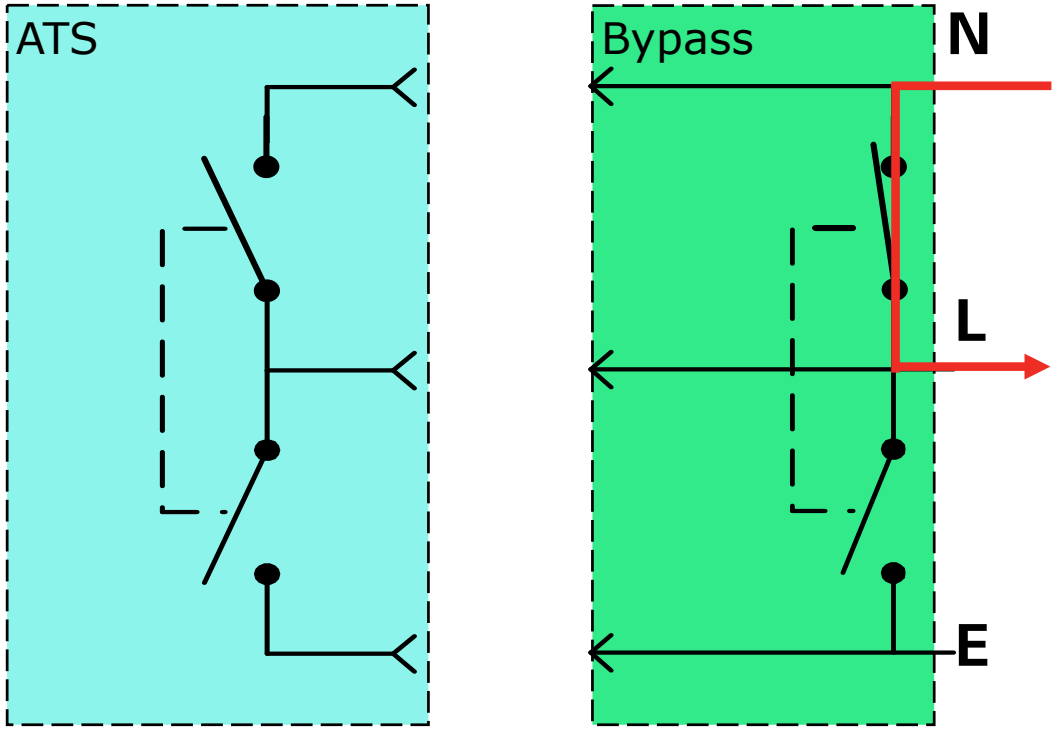


# Bypass Transfer Switch

## Sequence of Operation – Isolation Mode

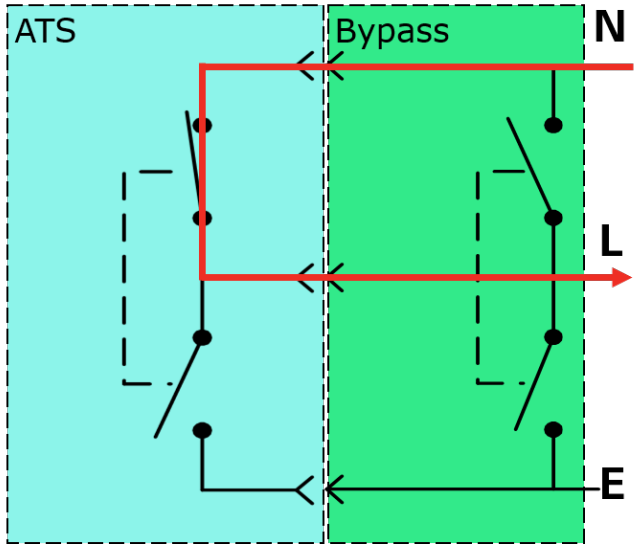
- With bypass closed, ATS can be opened, and drawn out for service
- ATS control is still active and sends a generator set start command upon normal power failure
- Loads can be manually transferred to alternate source using the bypass switch



