Technical Note 178

Automatic transfer switch technology & drives

ATS impact on drive operation

The following technical note will assist with understanding the different automatic transfer switch types, technology, and how the operation of an automatic transfer switch may impact the operation of a variable frequency drive. Concepts discussed will apply to a wide range of HVACR applications and identify considerations for both the sequence of operation for the ATS as well as the programming of a ACH580-01 series drive. While the ACH580 is used as an example, many of the concepts are universal to other ABB and non-ABB drives. This document will focus on automatic transfer switch technology and operation.

This technical note is intended for an audience that has experience working with VFDs and motors in HVACR applications and as a supplement to the existing ACH580 firmware manuals. It is not intended to replace any installation manual, design criteria, or sequencing for the ATS.

Topics to be covered:

1. Introduction of ATS technology
   - How they work
   - Switching types and scenarios
   - Commissioning and maintenance considerations for the ATS
2. How a drive works
   - What happens when we lose power
3. Application Impact
   - ATS types, testing vs real world conditions
4. Actions to take with the drive
   a. Faults
   b. Questions to ask the site
   c. Understanding the existing setup
   d. Fault handling with a drive

When and why ATS are used?

Transfer switch technology is used in data centers, hospitals, factories, and a wide range of commercial and noncommercial facilities that require continuous or near continuous operation. This will typically consist of a primary utility to uninterruptable power supply (UPS) or generator transfer (and back). In more rare instances this may be a switch from primary utility power to a backup utility power (and back).

ATS are applied to a variety of applications but are typically defined into four categories according to the National Electric Code. In NFPA 70 this includes article 700 emergency systems, article 701 legally required systems, article 708 critical operation power systems, and article 702 optional standby systems.

Figure 1 below illustrates a typical critical power system that has a utility supply that will transition via the ATS to the backup generator (genset) when needed. These sources provide power to the drives that are running fans and pumps in the system.

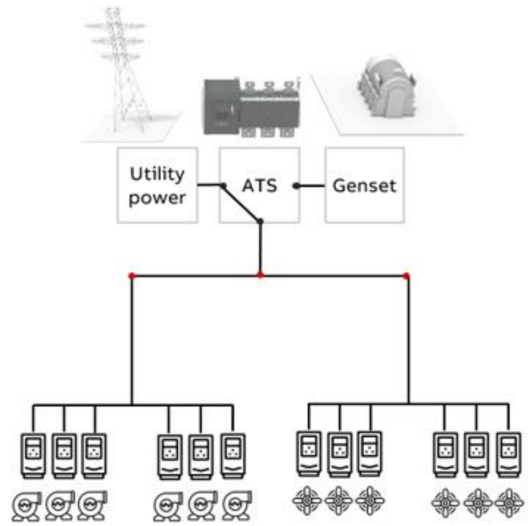


Figure 1 Example of a typical critical power system

Introduction of ATS types, technology, and equipment

Throughout this document both automatic transfer switches and static transfer switches will be referred to as “ATS.” The difference between these two types of switching technology is that static transfer switches use power electronics (SCR’s) for the switching process, while automatic transfer switches use other hardware such as contactors, switches, or circuit breakers. Both technologies will be generalized under an ATS reference based on this technical note’s focus on how the transfer type and sequence might impact variable frequency drive operation.

