Power Quality Guidelines For Airports

A TechCommentary of
the EPRI Airport Initiative

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Introduction

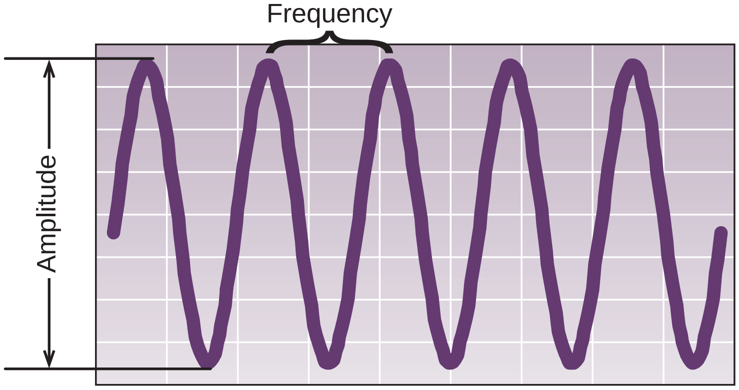
The recent introduction of electronic equipment into the airport environment has increased energy efficiency, reduced manual labor, and increased productivity. Ultra-modern airports use electronic equipment such as adjustable-speed drives and programmable logic controllers to handle and transport baggage, operate jetways, and control people movers.

Wherever airport operations require automation or precise control, high-technology devices are becoming indispensable. However, these devices have a liability associated with most electronic technologies: They are vulnerable to common electrical disturbances in the power system, such as voltage sags, brief power interruptions, and surges. A common voltage sag, for example, can affect an airport system in ways that could impair the operation of the entire airport or adversely affect the comfort and safety of occupants in airport terminals.

This TechCommentary describes the sources of potentially disruptive electrical disturbances, their properties, their effects upon modern automation equipment used in airports, and ways to mitigate those effects. Because the equipment commonly found in control towers is technically under the domain of the Federal Aviation Authority (FAA), this document will not deal specifically with such equipment.

Sources of Electrical Disturbances

All electrical environments—whether they be residential, commercial, or industrial—expose equipment to common, unavoidable electrical disturbances. These disturbances, which for the purposes of this TechCommentary are defined as any abnormal variation in voltage, may be the result of natural or man-made events. As shown in Figure 1, such events may alter the amplitude, wave shape, or frequency of the voltage within an airport. For example, lightning striking a nearby power line or routine utility activities such as capacitor switching may create a sudden increase in voltage amplitude



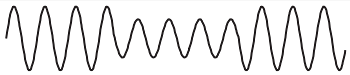
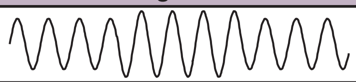
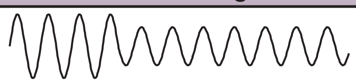
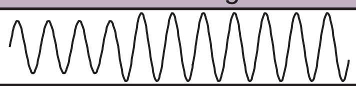
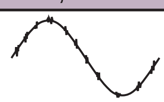
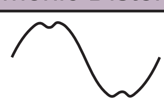
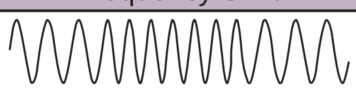
Amplitude: The standard amplitude of utility-supplied electricity is constant at the rated voltage. The end-user RMS voltages of North American electricity (peak-to-peak amplitude divided by two times the square root of two) are 120 and 240 volts for single-phase systems, and 120, 208, 240, 277, and 480 volts for three-phase systems. The maximum and minimum levels of each voltage rating are defined in the ANSI standard C84.1–1989.

Wave Shape: The standard wave shape of utility-supplied voltage is a sine wave.

Frequency: The standard frequency of utility-supplied voltage in North America is sixty cycles per second.

Figure 1. Standard Amplitude, Wave Shape, and Frequency of North American Utility-Supplied Voltage