# Bypass Positions

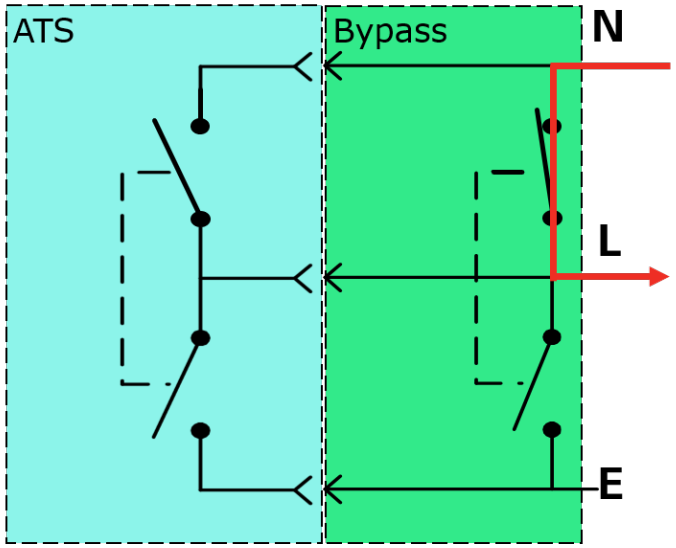
Reference Cummins White Paper “Bypass Transfer Switch Mechanisms” for more details!

## Normal



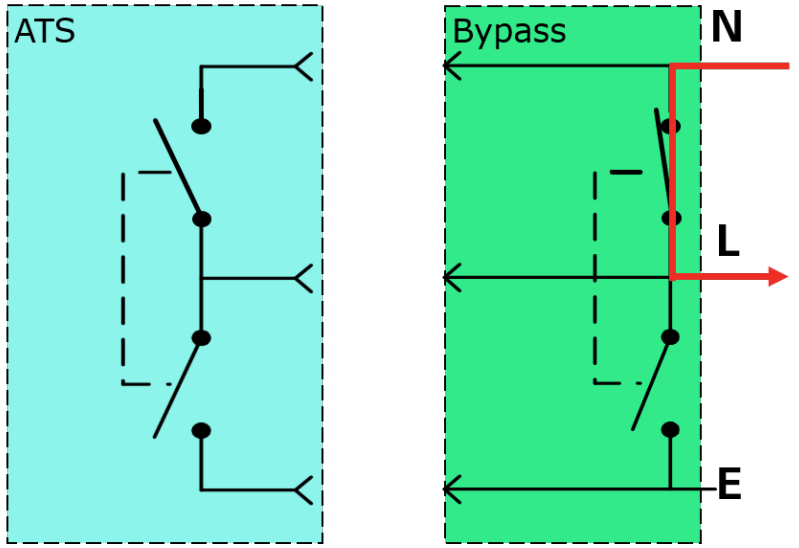

- Normal automatic operation
- Bypass is open

## Test




- Bypass closed and carries load
- Manual transfer. No power across ATS
- ATS retains sensing and operating functionality

## Isolation




- Bypass closed and carries load
- Manual transfer
- ATS removed for service or

**Spec Note** Provide bypass isolation type switch. The transfer switch shall be capable of bypassing the power flow between two live sources before isolation of the automatic mechanism. This first bypass then isolation mechanism shall not result power interruption under normal sequence of operation or when maintenance on the automatic mechanism is required

