Bypass transfer switch mechanisms

> **White paper**

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This paper describes the configuration and operation of commercially available bypass isolation transfer switches. It also describes major advantages and disadvantages of these designs. This overview looks at facility design considerations that should be made when applying these devices.

Automatic transfer switches manufactured by various suppliers are all virtually identical in their basic functions and operations. However, when comparing bypass isolation type transfer switches significant differences in the design and operation of the devices can be seen. It is critical that these differences are understood so that proper equipment is specified and procured for a project, and system design objectives are achieved.

A standard automatic transfer switch (ATS) has only three major functions: sensing normal source availability, sensing emergency source availability, and transferring power to the most desirable source at the appropriate time. While there are many contactor and control system designs to achieve these functions, and many options available to enhance system performance, all these systems operate in the same way.

TYPICAL AUTOMATIC TRANSFER SWITCH

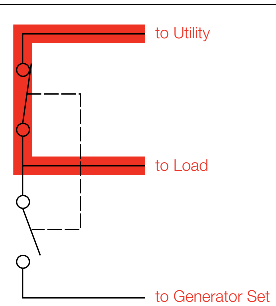

FIGURE 1

As shown in FIGURE 1, in a typical application, utility power is connected to the normal side of the transfer switch and flows through the transfer switch to the load. On sensing loss of the normal source, the ATS issues a signal to start an on-site generator set. On sensing availability of the emergency source, the transfer switch will open the normal contacts and then close the emergency contacts, connecting power to the alternate source. On return of the normal source, the emergency contacts open, the normal contacts close, and the on-site power system shuts down.

An automatic transfer switch is almost always energized from either the utility or the generator source. Because some loads are extremely critical (due to life safety or cost considerations), or inconvenient to shut down, bypass isolation designs were developed to allow testing or service of the automatic transfer switch mechanism and manual transfer of power without physically disconnecting power conductors to that device. In designing these devices, there are three major design objectives (in addition to all other transfer switch design objectives):

- The bypass function should occur without disrupting power to the load. It makes little sense to design a system to prevent power interruption to critical loads, and then allow normal operation of the bypass switch to defeat this objective.
- The system design must be safe to operate This may seem obvious, but in fact is a very critical design requirement, and not easy to achieve with

a device of this nature. Safety of the device should be considered to include ease of operation, capability of operating the bypass switch to either source at any time, and proper mechanical interlocking. Because a technician is likely to be working in the cabinet with energized components, barriers to prevent inadvertent contact with line voltages are critical. Shields should also be provided to protect from injury by moving parts.

- The design should allow easy removal of the automatic transfer switch from service without disconnection of power conductors to the device.

The facility designer should be aware that due to the complexity of bypass isolation transfer switch designs many suppliers may restrict access to the power transfer mechanism in the cabinet, so care should be taken to be sure that the equipment chosen can be connected as desired. Also, access may be required to both the front and rear of the equipment, both for connection of conductors and for normal switch operation. Many bypass designs (especially for large switches) incorporate floor roll out transfer switch mechanisms, which may not be suitable for use with the housekeeping pads which are commonly specified for transfer switch equipment. Finally, because of the many designs and configurations of bypass switches, the physical size of identical amperage equipment provided by different suppliers can vary dramatically.

The facility designer should also recognize that while the bypass isolation transfer switch is in the bypass mode, the automatic emergency system for the loads on that switch is disabled, and unable to automatically connect emergency power. Consequently, even though codes do not yet require it, it is a reasonable practice to annunciate “transfer system disabled” alarms at remote monitoring points, so the system is not inadvertently left disabled, and emergency manual operation procedures can be implemented in the event of an actual power failure while the bypass switch is engaged.

Cummins Power Generation recommends that the bypass isolation switch control system remain active, even when the bypass switch is engaged, so that on power failure, the generator set is running and ready to accept load when the bypass switch is manually closed to the load.

Bypass isolation switches in general

There are three major types of bypass isolation transfer switches available in the marketplace today. They are represented in one line format in FIGURE 2.