Table 1. Electrical Disturbances, Their Durations, and Their Causes

	Electrical Disturbance	Duration	Cause of Disturbance
Amplitude	Transients (Surges)  Oscillatory Impulsive	less than 3 ms (0.18 cycles)	• motors in air conditioners, HVAC equipment, elevators, water coolers, fans • lightning • photocopiers and laser printers • static discharge • routine utility activity • electronic air ionizers • kitchen appliances
Amplitude	Voltage Sag 	8 ms to 3 sec (0.5 to 180 cycles)	• motors in air conditioners, HVAC equipment, elevators, water coolers, fans • photocopiers and laser printers • routine utility activities
Amplitude	Voltage Swell 	8 ms to 3 sec (0.5 to 180 cycles)	• motors in air conditioners, HVAC equipment, elevators, water coolers, fans • photocopiers and laser printers
Amplitude	Undervoltage 	greater than 3 sec (180 cycles)	• improper wiring and grounding • improper voltage tap adjustment • defective building transformer
Amplitude	Overvoltage 	greater than 3 sec (180 cycles)	• improper wiring and grounding • improper voltage tap adjustment • defective building transformer • crossed power lines
Amplitude	Voltage Interruption 	greater than 8 ms (0.5 cycles)	• lightning • tripped circuit breaker, blown fuse • downed power lines
Wave Shape	Noise, Notches 	steady-state	• HVAC equipment • kitchen appliances • radios, telephones • light dimmers • overhead lines • electronic lighting • building transformers • electronic air ionizers • vacuum cleaners
Wave Shape	Harmonic Distortion 	steady-state	• computers • televisions, video cassette recorders • electronic lighting
Frequency	Frequency Shift 	less than 10 sec (600 cycles)	• switching from utility power to on-site generator • powerline faults • excessive loading of the utility power system

called a *transient*. Events that affect the amplitude of voltage are the most common causes of electrical disturbances. Notwithstanding harmonic distortion, which can affect building wiring and transformers, distortions in the shape and frequency of voltage rarely affect airport operations. (For more information on harmonic distortion, read PQTN Commentary No. 1, *Harmonic Current in Building Wiring*, available from EPRI.)

Electrical disturbances have existed ever since the first waves of electricity energized the industrialized world. However, common electrical disturbances have not greatly affected airports and their customers until the recent introduction of electronic equipment into the airport environment. Interruptions of airport systems are often attributed to electrical disturbances, which has led to a popular belief that the general quality of electrical power has declined. Yet there is no evidence that the quality of electric power has declined. In fact, the number of power interruptions and outages has dropped significantly over the past twenty years, while equipment resistance to electrical disturbances has significantly declined over the same period.

Table 1 shows the most common types of electrical disturbances, their durations, and their causes. These electrical disturbances vary in duration from microseconds (transients) to steady-state (noise, harmonic distortion, undervoltages, and overvoltages). Voltage sags and swells are distinguished from under- and overvoltages only by duration. Voltage sags and swells are defined as a decrease or increase in the amplitude of voltage lasting less than three seconds but more than one half cycle. A voltage interruption lasting more than one minute is considered a power outage, not an electrical disturbance.

As shown in Table 1, not all electrical disturbances are generated on the utility side of the meter. For example, large motors controlling elevators and the like can create voltage sags of sufficient magnitude to disrupt certain electronic equipment. Other examples of airport equipment that can cause electrical disturbances include large banks of computers, which can significantly distort the shape of voltage, and various electronic devices that can generate electrical noise.

Although lightning is a prime source of surges, man-made disturbances are more common and may upset nearby equipment more than a surge caused by a remote lightning strike. For example, electric utilities routinely switch large banks of capacitors onto distribution lines to stabilize the utility voltage. This activity may cause an oscillatory voltage transient similar to the one shown in Figure 2. Such transients may enter the electrical environment and disrupt airport systems.

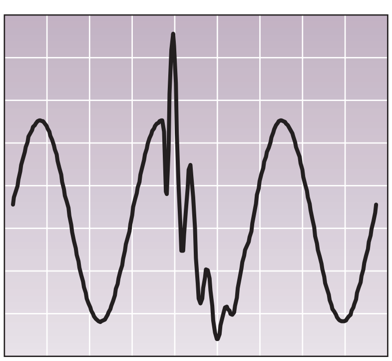
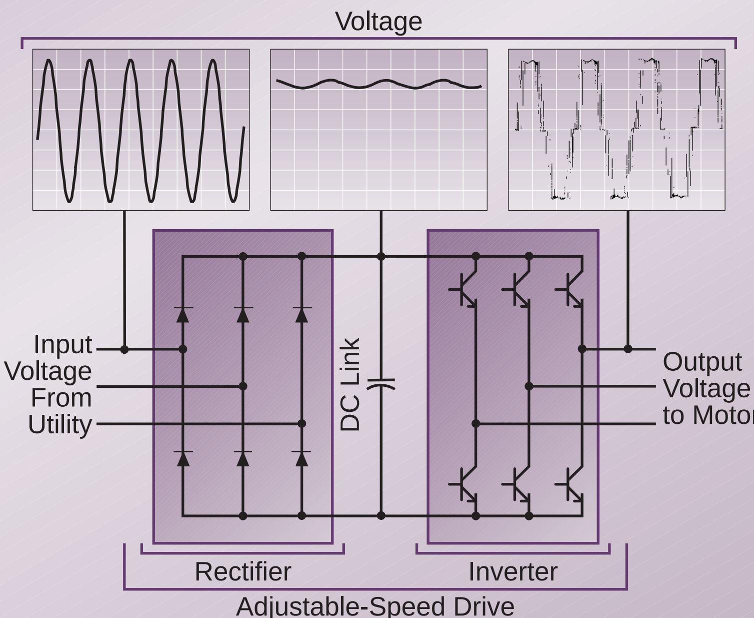