Transition types and scenarios

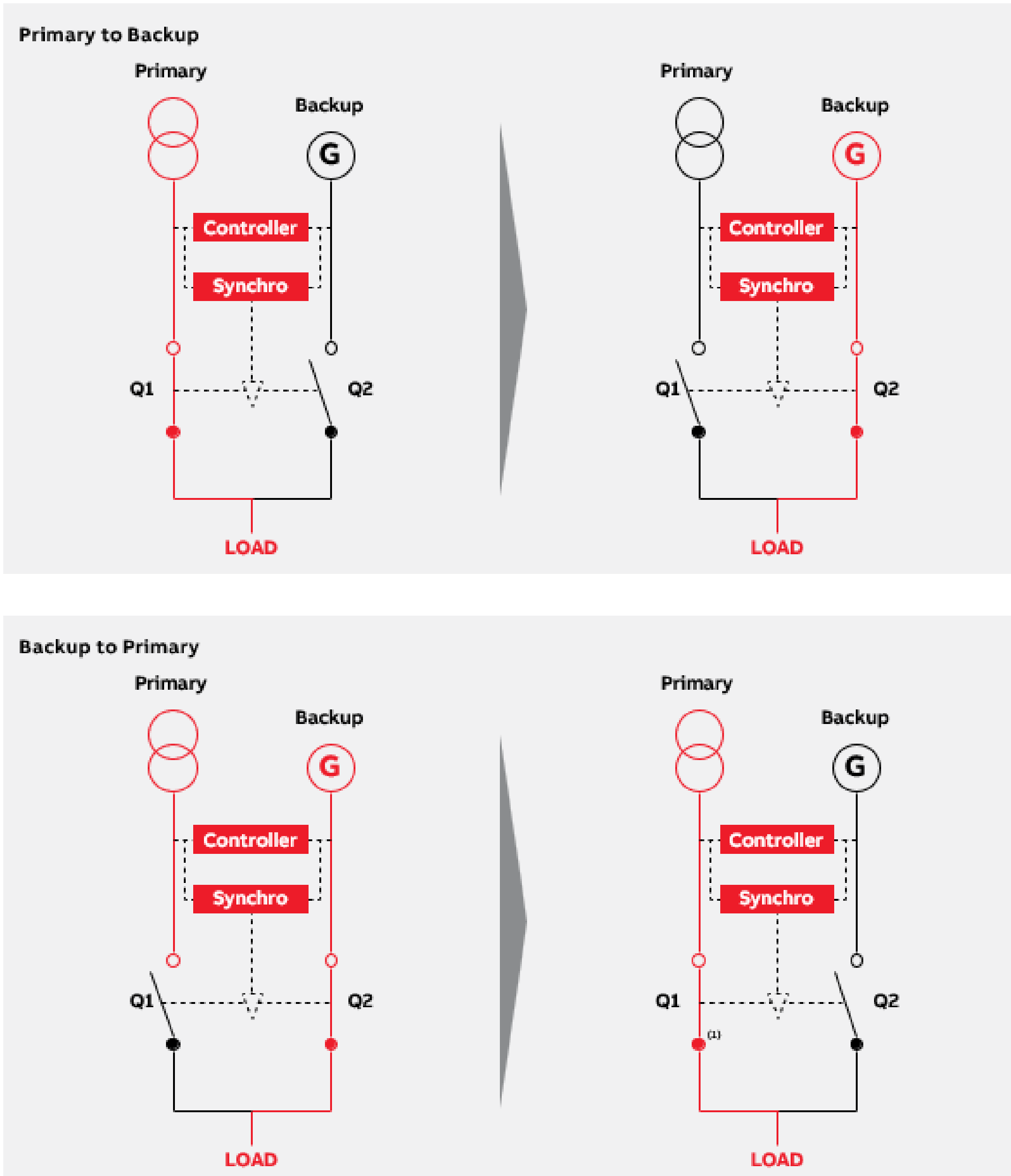
There are three transition types supported by ATS operation. These include open, open delayed, and closed transitions. Each transition type has its own requirements that must be met before the transfer takes place. Before reviewing the three transition types in detail, the transfer scenarios should be acknowledged. The first scenario is a traditional power loss event which would be unplanned, such as loss of primary power during a storm. For the unplanned power loss event scenario, if the backup source is a generator, no matter what ATS transition method is used, there is a delay in time for the generator to come online before the ATS can begin a transition process. As a result, the transition process from primary source to generator, will look different than the process from generator back to utility (once the primary source is available) which would be a planned transition with both sources available. The second scenario is a routine test between two sources. In these cases, both sources are available. The time of transition will be dependent on both the transfer criteria being satisfied, the transfer type, and the type of secondary power source.

Open transfer

In the North American market, the most common type of transfer is an open transfer. This transfer consists of a break-before-make switch that contains two positions without a stable off position. The transfer between two live power sources occurs only when they are synchronized (voltage, frequency, and phase angle). This means the transfer switch must be equipped with in-phase monitoring. This transfer consists of a rapid contact transfer time usually less than 50 milliseconds between the two available power sources. The transfer will not occur if both sources of power are available but unable to meet the synchronization characteristics of both voltage and phase angle. Usually, these transfers are used for loads that are not sensitive to power interruptions lasting up to 50 milliseconds or have a downstream UPS that supports this power interruption period for equipment.