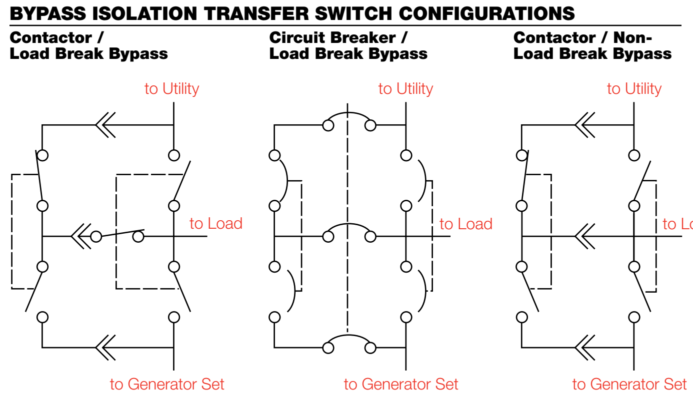

FIGURE 2

These are: contactor/load break; circuit breaker/load break; contactor/non-load break. Non-bad-break bypass isolation switches allow the operator to perform the bypass operation without disrupting power to the load. Load break type designs require the operator to first isolate the load from its power source, and then perform the bypass function. Load break bypass designs require a power interruption, the load as normal course of their operation. Load break bypass switches are available in both two source designs (as shown in FIGURE 2), and in single source designs (as shown in FIGURE 3). Single source bypass switches are considerably less expensive than two source designs, but are not capable of transferring power to the alternate source when the ATS is disabled. Also because the generator set is directly connected to the emergency

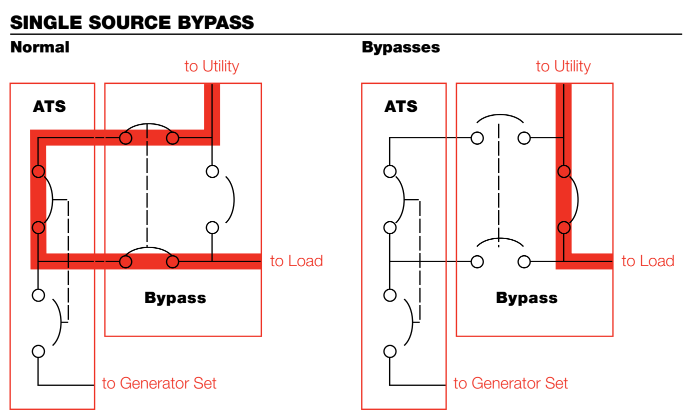

FIGURE 3

side of the ATS, the ATS is not automatically isolated for repair and servicing when the bypass is engaged, as would be the case with a two source design.

In bypass switch designs, the automatic transfer switch is intended to be removed from the power conductors of the device. Often, the automatic transfer switch is provided with drawout "fingers," much like the ones used on power circuit breakers, for connecting the automatic transfer switch buswork to the bypass switch buswork. In other designs, the automatic switch is bus or cable connected to the bypass structure, so removal of the ATS from the cabinet is much more difficult. The bypass switch is connected in parallel with the automatic switch.

Both the automatic transfer switch and the bypass switch commonly include mechanical interlocks to prevent interconnection of the on-site power generating equipment with the utility service. Provisions must also be made to prevent accidental paralleling of the utility and generator sources through the bypass and automatic switches due to closure of the "opposite" contacts in each switch mechanism. Mechanical interlocks are preferable to electrical interlocks for this cross interlocking function, due to the reliability of the mechanical device under both energized and de-energized operating conditions.

Dead source interlocks are provided on some bypass switches to prevent manual operation of the bypass switch to a source that is not energized. This is important, because the bypass switch is often not in the same room as the loads it serves, and de-energization of the load bus may not be apparent to the operator of the bypass switch. The dead source interlock can prevent an accidental power outage to critical loads due to operator error.

CONTACTOR TYPE LOAD BREAK BYPASS SWITCH

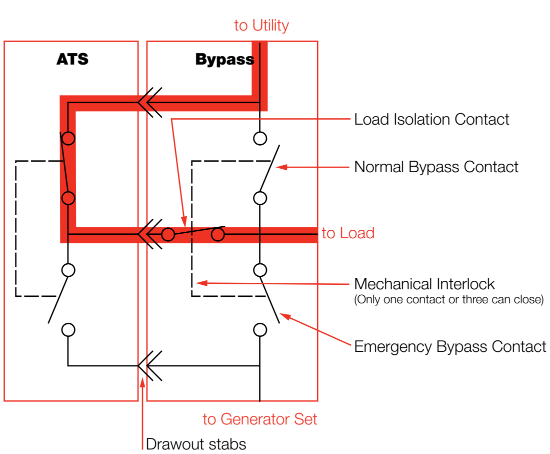

FIGURE 4a

Contactor type load break bypass switches

Contactor type load break bypass switches are configured so that the automatic transfer switch is isolated from the bypass switch by a set of isolating "fingers" (such as are used in drawout circuit breakers) find a set of load isolation contacts (FIGURE 4a). Normal and emergency power flow paths through the device are shown with a shaded line (FIGURE 4b).