Figure 2. Oscillatory Voltage Transient Caused by Routine Capacitor Switching

Adjustable-Speed Drives

The speed of an AC induction motor depends upon the frequency of the power it receives. As the frequency of the voltage increases, the motor's speed increases. An adjustable-speed drive receives status signals from motor sensors that enable its control circuits to determine the correct output voltage for the motor. The speed and torque of the motor are thus precisely maintained. Today, most ASDs used in the U.S. convert the utility-supplied voltage to a voltage with the frequency and amplitude required by the motor. This conversion is accomplished by rectifying the incoming AC voltage to a DC voltage—called the *DC link*—and then inverting the DC voltage back to AC voltage.



Vulnerable Airport Equipment

Adjustable-Speed Drives

Because adjustable-speed drives (ASDs) enable efficient, precise control of motors, their popularity in airports is growing. ASD-controlled motors are generally used to drive fans and conveyor belts, and to open and close vents and doorways. ASDs are specifically used in airport systems such as heating, venting, and air-conditioning systems (HVAC); baggage-handling systems; and jetways. Although they enhance many airport systems, ASDs have very little stored energy and are therefore often susceptible to common voltage sags.

During a voltage sag, the DC voltage in an ASD declines. Once the DC voltage falls below the setting of the ASD's undervoltage protection—herein called a *shutdown point*—the ASD will shut down. Testing of commercially available ASDs revealed that ninety percent of the tested ASDs shut down during a five-cycle voltage sag down to fifty percent of the normal supply voltage—a sag lasting only about eighty-three milliseconds.

Adjustable-speed drives are also vulnerable to voltage transients, such as those caused by routine capacitor switching. During a transient, the voltage of the DC link increases. Once the DC voltage exceeds the setting of the ASD's overvoltage protection—again called a *shutdown point*—the ASD will shut down.

When an ASD shuts down, the entire motor-driven process it controls may misoperate, resulting in a variety of undesirable consequences ranging from the merely bothersome, such as the loss of climate control when an air-handling unit shuts down, to something as serious as a malfunctioning jetway.

Programmable Logic Controllers

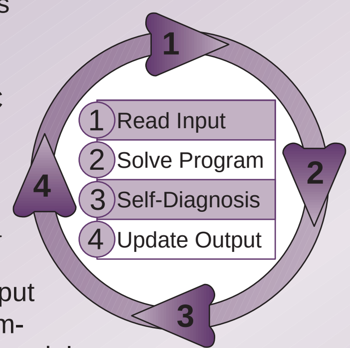
In state-of-the-art airports, the programmable logic controller (PLC) is the primary component for automating mechanical processes such as conveyors, doors, and hydraulics. First introduced as a simple solid-state replacement for relay-logic systems, the PLC has evolved into a sophisticated computer capable of controlling a wide range of precise operations. PLCs have multichannel input and output modules enabling them to interpret and respond to changing system conditions.

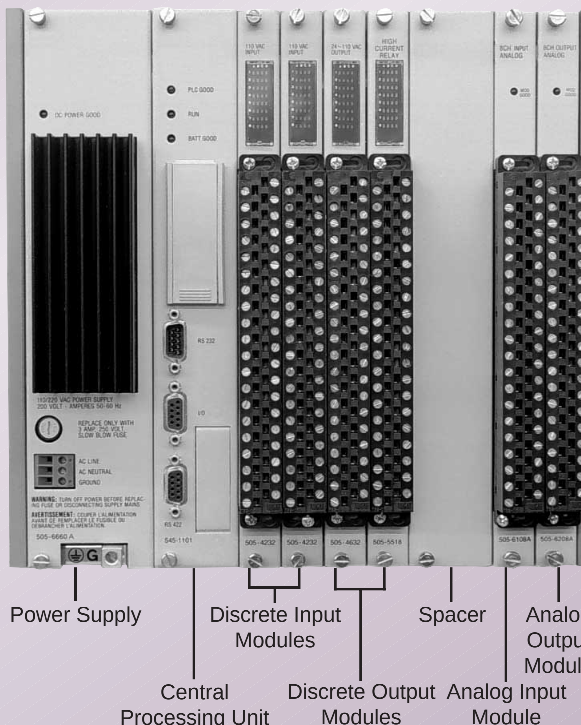
One example of a PLC-controlled airport system is the modern baggage-handling system, which uses PLCs to process data from bar code readers, identify a bag's destination, determine the proper path to route bags to their destinations, inform ASDs how fast to drive the conveyor to move baggage, and operate gates equipped with photo-electric eyes. Baggage may thereby travel from the check-in terminal to the airplane, from the airplane to the baggage claim area, and between planes for connecting flights without the touch of a human hand. These systems thus require fewer people to operate them than conventional tug-and-cart systems.