# Concept Check

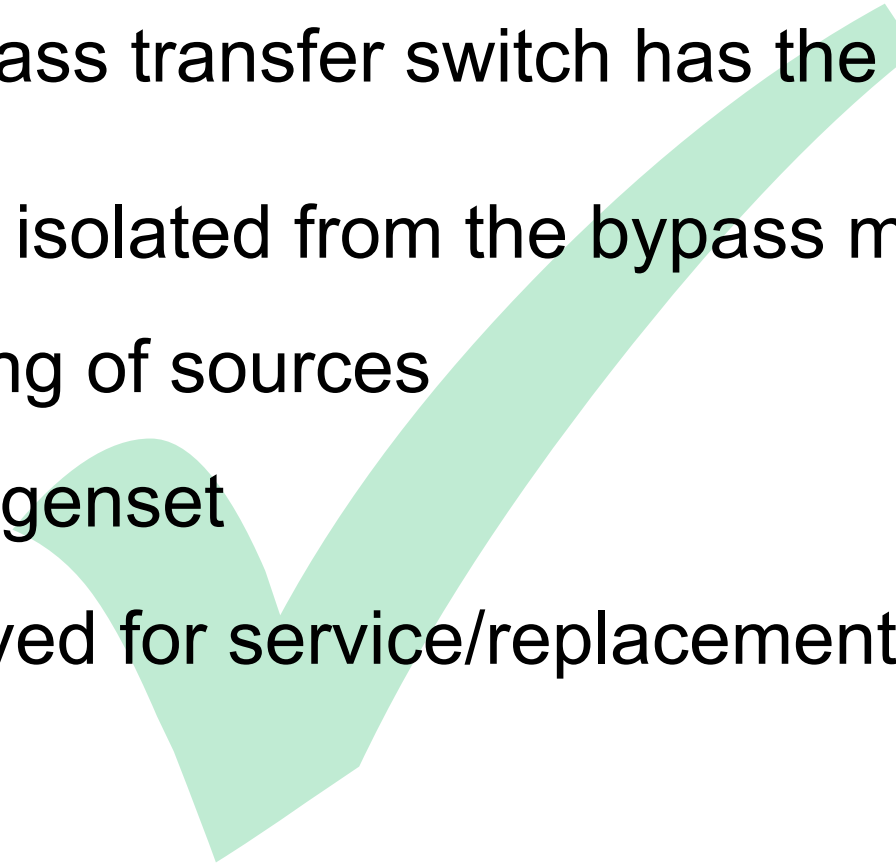
In test position, a bypass transfer switch has the following property:

a) ATS is completely isolated from the bypass mechanism

b) ATS retains sensing of sources

c) It cannot start the genset

d) ATS can be removed for service/replacement



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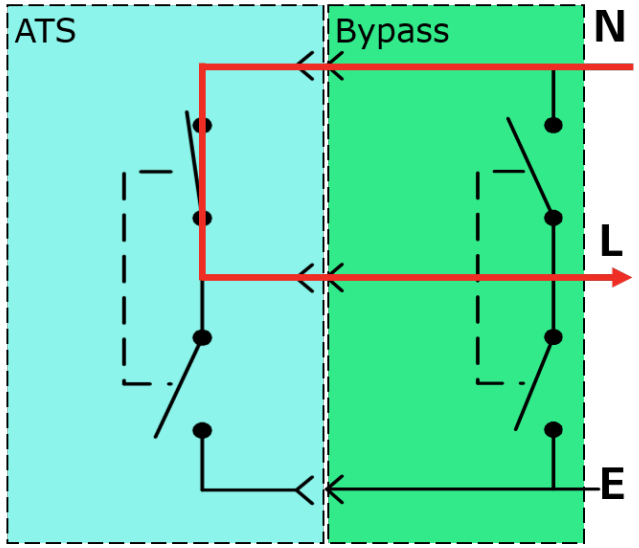
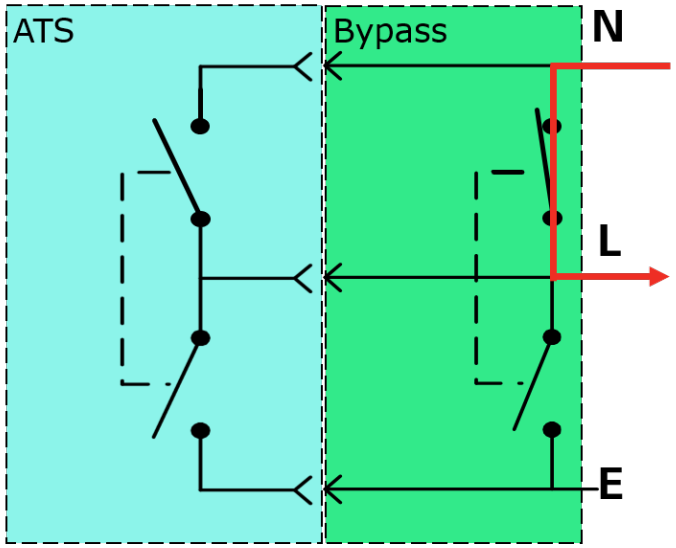
# Bypass Positions