CONTACTOR TYPE BYPASS POWER FLOW PATHS

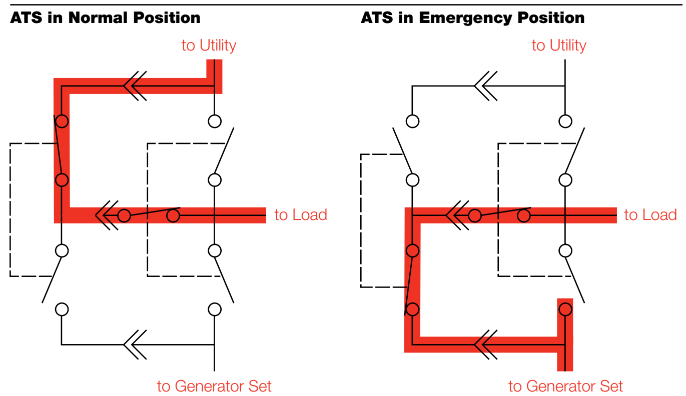

FIGURE 4b

The automatic transfer switch, as is typical with almost all transfer switches, has mechanical interlocks to prevent simultaneous closure of both the normal and emergency side contacts of the mechanism. The bypass switch is similar in construction, except that it is manually operated, rather than electrically operated. To prevent simultaneous closure of the normal contacts on the automatic switch and the emergency contacts on the bypass switch, a set of load isolation contacts are provided. In order to close the bypass contacts, the load side isolation contacts must first be open.

With the automatic transfer switch connected to normal (bypass contact sets both open and load isolation contacts closed), the automatic transfer switch test or isolation function is typically performed as follows (FIGURE 5):

1. The source to be bypassed to is selected. The operator typically operates a dead source interlock switch, which allows (as noted previously) operation of the bypass mechanism only if the source is available. With the button held closed, the bypass switch is operated, which first opens the load isolation contacts (FIGURE 5b) then closes the bypass contacts (FIGURE 5c). The load is exposed to a short power outage, because the load contacts open, isolating the load, before the

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CONTACTOR LOAD BREAK BYPASS OPERATION

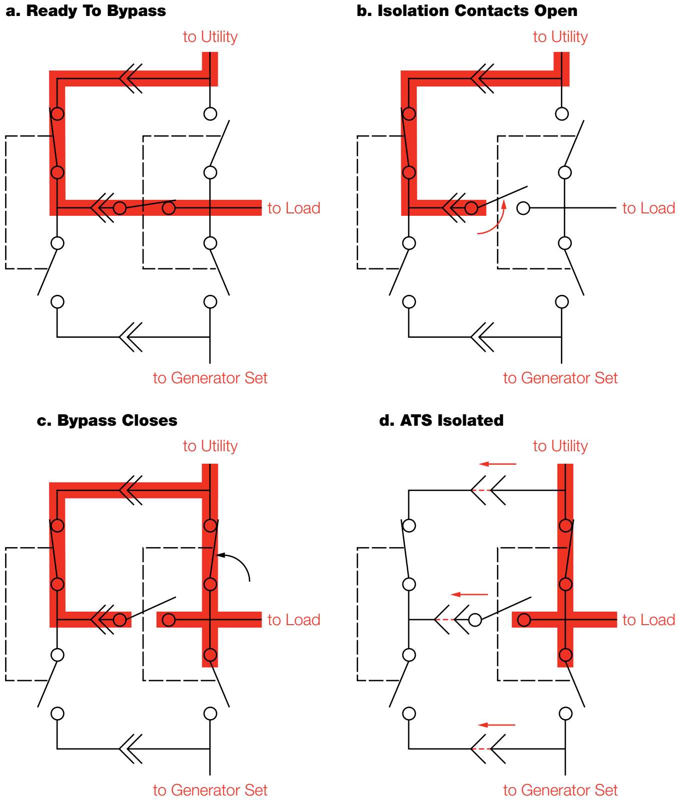

FIGURE 5

bypass contacts close to the chosen source. This operation is similar to manually operating a transfer switch. Note that the operator does not control the speed of operation of the contacts.

2. If a test of the automatic switch is desired, it can now be accomplished, because the power connections on both sides of the switch are still in place, and the load is disconnected from the automatic switch. The automatic transfer switch can switch back and forth between sources without further disruptions to the load, because it is not connected to the load (the isolation contacts are open).
3. If isolation of the ATS is desired, it can then be drawn out for service for maintenance (FIGURE 5d). Since the load isolation contacts are open, no current is flowing through the automatic transfer switch contacts and it can be isolated from the bypass transfer switch mechanism without further disruption of power to the load.