PLCs are also used to control airport jetway systems for boarding. They can control the speed of the jetway or stop the jetway when it encounters resistance. PLCs also govern the motion of people movers: when they stop, how long they remain at a stop, when they go, and when they begin braking for the next stop. PLCs can diagnose when doors are blocked, and control the public address system to announce warnings or instructions.

Programmable Logic Controllers

The PLC controls an automated system based upon a four-step control program: The PLC 1) reads input data, 2) solves its control program, 3) diagnoses itself, 4) modifies its outputs according to its program or interrupts its program if the diagnostics detect a problem. The amount of time it takes the PLC to complete all four steps can be as short as twenty milliseconds. The central processing unit of the PLC makes all decisions based upon the data it receives from the input modules. Examples of devices connected to the input modules include position sensors, tachometers, and push-button switches. Output modules drive devices such as relays (which in turn can control other devices and equipment), motor contactors, and status lights.





Like ASDs, PLCs are vulnerable to electrical disturbances, especially voltage sags. In fact, some PLCs malfunction during voltage sags down to eighty percent of the normal voltage for only two cycles (about thirty-three milliseconds). Not only can voltage sags interrupt the control program of a PLC and thereby shut down an entire system, they can also corrupt process data, resulting in system malfunctions. In an automated baggage-handling system, a misinterpretation of data can result in baggage being routed to the wrong destination, baggage being loaded onto carts that are already full, and baggage continuing to be unloaded onto jammed conveyor belts. Misoperation of PLCs in people movers can cause doors to open and close at improper times, the bypassing of concourse stops, or the shutdown of the entire system.

Metal Halide Lighting

Metal halide lighting provides a high-intensity light with excellent color rendition. These qualities, along with energy efficiency, make metal halide lighting a common choice for lighting airport interiors and exteriors, including aprons where passengers board planes. However, as is the case with ASDs and PLCs, metal halide lighting is vulnerable to voltage sags. When the voltage declines below the minimum operating voltage of a metal halide lamp, the lamp ballast can no longer operate the lamp. Depending on the type of ballast used, metal halide lamps can black out when the voltage declines to eighty percent or less of the normal voltage for a just a few cycles.

Once the arc in a metal halide lamp is extinguished, the lamp does not immediately return to full intensity after the voltage is restored. The lamp must first cool down before the arc can be re-ignited, a period known as *recovery time*. The recovery time can last as long as fifteen minutes before a lamp returns to its full intensity, posing numerous potential safety, security, and other problems. Recovery time depends upon 1) the lamp wattage (the higher the wattage, the longer the recovery time), 2) the ambient temperature of the lamp environment (the higher the temperature, the longer the recovery time), and 3) the mounting position of the lamp and its ballast (mounting the lamp according to the manufacturer's recommendations ensures the shortest recovery time).

As shown in Figure 3, the tolerance of these lamps to voltage sags varies significantly depending on the type of ballast used. Of the three main types of commercially available ballasts, a non-regulating ballast affords the least sag tolerance but is also the least expensive. Magnetic- and auto-regulator ballasts regulate the supply voltage to the lamp and afford more tolerance to voltage sags. Of the two regulating ballasts, the auto-regulator ballast affords the greatest tolerance. However, after a blackout, the magnetic-regulator ballast (the most expensive of the three types) will return to full intensity at least twice as fast as the auto-regulator ballast. The characteristics of these three types of ballasts must be carefully weighed against their cost and their intended application.