## Normal



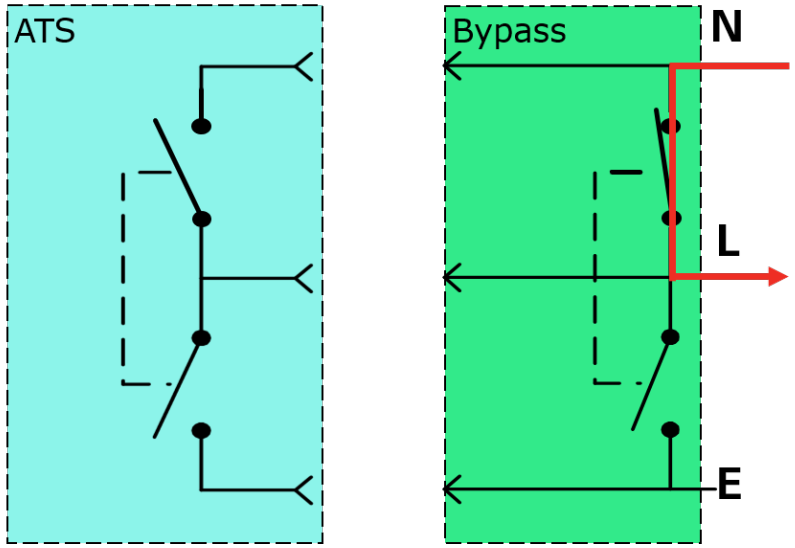

- Normal automatic operation
- Bypass is open

## Test




- Bypass closed and carries load
- Manual transfer. No power across ATS
- ATS retains sensing and operating functionality
- Functional testing without load interruption

## Isolation




- Bypass closed and carries load
- Manual transfer
- ATS removed for service or replacement

**Spec Note** Provide bypass isolation type switch. The transfer switch shall be capable of bypassing the power flow between two live sources before isolation of the automatic mechanism. This first bypass then isolation mechanism shall not result power interruption under normal sequence of operation or when maintenance on the automatic mechanism is required

