Electrical Safety Task Group

Electrical Safety Risk Analysis for Uninterruptible Power Supply (UPS) Back-feed

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Introduction

An uninterruptible power supply or uninterruptible power source (**UPS**) is an electrical apparatus that provides backup or emergency power to a load when the normal input power source is purposely removed or fails. There are three common UPS topologies that will be considered in this risk analysis: standby, line interactive, and double conversion.

Discussion

A typical UPS consists of 4 main components, a rectifier, inverter, static bypass switch, and battery. During normal operation, the rectifier converts normal input power to direct current (DC) to charge the battery and supply DC to the inverter. The inverter switches the DC from the rectifier into alternating current (AC) to power the critical load. Upon loss of normal input power, the UPS draws energy from the battery to supply power through the inverter to the critical load. In the event of a rectifier or inverter fault the static bypass switch automatically connects the critical load to the battery or to a secondary (bypass) input source bypassing the rectifier, inverter, and batteries. The bypass source is either a separate input or is internally connected to the main input.

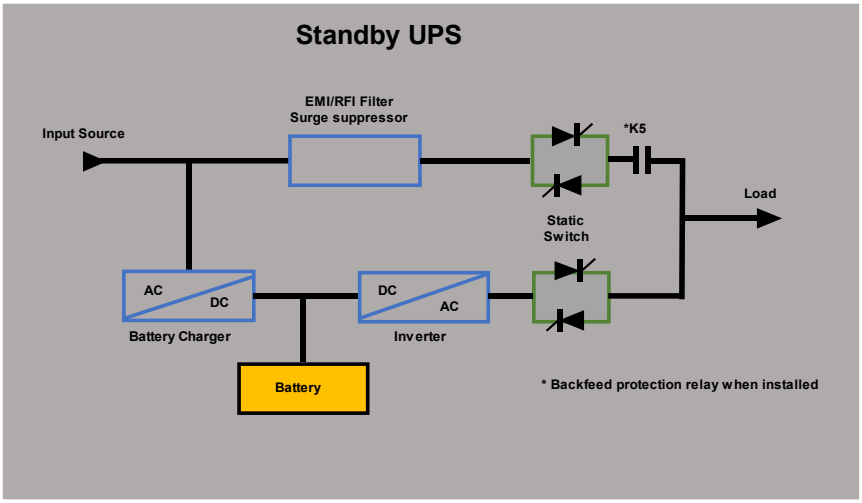
When input power to a UPS is removed for any reason the battery is automatically connected and supplies the critical load through the inverter until the input power is restored or the battery is depleted. With all UPS topologies there is a possibility for hazardous electrical energy to flow (back-feed) from the inverter output to the normal input or in some cases the bypass power source when the UPS is drawing power from the battery. Back-feed to the normal input source is only possible if there is a path from the output of the inverter back to the normal input, as in the case of a UPS that uses the normal input as the source of bypass power as well. A UPS that has a separate source of bypass power is not capable of back feeding the normal input but could back-feed into the bypass input source. A back-feed, should it occur, could expose personnel working on the input (normal or bypass) of a UPS to hazardous electrical energy and appropriate risk control methods based on a risk analysis may need to be taken to eliminate or reduce the risk of exposure.

Manufacturers of UPS systems are aware of the potential for back-feed and identify the hazard with warnings in their literature, instructions, and bulletins. IEC 62040-01 2017 and UL-1778 require back-feed protection for all UPS systems. Manufacturers of UPS systems that are listed or certified to UL-1778 or IEC 62040-01 2017 have incorporated back-feed protection circuitry into UPS designs since it was first required in the early 2000's.