It should be noted that the normal bypass operation of this equipment is isolation bypass, rather than bypass isolation. This means that there is a power outage to the loads connected to the device every time that the bypass function is performed. Because the bypass function has been added to improve the reliability of the service to the loads, this seems inconsistent, and is a major disadvantage of this design.

Because speed of operation of the isolation/bypass contacts is not controlled by the operator and contact operation speed is very fast (approximately 5 cycles), there can be serious problems with the use of the switch on large inductive loads such as motors and transformers. Even if the automatic switch is provided with programmed transition, the isolation/bypass function cannot be controlled in the same way because it is purely mechanical in operation, and its operation speed is not controlled by the operator. The result can be a catastrophic failure of loads, shortening of load life, or nuisance tripping of circuit breakers each time the bypass function is used. Refer to Cummins Power Generation Power Topic #7017 for more information on this phenomenon. The advantage of the non-operator controlled bypass function is that the switch is not likely to remain disconnected from both sources inadvertently.

The load isolation contacts are in the normal "power path" through the device, so a major fault (exceeding the withstand and closing rating of the device) on the load side of the switch may damage both the automatic and isolating contacts, making bypass impossible, even though the bypass switch mechanism is not damaged. It should be emphasized that damage due to a fault is less likely if the transfer switch is properly applied. Also, if isolation contacts are damaged, because they are connected to the normal source, a shutdown of power to the device will be necessary for their service.

The most significant advantages of this design are that the mechanical cross interlocking between the automatic transfer switch and the bypass switch is easy to accomplish and the bypass switch can be operated at any time without regard to the automatic switch position. This makes the bypass switch an effective manual transfer device for those situations where either the automatic switch is removed from service, or when the automatic switch malfunctions for some reason. Finally, since the bypass switch is not intertied with the automatic switch, it is physically possible to add the bypass function to an existing automatic transfer switch.

It is physically possible to use this design in single source bypass configurations that allow bypass of only the normal or emergency contacts but not both. These designs are not recommended, because if the automatic switch were bypassed, it would not be possible to transfer the loads to another source on failure of the operating power source.

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BREAKER TYPE BYPASS POWER FLOW PATHS

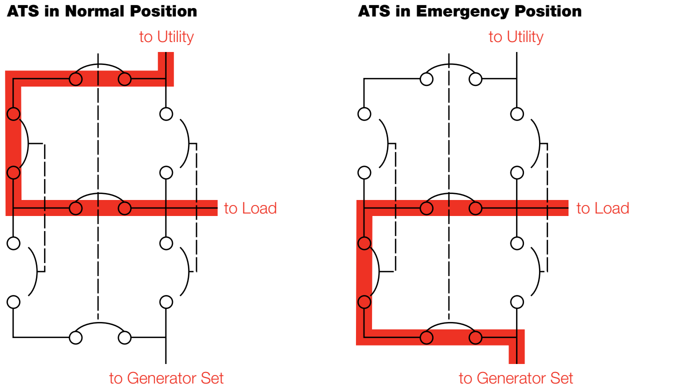

FIGURE 6a

BREAKER TYPE LOAD BREAK BYPASS SWITCH

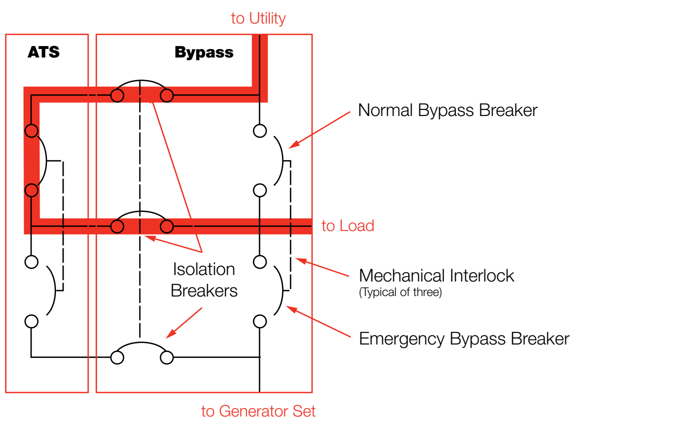

FIGURE 6b

Breaker type load break bypass equipment

The breaker type load break bypass design has a similar one line arrangement to the contactor type device, but its operation is slightly different (FIGURE 6) where normal and emergency power flow path through the device are shown with a red line). Breaker type bypass/isolation switches typically utilize stationary non automatic circuit breakers (circuit breakers without trip units) for isolation contacts: one set for the load side of the switch (as in contactor type designs) and one set for isolation of each source non-automatic breakers are also used for the bypass contacts. Either automatic breakers or non-automatic stationary breakers can be used for the automatic transfer switch contacts.