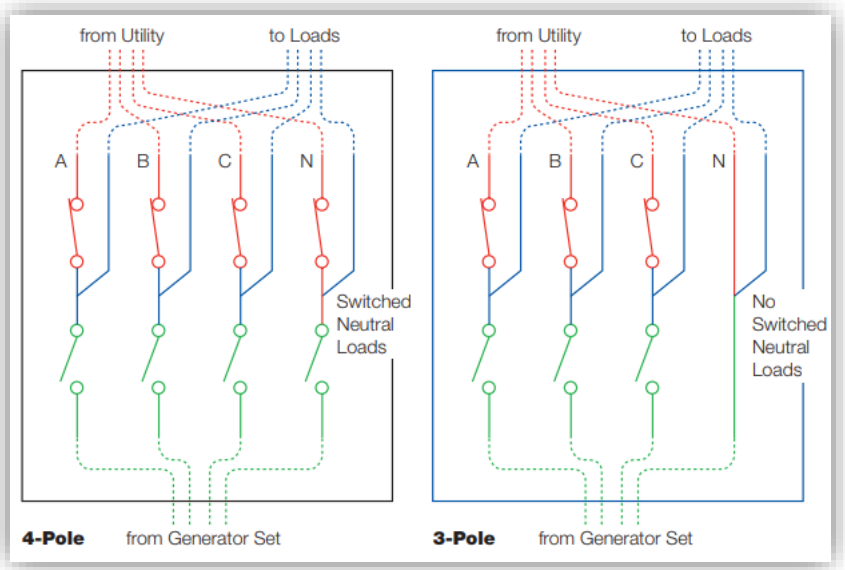
# Transfer Switch Selection

## 3 Pole vs 4 Pole

**Use a 4 pole transfer switch when ground fault sensing is required**

- Most common method is to use GF protection in breaker at the service disconnect
- Two rules for proper GF sensing
  - There must be only one neutral/ground bond on any neutral bus at one time
  - Ground fault sensors must be downstream from the bond

These two rules drive the requirement that 4 pole transfer switches must be used when ground fault sensing is required or may be required in the future.




IEEE Std 446-1995 (Orange Book)
7.9.1 "for most emergency and standby power systems with ground-fault systems, switching of the grounded circuit conductor by the transfer switch is the recommended practice."

# Course Summary

## Transfer Switch Operation and Application

- Transfer switches
  - Provides means of transferring loads between two power sources
  - Allows shedding of non-critical loads. Requires a 3 position switch.
  - Allows stepping of loads onto a single generator set.
- Transition types
  - Delayed / Programmed Transition should be used for motor loads. Requires a 3 position switch.
  - Closed transition transfer switches offer transition without power interruption but introduces risks and costs
- Bypass transfer switch allows service of ATS without disrupting power to critical loads. Specify Bypass Isolation switch.
- 4 Pole transfer switches should be used when ground fault sensing is required

**Specify:**

- 3 position mechanism that is required for load shed and delayed transitions.
- Bypass isolation mechanism for uninterrupted power transfer.
- 4 pole transfer switch for effective ground fault sensing

**Avoid specifying:**

- Brand-specific components that can limit design options and increase cost

# Additional Resources

**Cummins White Papers**:

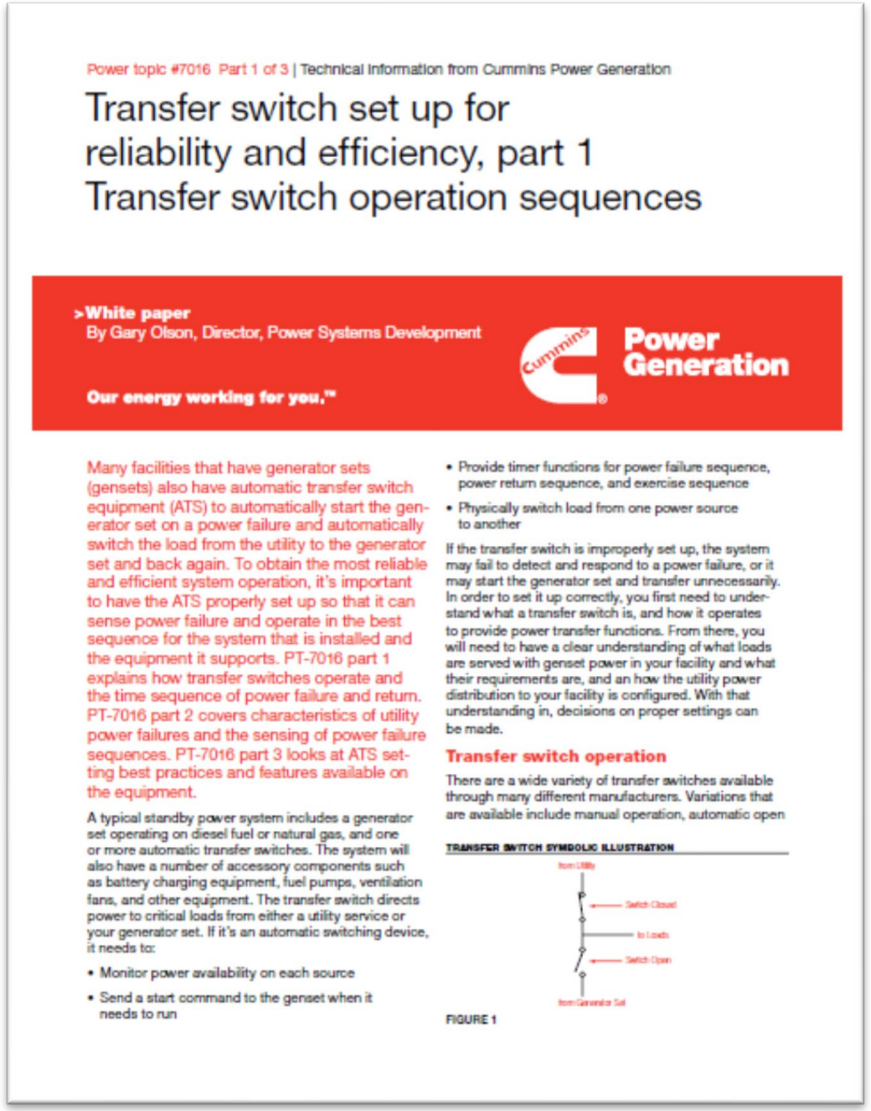
- Transfer switch set up for reliability and efficiency, part 1, 2 & 3
- Considerations for reliable closed transition switches
- Bypass transfer switch mechanisms