UPS Topologies

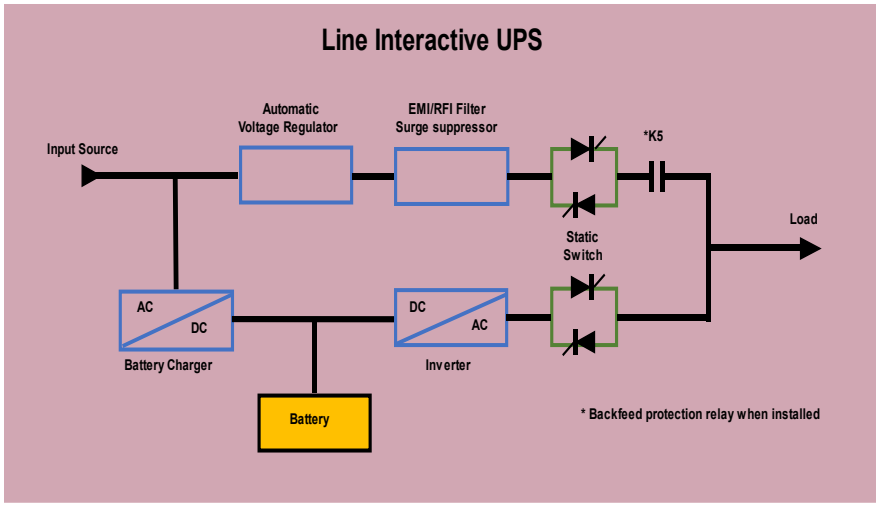
Standby

Standby UPSs are used mainly to provide normal and backup power to personal computers and other small electronic devices via cord and plug connection to a branch circuit. When the input power is removed or fails the static switch electronically disconnects the normal input source and connects the battery to power the critical load. Back-feed or leakage current to the normal input source is possible through the electronics of the static switch if the UPS does not have back-feed protection or the back-feed protection fails.



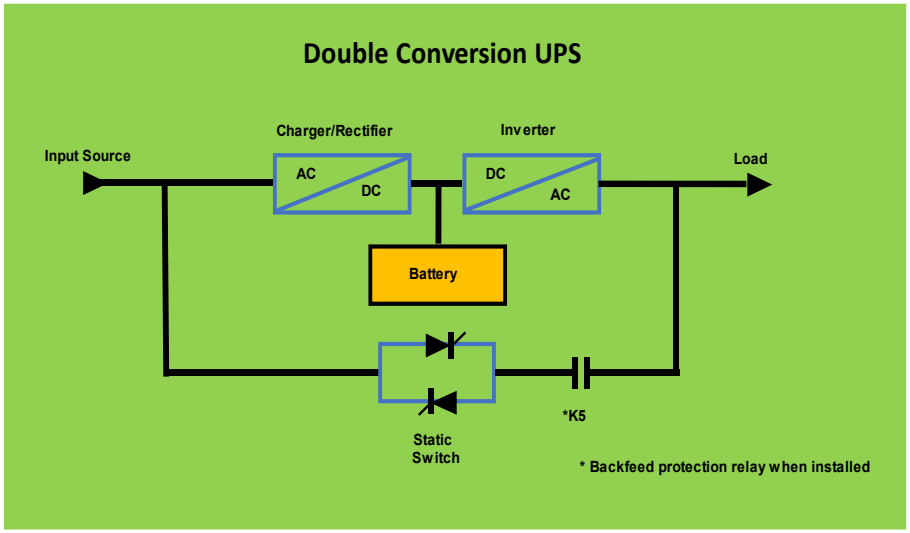
Line Interactive UPS

A Line interactive UPS is essentially an upgraded standby UPS. A line interactive UPS adds automatic voltage regulation that can adjust for minor voltage inconsistencies that would otherwise cause a standby UPS to switch to battery power. When the input power is removed or fails the static switch electronically disconnects the normal input source and connects the battery to power the critical load. Back-feed or leakage current to the normal input source is possible through the electronics of the static switch if the UPS does not have back-feed protection or the back-feed protection fails.