In this design, the bypass operation is performed as follows (FIGURE 7):

1. The source/load isolation breakers are all simultaneously opened, usually via a sliding interlock mechanism (FIGURE 7b).
2. Opening these breakers exposes a key, which can be removed, and is used to close either the utility or emergency bypass breaker (FIGURE 7c).
3. At this point, the automatic transfer switch can either be tested or removed for service.

BREAKER TYPE LOAD BREAK BYPASS OPERATION

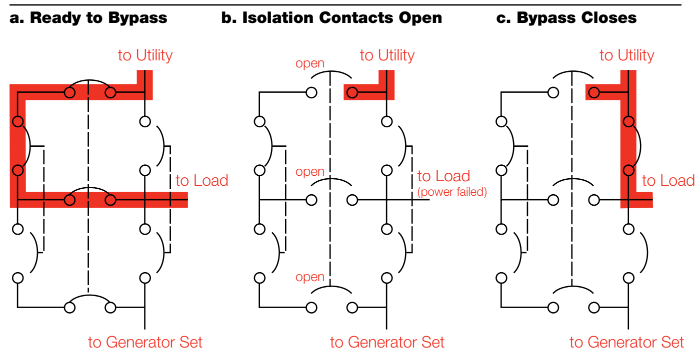

FIGURE 7

Note that in some breaker type arrangements, the automatic breaker mechanisms are bolted into place, rather than provided on drawout rails, so removal may not be easily accomplished. Note also that in many designs of this type, the ATS is provided in a separate enclosure from the source isolation bypass equipment. This makes it somewhat safer to service the automatic switch because the switch is then electrically isolated from the power sources. However, caution must still be used around the device, because the control may still be energized by the available sources, and present a hazard to the service technician. The isolation of the automatic and bypass switch has no value in terms of fault isolation, because the normal power path throughout the system includes the isolation contacts. Consequently, a major fault probably would disable both the automatic and isolation functions.

As with the contactor type device, a power interruption to the load is necessary in order to perform the bypass function. Unlike the contactor device, however, the duration of the power outage to the load is not controlled and is in fact an inadvertent misoperation could easily leave the load disconnected indefinitely.

Typical breaker type isolation schemes are mechanical in operation and therefore not provided with dead sources interlocking provisions. Loads easily could be manually connected to a source that is not available. Because the loads connected to a bypass switch are often not close to the bypass switch, there may be no indication to the operator that misoperation has caused a power failure elsewhere in the facility.

Use of molded case breakers as the switching mechanism leaves some questions as to the proper fault ratings of the device. When installed with trip units the device has a defined interrupting rating, but without trip units, the breaker performance is not defined. This is a particular concern with bypass switches that incorporate non-automatic breakers (breakers without trip units) in the normal power path through the device. Molded case breakers may also be an issue if coordination of the distribution circuit is required. If the breakers used incorporate trip units, selective coordination of the distribution system may be difficult to achieve.