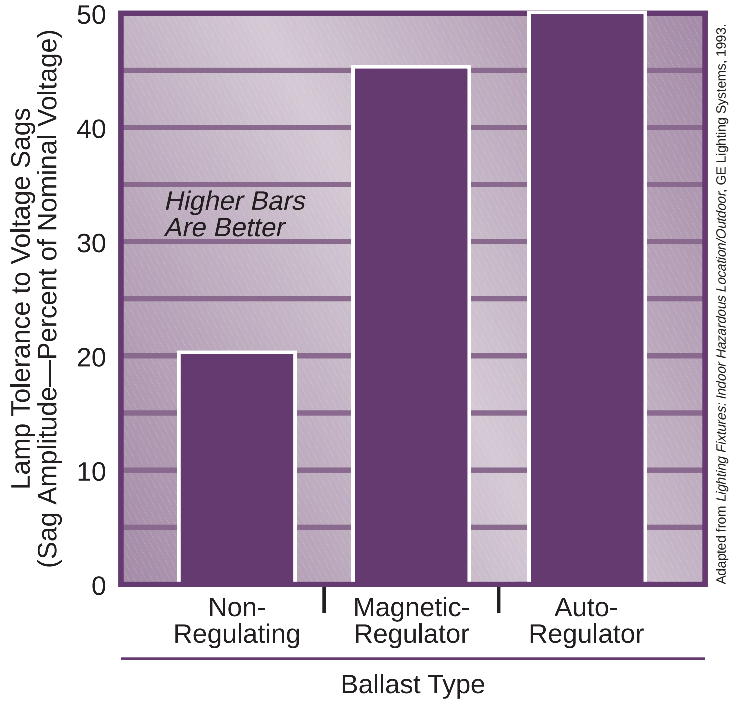


Figure 3. Voltage-Sag Tolerance of Metal Halide Lamps Based upon the Type of Ballast

Unwanted Equipment Interactions

Many types of equipment can produce unwanted effects in other equipment. This adverse equipment interaction is especially common in airports because of the wide variety of equipment used by security personnel, terminal personnel, and travelers. The two most common types of airport equipment that either cause interference or that malfunction because of interference are fluorescent lighting and equipment that uses the power line to control remote devices, such as energy management systems and automatic clock systems.

Fluorescent Lighting

Some fluorescent ballasts operate at high frequencies, anywhere between twenty and forty kilohertz. The normal operation of high-frequency fluorescent lighting may result in radiated electromagnetic energy that can interfere with equipment that uses infrared control. Examples of such equipment include laptop computers and printers with infrared ports, as well as televisions and VCRs with remote-control features. Normal operation of high-frequency lighting can also affect alarm systems, security systems, and the infrared detectors used in baggage-inspection areas.

Energy Management and Automatic Clock Systems

Some technologies enable two devices to communicate through the existing electrical wiring by superimposing a communication signal, called a *powerline carrier*, on the power. For example, airports may use energy management systems to control HVAC equipment and lighting. Automatic clock systems rely upon a master timekeeper to synchronize clocks throughout an airport.

Although all electrical wiring carries some "noise," a device that is supposed to receive the powerline carrier may not be able to distinguish between the carrier and the noise if the amplitude of noise competes with the powerline carrier. Moreover, some electronic ballasts can attenuate the amplitude of a powerline carrier. In such cases, electronic ballasts act as a filter at the frequency of the powerline carrier, disabling communication between signal generators and slave devices distributed throughout the airport.

Mitigation Methods

Purchasing the Right Equipment

A good purchasing strategy starts with a general specification for good sag-ride-through performance and high immunity to voltage transients. Other advantageous equipment specifications are particular to the type of equipment.

Adjustable-Speed Drives Most older ASDs cannot restart after shutting down until the motor comes to a complete stop. To remedy this shortcoming, some modern ASDs have a "flying restart" feature, which enables an ASD to restart while the motor is rotating. Also, some ASDs can be programmed to automatically restart after a shutdown. This feature should be activated for motor-driven systems that are not part of an integrated process, such as air-handling units and elevators.

Other ASD features, such as built-in reactors, will increase an ASD's resistance against surges. Before purchasing an ASD for an airport system, the installation engineer should ask the ASD manufacturer for specific performance data to determine how the ASD will perform during voltage sags and transients.

Metal Halide Lighting When the color of light is not a critical lamp feature, use a metal halide lamp that has a low color-rendering index (CRI), such as 65 to 70. The minimum operating voltage of this type of lamp is lower than a typical metal halide lamp, affording better lamp tolerance to voltage sags.

If metal halide lamps are used for emergency lighting, consider installing instant-restrike metal halide lamps with hot restrike ignitors. This type of lamp starts nearly instantly after a blackout, but they are expensive. Other options for emergency lighting include high-pressure sodium systems with tungsten-halogen lamps or double-arc-tube, high-pressure sodium lamps.

Infrared Equipment When selecting any devices and equipment with an infrared port, ensure that their communication frequencies do not overlap the switching frequency of existing electronic ballasts. In areas with many infrared devices, consider using incandescent lighting or fluorescent lighting with magnetic or hybrid ballasts to avoid interference problems.