Figure 2 below illustrates an open transfer between primary to backup power, then the transition back to the primary source.

Open Transition – MAIN-GEN transfer sequence



1) Supply interruption up to 50ms

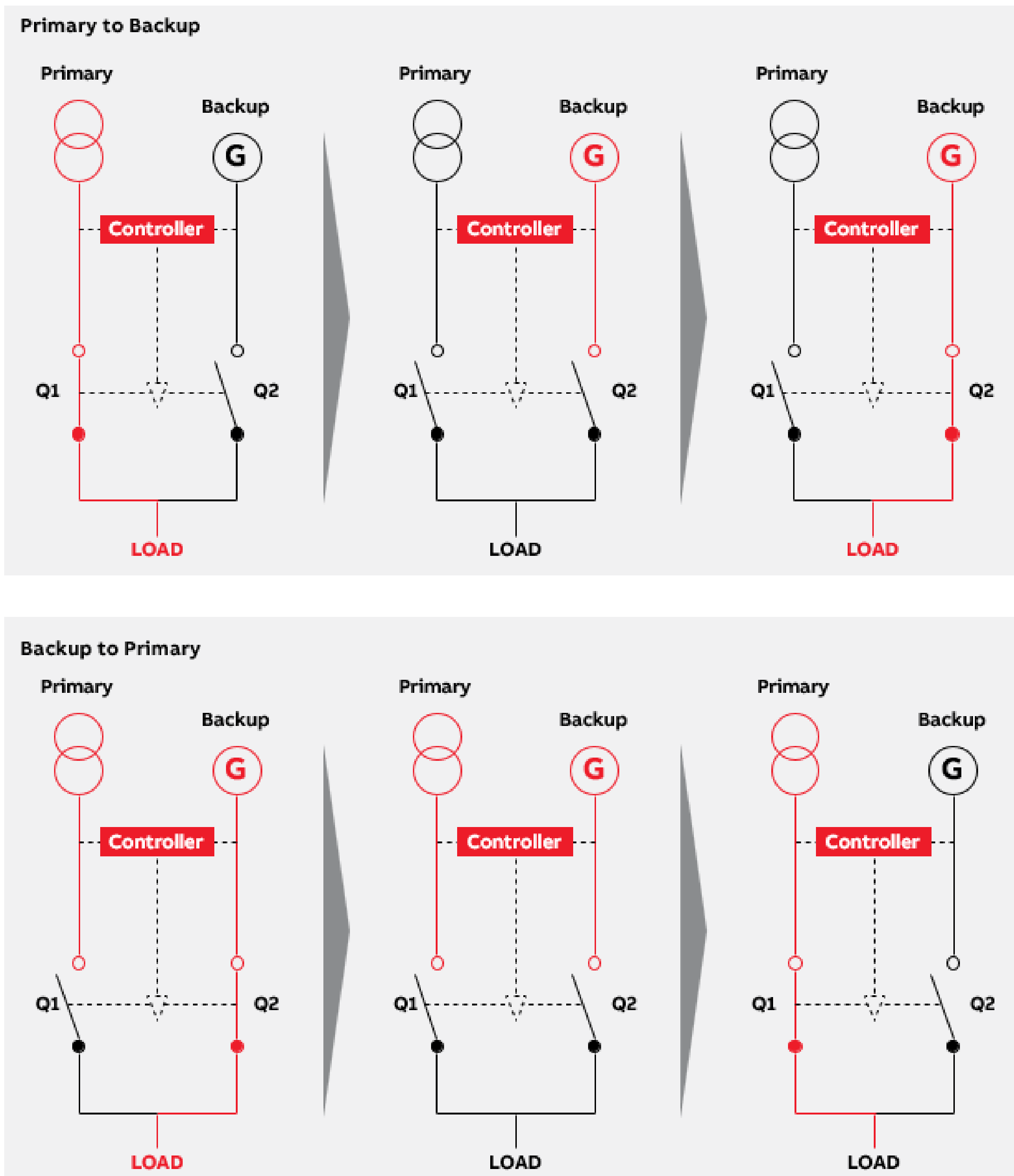
Figure 2 Standard open transition

Open Delayed Transfer

A delayed transition is the most popular transfer type in the IEC market (European). It has a stable off position between sources and operation is independent of electrical synchronization between the two power sources. A mechanical or electrical interlock is required to prevent contacts from overlapping. The time delay in the off position prevents high current and high torque transients from occurring in the case of inductive loads such as direct on-line pumping applications or a manufacturing process. The duration of these transfers will be in seconds.