CONTACTOR TYPE NON-LOAD BREAK BYPASS SWITCH

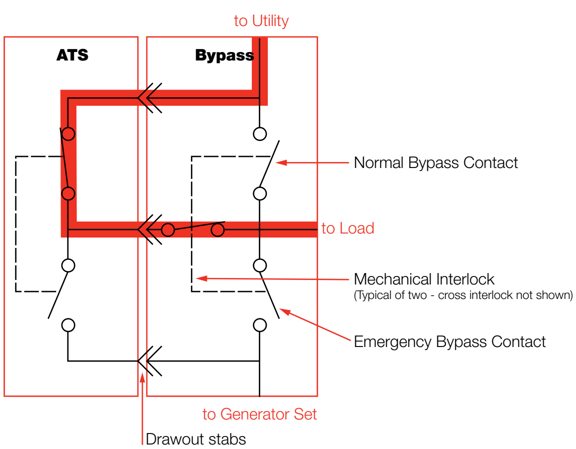

FIGURE 8a

CONTACTOR TYPE NON-LOAD BREAK BYPASS POWER FLOW PATHS

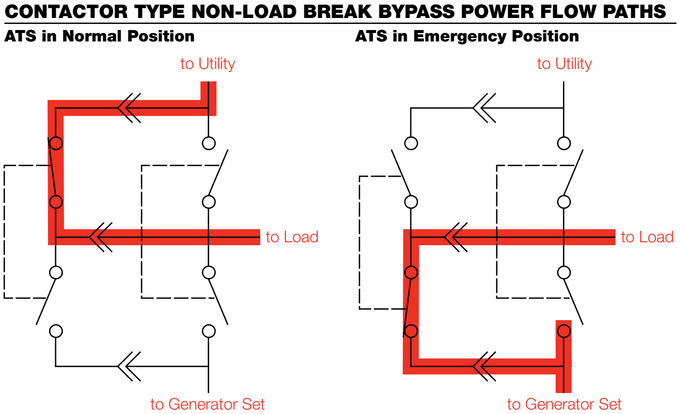

FIGURE 8b

As with a contactor type load break bypass switch, the most significant advantages of this design are that the mechanical cross interlocking between the automatic transfer switch and the manual bypass switch is easy to accomplish and the bypass switch can be operated at any time without regard to the automatic switch position. This makes the bypass switch an effective manual transfer device for those situations where either the automatic switch is removed from service, or when the automatic switch malfunctions for some reason. Finally, because the bypass switch is not intertied with the automatic switch, it is physically possible to add the bypass function to an existing automatic transfer switch.

It is also physically possible to use this design in single source bypass configurations, which allow bypass of only the normal or emergency contacts, but not both. Again, these designs are not recommended, because if the automatic switch were bypassed, it would not be possible to transfer the loads to another source on failure of the operating power source.

Contactor type non-load break bypass equipment

In this equipment arrangement, two transfer switches are connected in parallel, with the automatic transfer switch providing all normal functions, and the manual bypass switch contacts both being normally open. FIGURE 8a illustrates this design. Normal and emergency power flow paths through the device are shown (FIGURE 8b) with red lines.

Actual operation of different manufacturers' non-load break bypass switches varies with the manufacturer. In general, with the automatic switch connected to normal, the bypass functions simply by closing the bypass contact to the normal position (FIGURE 9b). This provides an alternate current path to provide power to the load through the bypass switch. The automatic switch then can be opened (FIGURE 9c) and isolated by disconnecting it from the stationary bypass mechanism via the isolation tabs (FIGURE 9d). At this point, the automatic switch can be tested or serviced without affecting power supplied to the load, because the power conductors of the automatic switch are not connected to any power source or the load.

As previously noted, the most important advantage of the non-load break design is that *power to the load is not interrupted in any normal bypass operation*. Consequently, bypass functions can be performed at any time, without danger of disrupting power to critical loads.

NON-LOAD BREAK BYPASS OPERATION

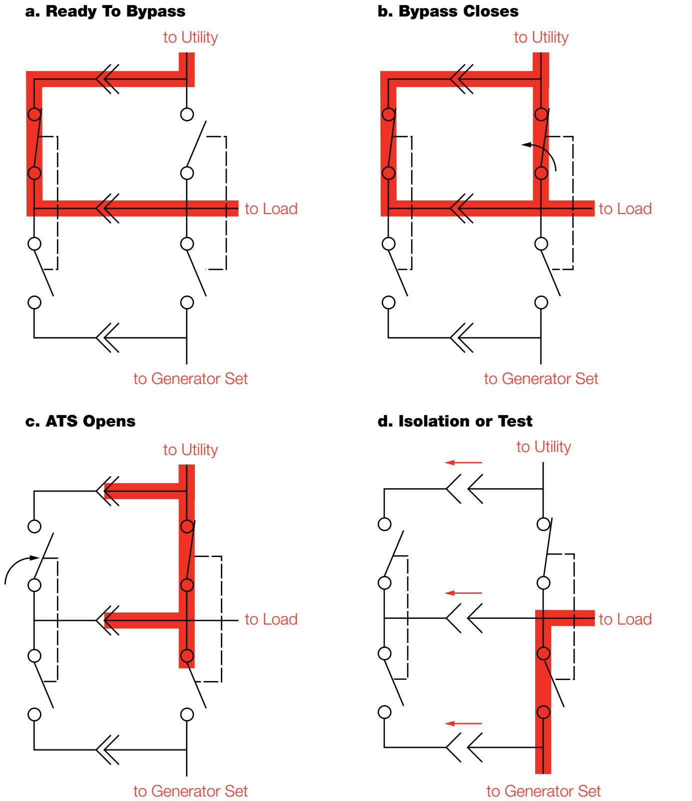

FIGURE 9

Different suppliers do the mechanical cross-interlocking provided in this equipment configuration in different ways. The method of cross interlocking is significant, because it affects the flexibility of the transfer switch in dealing with abnormal operating conditions. It is important that the cross interlocking system used is mechanical, so that the transfer switch is not inadvertently connected to both sources when the switch is de-energized. If this occurs, an out of phase paralleling condition is likely when both of the sources are energized, or when the automatic switch is installed into the mechanism after service. Also, electrical interlocks, or other systems that rely on operation of microswitches, are notoriously unreliable and subject to misadjustment. Because this misadjustment may result in a catastrophic failure of the generator set, electrical (only) interlocks in bypass switches should be avoided.