**Cummins On-Demand Webinars**:

- Functions and Features of Generator Set Control Based Paralleling

**Future Power hours**:

- Withstand and close on ratings for Transfer switches - November 2019



Power topic #7016 Part 1 of 3 | Technical information from Cummins Power Generation

Transfer switch set up for reliability and efficiency, part 1
Transfer switch operation sequences

>White paper
By Gary Olson, Director, Power Systems Development

Our energy working for you.™

Power Generation

Many facilities that have generator sets (gensets) also have automatic transfer switch equipment (ATS) to automatically start the generator set on a power failure and automatically switch the load from the utility to the generator set and back again. To obtain the most reliable and efficient system operation, it's important to have the ATS properly set up so that it can sense power failure and operate in the best sequence for the system that is installed and the equipment it supports. PT-7016 part 1 explains how transfer switches operate and the time sequence of power failure and return. PT-7016 part 2 covers characteristics of utility power failures and the sensing of power failure sequences. PT-7016 part 3 looks at ATS setting best practices and features available on the equipment.

A typical standby power system includes a generator set operating on diesel fuel or natural gas, and one or more automatic transfer switches. The system will also have a number of accessory components such as battery charging equipment, fuel pumps, ventilation fans, and other equipment. The transfer switch directs power to critical loads from either a utility service or your generator set. If it's an automatic switching device, it needs to:

- Monitor power availability on each source
- Send a start command to the genset when it needs to run
- Provide timer functions for power failure sequence, power return sequence, and exercise sequence
- Physically switch load from one power source to another

If the transfer switch is improperly set up, the system may fail to detect and respond to a power failure, or it may start the generator set and transfer unnecessarily. In order to set it up correctly, you first need to understand what a transfer switch is, and how it operates to provide power transfer functions. From there, you will need to have a clear understanding of what loads are served with genset power in your facility and what their requirements are, and an how the utility power distribution to your facility is configured. With that understanding in, decisions on proper settings can be made.

**Transfer switch operation**

There are a wide variety of transfer switches available through many different manufacturers. Variations that are available include manual operation, automatic open

TRANSFER SWITCH SYMBOLIC ILLUSTRATION

FIGURE 1

# Q&A

Type your questions, comments, feedback in the **WebEx Q&A box**. We will get to as many questions as we can

We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

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