Figure 3 below illustrates the delayed open transition from primary, to an off position to a backup source, then the transition back from the backup power to an off position, then to the primary source.

Delayed Transition [1] – Transfer sequence MAIN-GEN



1) Delayed transition is also known as Open transition with stable OFF between positions I and II

Figure 3 Delayed open transition

Closed transfer

A closed transition is designed to have no power interruption when transferring between two live sources. This consists of a make-before-break switch, which has a transfer between live sources that occurs only when they are in sync (voltage, frequency, phase angle). Many utilities require closed transitions to comply with interconnect requirements, such as NEC Article 705, which provides guidance on how to connect additional power sources to existing wiring to allow them to operate in parallel with the primary source. The aim of these interconnect requirements is to preserve the power quality and protect the utility. Closed transitions can produce higher fault currents. In this transition the controller checks the synchronization between the two sources. When both sources are synchronized, a contactor closes connecting both power sources together. The overlap period during which both sources are simultaneously connected (paralleled) usually lasts no more than 100 milliseconds to comply with these interconnect requirements.

Figure 4 illustrates a closed transition example with a generator as the back-up source, in a traditional power loss scenario (unplanned). The primary utility power source is lost, the generator starts up and comes online and the transition occurs. The transition from generator to utility then follows the closed transition.