Bypass switch safety issues

Another consequence of cross interlocking design is the effect of the design on the bypass to an alternate source, when the automatic transfer switch is connected to the normal source (FIGURE 10). Ideally, the bypass switch cross interlocking design should allow this function to occur at any time, so that the bypass switch becomes an effective manual transfer mechanism in the system. However, some bypass switch designs require the bypass first to be closed to the source connected to the automatic transfer switch, and then isolation of the automatic transfer switch, before a manual transfer to the alternate source can occur. If the automatic transfer switch has been damaged or the source that the switch is closed to has failed, this may not be easy (or even possible) to accomplish. At best, it complicates system operation at a time when ease of operation may be critical.

Probably the most important safety feature of the bypass isolation transfer switch assembly is the interlocking of the switch contacts to prevent accidental paralleling of the generator set with the utility service. In general, for U. S. transfer switch manufacturers, all standard automatic transfer switches incorporate a mechanical interlock between normal and generator power contacts in both the automatic and bypass switches to prevent paralleling of the sources. It is also generally true that for load break type bypass switches, there is always a mechanical interlocking provision to prevent this occurrence.

BYPASS TO ALTERNATE SOURCE WITH NON-LOAD BREAK BYPASS SWITCH

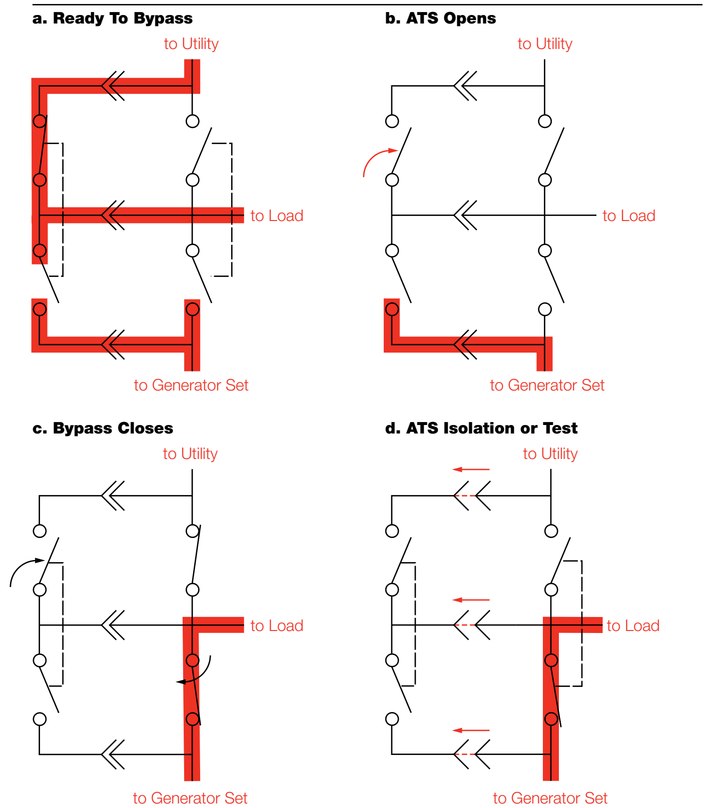

FIGURE 10

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With non-load break designs, however, the cross interlocking of the bypass and automatic transfer switches is not always performed with mechanical interlocks. Consequently, it is physically possible with some designs to close the bypass and normal contacts to different sources (especially when the device is de-energized). If this occurs, on energization of the device, very serious damage could occur in the system. All Cummins Power Generation bypass isolation type transfer switches include mechanical cross interlocks, to prevent closure of the two sources together, whether or not voltage is available in the switch enclosure.

In a standard automatic transfer switch, the shielding, guarding, and other safety features of the transfer switch are not as critical as with a bypass switch, because, in general, an operator or technician is not expected to enter the enclosure unless the device is de-energized (of course, they often do, so a supplier should make the design as safe as possible with the door open). With a bypass switch design, however, the technician will be expected to enter the cabinet for servicing and removal of the automatic switch, with the device energized. Consequently, guards, shields, and transfer switch removal procedures should be designed to minimize the possibility of accidental electrical shock to the technician. To minimize arc flash danger, the bypass and drawout functions should occur with the bypass switch door securely closed.