Energy Management Systems If an energy management system (EMS) is installed in a passenger terminal, the system should comply with the *X-10 protocol* (a standard for powerline-carrier devices). The X-10 protocol requires a 120-kilohertz burst as the powerline carrier so that engineering expertise and equipment parts necessary to remedy most interference problems will be available.

Because an EMS must be connected to the lighting circuits to control the building lighting, separating the EMS and the lighting circuits is not an option as it is with automatic clock systems. However, most manufacturers of X-10 systems offer conducted-noise filters to shunt the noise generated by electronic ballasts and high-frequency compact fluorescent lamps.

Preventive Measures

Adjustable-Speed Drives In some cases, the shutdown points on an ASD can be adjusted by the manufacturer or vendor. Lowering the low-voltage shutdown point will afford a slight increase in sag tolerance. Also, if the ASD has a flying-restart feature, enabling it will accelerate the startup of an ASD after a shutdown. Finally, avoid putting a contactor between the source voltage and an ASD. Modern ASDs have built-in contactors, and installing an external ASD contactor may decrease the tolerance of the entire system to voltage sags. Instead of installing an external contactor, install a fused disconnect switch or circuit breaker according to the National Electric Code.

Metal Halide Lighting Standard wiring practices require that branch circuits for lighting systems not be connected to other equipment or receptacles. In airports, as in any industrial or commercial facility, connecting lighting and large loads such as motors to the same sub-panel may promote blackouts of metal halide lamps. For example, turning on large air handlers in a warehouse may cause voltage sags that extinguish metal halide lights connected to the same sub-panel. Transferring the lighting system to a different, dedicated panel will reduce the potential effect of those sags on metal halide lamps.

Also, every airport with metal halide lamps should have a maintenance schedule to ensure that ballasts are in good working condition. Records of lamp installations should also be kept and stored along with maintenance procedures from the ballast and lamp manufacturers.

Energy Management Systems Some manufacturers of energy management systems offer a set of low-cost portable transmitter/receiver units that can be used to determine which circuits in a building wiring system will support powerline carriers. These units help identify where to place EMS transmitters and receivers to minimize interference problems caused by electronic ballasts.

Using Power Conditioners

The most common electrical disturbance affecting vulnerable equipment is the voltage sag. In fact, a voltage sag is eight to ten times more common than a complete power outage. To minimize the effects of voltage sags and transients, power-conditioning devices can be connected between sensitive airport equipment and the power system.

The most common types of power conditioners are constant-voltage transformers (CVTs), uninterruptible power-supplies (UPSs), and, to a lesser extent, stored-energy inverters and reactors. Each type of power conditioner takes a different approach to mitigating electrical disturbances.

A CVT regulates the power without switching to an alternate power source. A UPS supplies a longer-term alternate source of power, usually from batteries. Stored-energy inverters supply an alternate source of power from capacitors for very short periods (up to one second). Reactors pose a high impedance to voltage transients and harmonic currents, thereby mitigating their effect upon equipment. Like reactors, isolation transformers mitigate the effects of transients and harmonics by posing a high impedance. And surge-protective devices, while not generally categorized as power conditioners, are designed to protect equipment from both oscillatory and impulsive transients.

Table 2 shows the various power-conditioning devices discussed in this TechCommentary and their effectiveness in mitigating various electrical disturbances.

Table 2. Effectiveness of Power-Conditioning Devices on Electrical Disturbances

Electrical Disturbance	Power-Conditioning Device					
	Uninterruptible Power Supply	Constant-Voltage Transformer	Stored-Energy Inverter	Isolation Transformer	Line and DC-Link Reactors	Surge-Protective Device
Transients (Surges) (Oscillatory, Impulsive)	▒	■		■	■	■
Voltage Sag	■	■	■			
Voltage Swell	▒	■				
Undervoltage	▒					
Overvoltage	▒					
Voltage Interruption	■					
Noise, Notches	▒	■		▒		
Harmonic Distortion	▒	▒			■	
Frequency Shift	▒					

■ The device will mitigate the indicated electrical disturbance.

▒ Mitigation depends upon the make and model of the device.

Constant-Voltage Transformer A constant-voltage transformer maintains a relatively constant output voltage despite harmonic distortion or brief variations in input voltage such as voltage sags. CVTs are often used to condition electrical power because they are relatively maintenance-free, with no batteries to replace or moving parts to maintain. However, a CVT is not an energy-storage device. As shown in Figure 4, a brief interruption on the primary of a CVT will appear as a very deep voltage sag on the secondary. During such an interruption, a CVT will not supply power to the connected equipment. As shown in Figure 5, a CVT will significantly mitigate a voltage sag by boosting the output voltage.