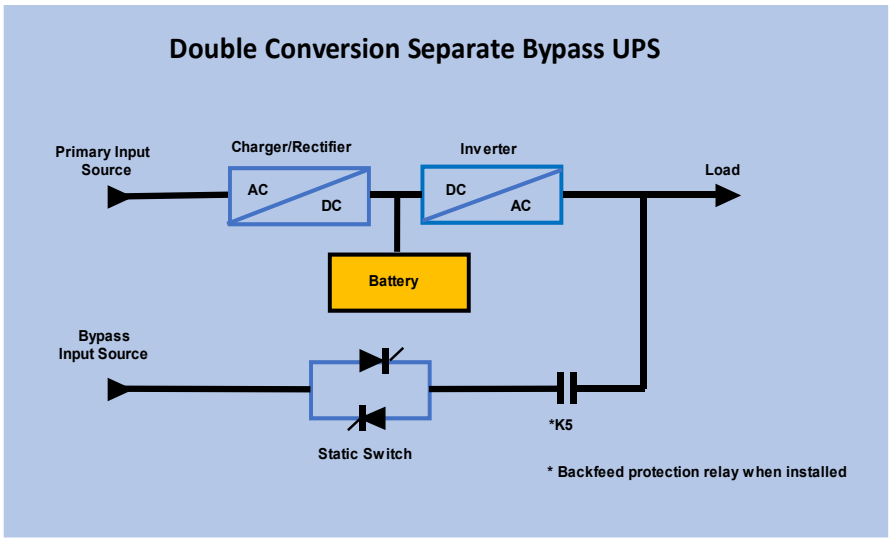
Double Conversion UPS

A double conversion UPS provides consistent, clean, near perfect power, regardless of the condition of the incoming power. They are used for data centers, communications networks, hospitals, and anywhere else clean consistent power is a necessity. When the input power is removed or fails the rectifier shuts off and the battery supplies power to the critical load through the inverter. Back-feed or leakage current to the normal input source is possible through the electronics of the static switch if the UPS does not have back-feed protection or the back-feed protection fails.



Double Conversion Separate Bypass UPS

A double conversion separate bypass UPS is essentially the same as a double conversion UPS except it has a second separate input source. When the normal input power is removed or fails the rectifier shuts off and the battery supplies power to the critical load through the inverter. Back-feed or leakage current to the normal input source is not possible but back-feed through the electronics of the static switch to the bypass input source is possible if the UPS does not have back-feed protection or the back-feed protection fails.



Conclusion

Considering the three UPS topologies the risk of back-feed is possible in standby, line interactive, and double conversion UPS designs that incorporate a static switch. A risk analysis of the potential back-feed from a UPS is required to determine the risk to personnel and whether additional control methods are needed to reduce the risk of injury.

An analysis of the different UPS topologies concludes that the risk of exposure to back-feed resulting in personnel injury or death is low for all three topologies whether they incorporate backfeed protection in compliance with IEC-62040-01 and UL-1778 or not.

The low risk is attributed to several factors including the use of 1) Qualified electrical workers wearing appropriate PPE for energized work, 2) Back-feed protection circuitry when incorporated in UPS system design, 3) Absence of voltage testing for establishing an electrically safe work condition, and 4) A review of incidents involving UPS back-feed does not reveal a history of failures resulting in personnel injury or death.

The incorporation of back-feed prevention circuitry in UPS design is an engineering control recognized by NFPA 70E as one of the more effective methods to reduce personnel exposure to hazardous electrical energy. When personnel perform work in a location subject to back-feed they are also exposed to hazardous electrical energy from the normal or bypass source of power to the UPS. When work in this location is performed energized, the risk of injury to personnel is reduced to an acceptable level by allowing only qualified electrical workers wearing appropriate PPE to perform the work. When work is to be performed de-energized under LO/TO then the steps to establish an electrically safe work condition are followed to reduce the risk to an acceptable level. Establishing an electrically safe work condition includes the use of qualified electrical workers wearing appropriate PPE and an adequately rated test instrument to verify absence of voltage from normal and bypass sources of electrical energy and from sources such as back-feed to ensure that the control methods (Elimination, Engineering Controls) are functioning as designed. When the steps to establish an electrically safe work condition are followed the risk of injury is reduced to an acceptable level and no additional personnel protective measures are required to further reduce the risk of exposure to UPS back-feed.

Risk Assessment Methodology

Issue - Potential back-feed from a UPS while drawing power from the battery.

Hazard - Potential exposure to hazardous electrical shock and or arc flash.

Shock Risk Assessment

The potential for shock from a back-feed is possible for all three UPS topologies when the gate signals for the static switch thyristors are off. A back-feed to the normal or bypass input power source can result from a leakage current passing through the electronics of a static switch.

There is evidence that back-feed can occur through the static switch but there is little to no evidence to support that it occurs frequently with or without back-feed protection circuitry installed. The addition of back-feed protection circuitry would further decrease the frequency of occurrence. The occurrence of back-feed from a UPS is unlikely.