Closed Transition – MAIN-GEN transfer sequence

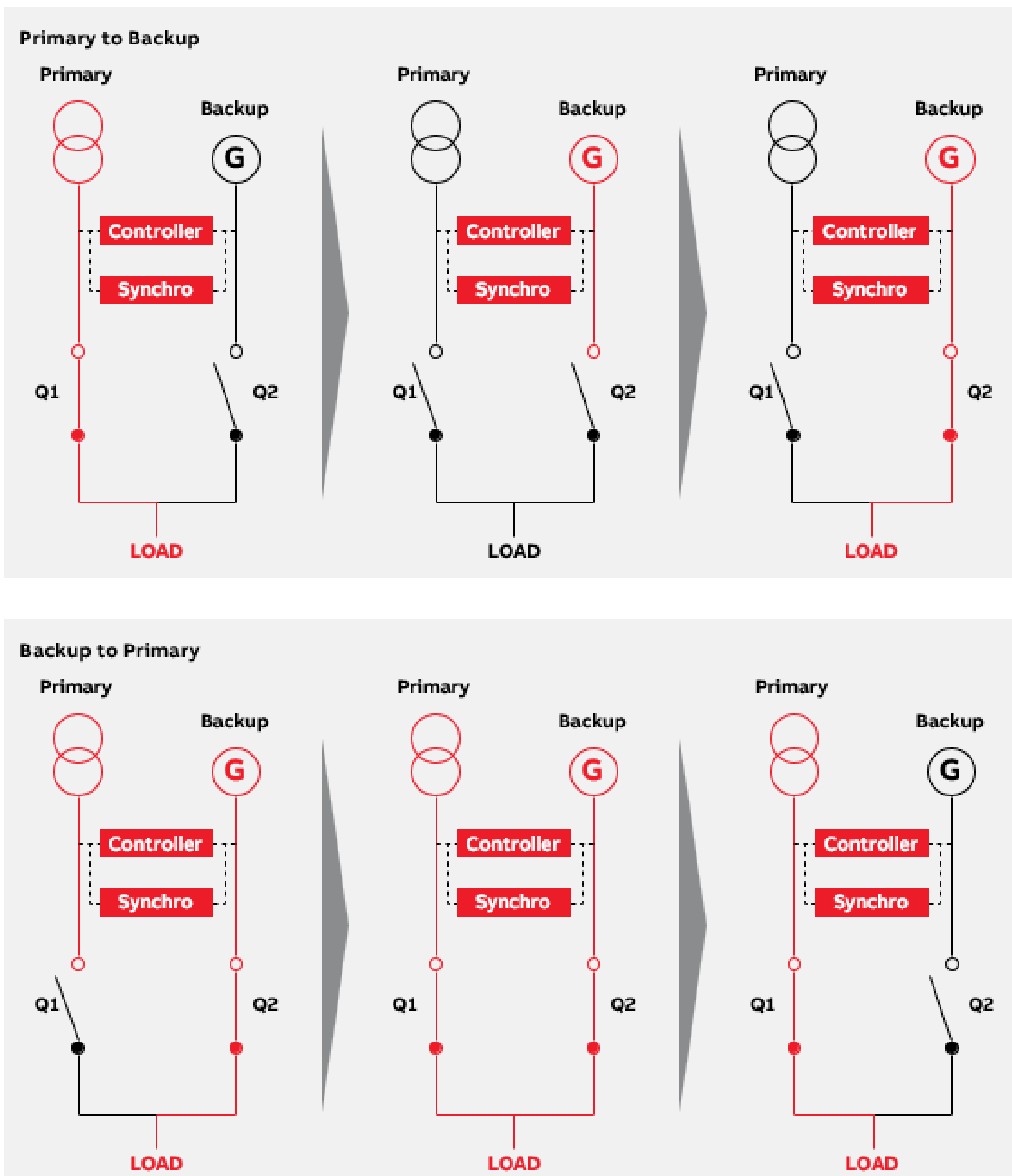


Figure 4 Closed transition

Open vs. Closed transition

Both a standard open transition transfer scheme as well as a closed transfer scheme require synchronization. The difference between the two schemes is in the power contacts for closed versus open transition. The switch contacts require time to open and close, so, in addition to the time required for the switch to find the synchronization point, there is a time where the switch contacts are in motion. While switching, there is a small power interruption for open transition ATS which may be up to 50 milliseconds or 3 cycles. The closed transition switch has temporarily, concurrently closed contacts that prevent any interruption in supply to the load when transferring between power sources.

Familiar challenges with ATS implementation and operation

To avoid issues with the operation of downstream equipment like variable frequency drives, ATS implementation should have a clear sequence of operation identified and should include input from the design team, owner, and equipment vendors to discuss all the features of the system. The sequence of operation should be the basis for establishing a detailed functional performance test. The commissioning and testing procedures should consider all dependent systems under all conditions to make sure that the generator system works when the ATS is activated under real world conditions. A training should be provided to ensure that the operators understand the process and interface of the equipment, as well as how to evaluate and maintain the system.

Implementation of an ATS can be challenging based on gathering all the information needed regarding the design, operational needs, as well as understanding all the equipment required to manage the transition. Some of the common mistakes in the implementation of an ATS are:

- The commissioning agent not having all the equipment settings provided by the design engineer or owner
- Implementing neutral bonding and grounding
- Lacking a clear sequence of operation
- Overcurrent device settings not being accurate
- Interface issues and/or lack of training regarding the different equipment in the system
- Accurate coordination of testing and validation of the system
- Lack of understanding of the needs of the equipment downstream of the ATS sequence

After correct implementation, maintenance of the ATS and system needs to be considered. Damaged wires, bad solenoids, controller issues, and grounding voltage quality can impact the ATS ability to operate and regular preventative maintenance should be performed.

Reference:
Commissioning best practices: Electrical — Top 10 deficiencies and challenges | Consulting - Specifying Engineer (csemag.com)

How a drive works

A variable frequency drive, downstream of the primary or secondary source of power and ATS, takes the AC power supplied by a transformer or generator, converts that AC power to DC, stores the power in the DC bus capacitors. Then uses insulated gate bipolar transistors to take that DC voltage and recreate an AC waveform for a motor using pulse width modulation.

Drives have a feature, undervoltage control, also commonly referred to as power loss ride-through. This feature leverages the power storage capability in the DC bus capacitors, along with inertia in the motor and application. If the drive's DC bus voltage gets too low, the drive will intentionally slow down the motor, allowing the motor to act like a generator and feed power back into the DC bus. The drive's power loss ride-through leverages the application's inertia, to use the motor itself as a power source, to maintain operation during very brief power outages.