CVTs are particularly applicable to programmable logic controllers and the control circuits of adjustable-speed drives. CVTs can be used to sustain the logic voltage of these devices during voltage sags. For example, a properly sized CVT can provide good voltage regulation down to forty percent of the normal supply voltage, thereby enabling connected equipment to operate during voltage sags of that magnitude or less. A CVT is usually installed between the 120-volt distribution panel and the equipment. However, if the 120-volt power of the equipment is derived from a step-down transformer, then the step-down transformer can be replaced by a properly sized CVT.

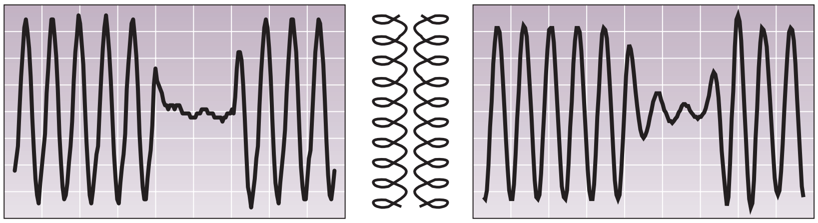


Figure 4. The Response of a CVT to a Three-Cycle Voltage Interruption

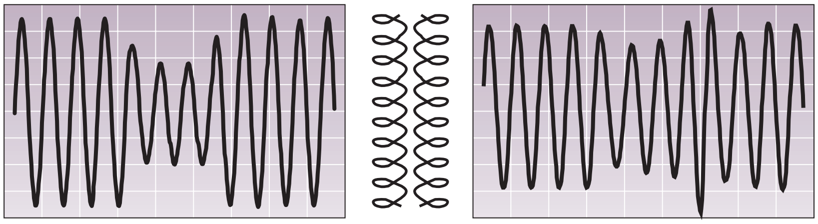


Figure 5. The Response of a CVT to a Three-Cycle Voltage Sag Down to Fifty-Eight Percent of the Normal Voltage

Uninterruptible Power Supplies The uninterruptible power supply is one of the most widely used power-conditioning technologies. It is designed to operate connected equipment with an alternate source of power, such as a battery, during power interruptions and certain electrical disturbances such as voltage sags and surges. UPSs applied to vulnerable airport equipment will generally be rated at less than 50 kVA. (For more information on sizing a single-phase UPS, read PQTN Application No. 5, *Sizing Single-Phase Uninterruptible Power Supplies,* available from EPRI.)

The four main types of UPSs are the rotary UPS, the standby power system, the rectifier/charger UPS, and the line-interactive UPS. Each type will power connected equipment with a break in output voltage no longer than one half cycle, which will not affect the vast majority of the types of equipment connected to UPSs. Each type of UPS has advantages and disadvantages that must be considered for a particular application.

The rotary UPS is typically the most expensive type of UPS and is generally used to support high-power equipment, which is atypical in the airport environment. This type of UPS uses an AC or DC motor to drive an AC generator, thereby creating a new power source for the connected equipment. When the normal voltage falls below or exceeds predetermined levels, a battery supplies power to the motor.

A rotary UPS provides very good steady-state voltage regulation and completely isolates the equipment from overvoltages in the normal power source. However, this system contains moving parts, a complex mechanical system, and numerous batteries, all of which increase maintenance requirements.

The standby power system, often called a standby UPS, is typically the least expensive of the four types. It is generally used in low-power applications, such as supporting personal computers. A standby UPS enables equipment to run on the normal power source until the voltage falls below or exceeds predetermined levels for a predetermined duration. If the voltage falls below or exceeds these values, a standby UPS will switch the connected equipment from the normal power source to a battery-powered source of AC voltage.

The standby UPS is efficient and can support high inrush currents, which are caused by the startup of connected equipment. However, it offers no overvoltage isolation between the connected equipment and the normal power source.

The line-interactive UPS relies on a transformer to regulate its output voltage. A UPS need only regulate its output voltage to be categorized as line-interactive. For example, a standby UPS with a tap-switching transformer may be called a line-interactive UPS. As the standby UPS does, a line-interactive UPS will switch to battery power during certain levels of voltage sags, surges, and interruptions. Line-interactive UPSs, especially those with a CVT (also called a ferro-resonant transformer), can continue to operate connected equipment from the normal power source during conditions that would cause a standby UPS to switch to battery power.