After bypass and isolation occurs, with the door open all points of the device that operate at a voltage higher than 50 volts should be shielded to prevent inadvertent contact. This is particularly important on the door, because a door swinging shut, or being backed into is not difficult to envision. Also, attention should be given to the fact that once the automatic transfer switch is removed from the cabinet, the manual bypass switch or bus bars may be exposed, and present a hazard. So, these also should be shielded. When the automatic transfer switch power conductors are isolated, the control power conductors should also be automatically isolated, so the operator does not presume that the transfer switch is de-energized, when it is in fact energized through the control wiring.

Consideration should also be given to the process of actually getting the automatic switch out of the enclosure. Ideally, it should roll out on rails, but in larger switches (due to the size of the switch) it may be necessary to have it roll out on to the floor. Lifting the switch out of the enclosure is not desirable, especially if the operator must be in close proximity of energized components to do it.

The control system of the device should have two sets of disconnect devices. A manual disconnect plug system to allow safe service or replacement of the control system, is desirable. Also, an automatic disconnect of the controls to the automatic switch mechanism during the isolation process will prevent exposure of the operator to dangerous voltages during this process.

Finally, it should be noted that UL safety standards for bypass isolation type transfer switches are primarily directed at preventing hazardous conditions in the event of an electrical fault. They do not offer significant review of the safety features of the device to a technician, and do not address (at all) durability and ease of operation of the manual bypass mechanism. Consequently, the specifier is left with the responsibility of specifying the level of prototype testing necessary to achieve reliable operation of the bypass device and safety of the technician servicing it.

Recommendations

Bypass isolation switches provided by various suppliers are very different in their design and operation, and the equipment that is actually received at a job site may surprise customers who blindly presume that "a bypass switch is a bypass switch." When reviewing a proposed product for a specific facility, at least the following items should be considered:

- Verify that the equipment is a "non load break" type; so that normal bypass test and service at the automatic transfer switch can be performed without disrupting power to the load.
- Verify that the equipment will fit into the available space, and that working space needed for operation and maintenance of the switch is available. Both front and rear or front and side access may be needed for many large transfer switch designs. Keep in mind that large automatic transfer switches are too heavy for a single person to lift, so portable overhead lifting equipment may need access to the transfer switch location.
- Verify that the switch has wiring access available for the intended installation. If the automatic transfer switch is a roll out design, verify that the switch is not mounted on a house keeping pad, or that provisions are made for proper removal of the switch.
- For critical applications, add "transfer switch disabled" remote alarm indications in an attended location, on the generator set remote alarm panel.

About the author

Gary Olson graduated from Iowa State University with a Bachelor of Science Degree in Mechanical Engineering in 1977, and graduated from the College of St. Thomas with a Master of Business Administration degree in 1982.

He has been employed by Cummins Power Generation for more than 25 years in various engineering and management roles. His current responsibilities include research relating to on-site power applications, technical product support for on-site power system equipment, and contributing to codes and standards groups. He also manages an engineering group dedicated to development of next generation power system designs.

- Review the safety provisions of the proposed equipment, from an operators perspective. The equipment should be capable of providing the test bypass and complete isolation of the automatic transfer switch without opening the doors of the cabinet.
- Verify that mechanical interlocks are provided for both the automatic and the bypass transfer switches, and that mechanical cross interlocking is provided between the automatic and bypass switches.
- A dead source interlock should be provided to prevent accidental manual bypass to a de-energized source.

Bypass isolation transfer switches may also have the following features, which are valuable, but not absolutely critical to the product design:

- Capability of using the manual bypass switch to transfer power directly between sources, without regard for the position of the automatic switch.
- Control disconnects to automatically disconnect control power from the automatic switch, as it is isolated from the bypass switch.
- Shielding to prevent inadvertent contact with line voltage points in the automatic transfer switch, control, and bypass switch, whether the automatic switch is in place, or removed for service.
- Prototype testing of the mechanical operating mechanism, to verify the durability of the mechanical components of the design for the expected life of the facility.

Careful consideration of these factors, along with other typical transfer switch considerations, will help a designer to avoid procurement of equipment which is not suitable for the intended operation of the facility and limit start-up and installation surprises.

For additional technical support, please contact your local Cummins Power Generation distributor. To locate your distributor, visit www.cumminspower.com.

A Note On Sources:
This information presented in this paper has been derived from various manufacturers literature, and is accurate as of the date of publishing of this paper.

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