What happens to a drive during a power loss

In the event of a loss of power, a variable frequency drive will attempt to continue to operate, by using the energy stored in the DC bus capacitors. The power loss ride-through function tries to keep the drive powered and in control of the motor. Applications with high inertia, such as a fan, have a much longer ride-through ability than a low inertia application, such as a pump. For example, the ride-through of a pump may only be 20 ms, while the ride-through of a fan is often measured in seconds.

In situations where an ATS is switching between two active power sources, drives on higher inertia applications often completely keep control of the motor throughout the operation of the ATS, especially with open and closed ATS transitions. Drives on low inertia pump applications may lose control of the motor during a ATS operation unless a closed transition is used.

The alternative situation is when a there is the unexpected loss of the primary power source and there is a delay in time for the secondary (typically a generator) source to come online. In these situations, from the drive's perspective, the type of ATS is less critical. The main time-based variable is the delay for the generator to come online. The key question is whether the drive will be able to power loss ride-through until the generator comes online, thus allowing the ATS to provide generator power to the drive. The drive will not be able to keep control of low inertia applications, but some high inertia (more power loss ride-through ability) may still allow the drive to stay in control of the motor.

Drives are designed to recover from both short-term and long-term power loss conditions. In the case of a pump application, the drive losing control of the pump may result in the pump stopping very quickly. In the case of a fan application, the fan may still be rotating. In both pump and fan applications, once power is restored to the drive, the drive will ramp the motor back to setpoint.

Controls and peripheral devices also play a role in how a drive responds during a power loss. The previously covered power loss ride-through and associated sequences of how the drive responds, all assume the drive is being told to run the motor, and the motor is connected to the drive. While these may appear as obvious assumptions, in practicality this is not always the case. From a control's aspect, there may be interposing relays that may remove a start/run, enable, or safety signal from the drive. A brief loss of power may result in the control relay opening, thus signaling the drive to stop. There may also be peripheral devices such as an output contactor. If the power supply source for the contactor does not ride-through the power loss, then the contactor will open, and the drive is no longer connected to the motor. If the drive is told to no longer run or the drive is no longer connected to the motor, then the drive's power loss ride-through feature cannot function.

Drive faults

In rare cases, a drive may fault as part of a ATS event. These drive faults may include undervoltage, overvoltage overcurrent, earth fault, or overcurrent. These faults may not be related to the ATS transition itself. The drive may fault because of a related event (i.e., lighting strike that preceded a loss of utility power) or application response (i.e., pump, fan) related.

- Undervoltage
  - This fault is unlikely to occur on an HVACR drive that has been configured to automatically reset after a power loss. Troubleshooting may be as simple as reviewing and correcting parameter settings.
- Overvoltage
  - This fault is most likely to occur when there is a high voltage event that occurs on the input side of the drive. This could be voltage transients caused by lightning strikes, other equipment failing, switching of power factor correction capacitors, or even a problem with the ATS operation itself inducing a voltage transient onto the network. A common solution is to have the drive configured to automatically restart after an overvoltage fault. However, if there is a problem within the electrical system that is going to cause repeated overvoltage transients, then those root causes should be identified and eliminated. Failure to eliminate the root cause may lead to premature failure of electrical equipment, such as drives.
- Earth fault
  - If a drive experiences a nuisance earth (ground) fault as part of troubleshooting, the first item to understand from the drive vendor is how the drive senses for an earth fault. Drives like the ACH580 that use (3) internal current transducers to sense earth faults and are less likely to experience nuisance faults than other drive designs that can be susceptible to being "tricked" into believing there is an earth fault due to a transient on the incoming line.
  - Another item to look for is if there are any contactors between the drive and motor. A short power loss or ATS transition can result in an output contactor chattering and causing the drive to fault.
- Overcurrent
  - An overcurrent fault is often caused by something on the output side of the drive. Like the above example, an output contactor chattering, or opening and closing while the drive is powering the motor, can cause an overcurrent fault.
  - When power is restored, the drive could fault on an overcurrent fault when it tries to start the motor and ramp it back to setpoint. The most common situation is a multiple motor application and having motors still in the process of coasting to a stop while rotating at different speeds from each other. The drive may not be able to accomplish the flying start if the motor speeds are too far out of sync, and an overcurrent fault may occur. In a case like the multiple motor application, the drive's start method could be adjusted.