	Severity of the injury (consequences)				
Likelihood of occurrence in period	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	L	L	L	M	M
Seldom	L	L	M	M	H
Occasional	L	M	M	H	E
Likely	M	M	H	E	E
Definite	M	H	E	E	E

There is also little to no evidence that back-feed has resulted in serious injury or death from a shock. However, since back-feed could cause a shock the severity of injury must be considered. Standard UPS outputs range from > 50 volts up to 600 volts and a shock in this range is considered hazardous if the current is equal to or greater than 5 mA's. The magnitude of current in a back-feed is an unknown factor and will be presumed to be greater than 5 mA's for the purposes of this paper. The severity of shock based on a UPS output ranging from 50-600 volts and current level equal to or greater than 5 mA's results in a range of severity from slight to catastrophic.

	Severity of the injury (consequences)				
Likelihood of occurrence in period	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	L	L	L	M	M
Seldom	L	L	M	M	H
Occasional	L	M	M	H	E
Likely	M	M	H	E	E
Definite	M	H	E	E	E

Additional protective measures due to the potential severity of shock are required and include awareness, administrative controls, and PPE. Reduction of risk due to back-feed is accomplished through LO/TO which establishes an electrically safe work condition for the input source/s. Establishing an electrically safe work condition requires the use of qualified electrical workers using appropriate personal protective equipment for shock in accordance with NFPA 70E while supporting a LO/TO program/procedure. Establishing the electrically safe work condition includes verifying that all sources of energy including UPS back-feed have been successfully reduced to an acceptable level.

Arc Flash Risk Assessment

The Incident energy (IE) of an arc flash is dependent on four main factors, 1) Available fault current, 2) Speed of the overcurrent device, 3) distance from the arc flash, and 4) Voltage.

It is possible that some UPS designs utilize a battery that have the capability to produce IE levels that pose a risk of injury due to arc flash.

The potential for a DC arc flash from a UPS battery exists in several locations including at the battery output terminals, the downstream overcurrent or disconnecting device, and the input to the inverter. A DC arc flash from the battery is not possible in a back-feed to the input source/s because of the inverter.

There is no evidence to support that AC arc flash from back-feed has or does occur. The potential for AC arc flash due to back-feed is unlikely due to the nature of the back feed (leakage current) and back-feed protection circuitry when installed.

	Severity of the injury (consequences)				
Likelihood of occurrence in period	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	L	L	L	M	M
Seldom	L	L	M	M	H
Occasional	L	M	M	H	E
Likely	M	M	H	E	E
Definite	M	H	E	E	E

The severity of AC arc flash from a back-feed needs to be considered to determine if an arc flash could result in exposure to 1.2 cal/cm² or higher. Exposure to AC arc flash is possible and could result in exposure to 1.2 cal/cm² or higher. The severity of injury due to an arc flash is medium to catastrophic.

	Severity of the injury (consequences)				
Likelihood of occurrence in period	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	L	L	L	M	M
Seldom	L	L	M	M	H
Occasional	L	M	M	H	E
Likely	M	M	H	E	E
Definite	M	H	E	E	E

Additional protective measures due to the severity of arc flash are required and include awareness, administrative controls, and PPE. Reduction of risk due to back-feed is accomplished through LO/TO which establishes an electrically safe work condition for the input source/s. Establishing an electrically safe work condition requires the use of qualified electrical workers using appropriate personal

protective equipment for arc flash in accordance with NFPA 70E while supporting a LO/TO program/procedure. Establishing the electrically safe work condition includes verifying that all sources of energy including UPS back-feed have been successfully reduced to an acceptable level.

Final Risk Assessment

Considering the potential for shock and arc flash from a UPS back-feed it is concluded that back-feed is unlikely to occur. Should back-feed occur the severity of injury is reduced to an acceptable level by using shock and arc flash PPE to establish an electrically safe work condition to achieve a final level of low risk.

	Severity of the injury (consequences)				
Likelihood of occurrence in period	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	L	L	L	M	M
Seldom	L	L	M	M	H
Occasional	L	M	M	H	E
Likely	M	M	H	E	E
Definite	M	H	E	E	E