As with most advanced electronic equipment, drives can experience nuisance problems when there are brief power outages or power quality issues. This technical note covered the undervoltage, overvoltage, earth fault, and overcurrent faults in more detail as they are the most likely to occur. But there could be other fault types beyond those four types. Understanding the circumstances surrounding the moment of drive fault is key to troubleshooting a fault. Appreciating ATS functionality helps identify how long the drive and overall system was without power. The following sections provide additional fact-finding guidance and solutions that can assist in troubleshooting drive faults associated with an ATS transfer.

Questions to ask the site:

- What is the transfer type, order of operation, speed of transfer and process of bringing the drives online? Clarify if issue happens on a utility to utility, utility to gen, or gen to utility transfer.
- Use software tools such as Drive Composer for the ACH580 to gather support packages available from the drives that have had issues to get specifics of the faults.
- Understand the timeline on these issues. When did they start? Was there a change to the sequence or test sequence?
- Are there past issues with the site?
- What is the expected operation of the drives during the ATS transition (continues motor control, not fault but can motor can stop running)?

When the transfer takes place, it may impact the run command for the drives. If we remove the run command, we need to ensure that it returns when power returns. Consider how that run command is being provided to the drives.

- How are the drives being controlled?
    - Start/stop into DI1 and a safety into DI4?
    - Are there interposing relays?
        - Do signals ride-through the transfer event (UPS) or do they drop out?

Evaluate the packaging of the drive hardware and how that may be impacted by the transfer process.

- Is this a drive by itself, or a redundant drive, or a drive and bypass package?
    - Are any devices on the output side of the drive, like a contactor?

Understanding the existing setup

The answers to these questions will allow for a better understanding of the magnitude of an issue and help in determining the root cause of the nuisance fault condition. Issues that appear to be power quality or ATS related should have an oscilloscope measurement taken at the input of a drive during the transition. Document the break-to-make time when the transfer switch operates. The oscilloscope should be capable of and programmed to record events in the microsecond range.

Drive specific considerations based on expectation of operation

- Establish expectations and needs for the drive operation in the event of a transfer
- Evaluate the ride through time compared to transition time
- Understand the status, run command, and safeties
- Take oscilloscope measurements on the input of the drive
- Understand the fault reset parameters in the drive

If conditions exist in the ATS that cannot be addressed, or in the stability of power onsite, an ACH580 drive can be configured to automatically reset if an overvoltage, undervoltage, or overcurrent fault occurs. While this does not address the root cause problem, it will allow the drive to reset and operate after the transition. This can be configured in group *31 Fault function*s.

Figure 5 illustrates the bits available in parameter *31.12 Fault reset* that can be selected to Autoreset.

Parameter	Bit	Description
31.12	0	Overcurrent
	1	Overvoltage
	2	Undervoltage

Figure 5 Parameter 31.12 fault reset example

Other important parameters to configure are *31.14 Number of trails*, which defines the maximum number of automatic resets that the drive is allowed to attempt within the time specified by *31.15 Total trails time*. The reset attempts will be made at intervals defined by *31.16 Delay time.*

Another action that can be taken is to disable “undervoltage control” in parameter 30.31. This will allow for the drive to power down faster. The drive will release the motor to come to a stop and restart when power returns, rather than attempting to ride through the power disruption. While extremely rare, this adjustment may also eliminate an overvoltage fault or overcurrent fault that occurred when the drive was trying to maintain operation of a motor in an undervoltage condition.

Summary

Documenting and understanding the detail of the transfer switch type, sequence of operation, as well as understanding the impact of the ATS on downstream equipment, will lead to a successful transition between power sources. If issues arise due to the transfer process or external factors, evaluate these characteristics along with the requirements of the equipment downstream of the transition. Understand the status, run command, and safeties for the drives. Advanced troubleshooting may require oscilloscope measurements on the input of the drive during the transition. Then evaluate what needs to be addressed. If necessary, configure the fault reset parameters in the drive. Keep in mind that application related issues (i.e., fan array with motors coasting at different speeds) may result in a fault during an ATS transfer, thus troubleshooting shall begin at the system level and be narrowed down from there. Reach out to the local ABB Drive Specialist if there are questions.