Most line-interactive UPSs are more efficient, offer better overvoltage isolation, and have higher starting current than rectifier/charger UPSs. However, they are generally less efficient, have lower starting current, and cost more than similarly sized standby UPSs.

The rectifier/charger UPS rectifies the normal AC power to a DC voltage, then inverts the DC voltage back to AC voltage to power the connected equipment, similar to the inverter operation of an ASD. The DC voltage charges a set of parallel-connected batteries, which supply DC voltage to the inverter. The connected equipment is therefore always powered by the inverter, not the normal power source.

Rectifier/charger UPSs provide good overvoltage isolation and steady-state voltage regulation. However, they are less efficient, have less starting current available to connected equipment, and cost more than similarly sized standby UPSs.

The performance of a UPS will vary from type to type and model to model. Therefore, the specifications of a UPS should be compared to the requirements of connected equipment. The most important criteria to consider include:

- Voltage Regulation
- Overvoltage Isolation
- Surge Protection
- Ability to Handle Inrush Current
- Attenuation of Harmonic Current
- Battery Run Time
- Transfer Continuity
- Ability to Operate with a Generator
- Output Neutral-to-Ground Bond
- Cost
- Maintenance

Stored-Energy Inverters Stored-energy inverters are typically used for low-power equipment such as control relays, starters, and PLCs. Typically rated for 3 kVA or less, these devices are relatively small and inexpensive. Stored-energy inverters operate like a standby UPS. However, instead of battery power, they use a capacitor to store energy and supply DC voltage to an inverter that powers connected equipment. Although even large capacitors can supply power for only a second or so, capacitors require significantly less maintenance than batteries.

Reactors Connecting line reactors (often called *chokes*), DC-link reactors, or both to ASDs will mitigate the effects of capacitor-switching and other types of transients and will reduce the harmonic distortion otherwise caused by an ASD. Sometimes a properly sized isolation transformer can provide the same benefits as a line reactor. The cost of a reactor depends upon the size of the ASD (the bigger the ASD, the greater the cost).

Using Surge-Protective Devices

Voltage transients, also called surges, can cause permanent damage to airport equipment. Therefore, it is common practice to protect sensitive electronic equipment from surges. Manufacturers of sensitive equipment usually build surge-protective devices (SPDs) into their products. Airport facility engineers can divert and clamp surges by installing SPDs at various locations within the airport.

Installing an SPD where sensitive equipment interface the electrical system is the most common method of mitigating the effects of surges. However, a more effective way to mitigate surges is the two-stage method of surge protection. As shown in Figure 6, a primary SPD called a *surge arrester* can be placed near a potential source of surge, such as the circuit powering a large motor (first stage). For surges generated on the utility side of the meter, a primary SPD can be installed at the service entrance, either at the utility meter or at the primary distribution panel. A primary SPD will divert to ground most of the surge energy. A secondary SPDs called a *suppressor*, installed at the equipment to be protected, will clamp any residual surge voltage in the circuit. Additionally, the line impedance between the primary and secondary SPD will restrict a surge as it travels through the building wiring.

When installing SPDs according to the two-stage method, the clamping-voltage ratings of all installed SPDs must be properly coordinated. The clamping voltage is the voltage at which the SPD begins to divert surge current. When the voltage across the SPD terminals exceeds the clamping voltage, the electrical characteristics of the SPD changes to shunt excess current to ground.

To ensure that the primary SPD operates to divert the majority of the surge, the clamping voltage of the primary SPD must be lower than the clamping voltage of the secondary SPD. Nevertheless, there is a growing trend among SPD manufacturers to

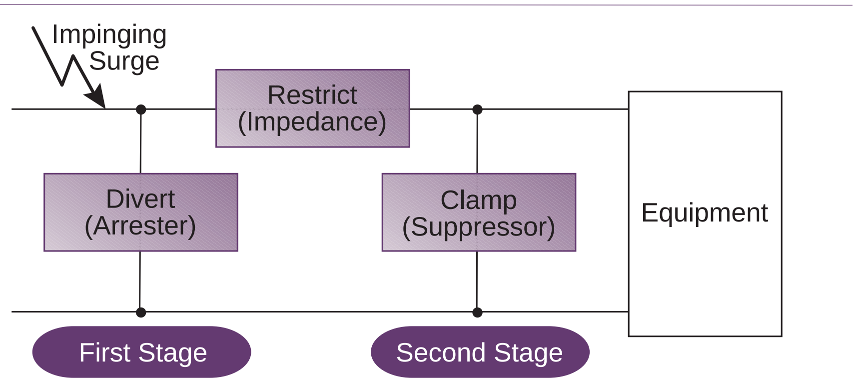


Figure 6. Two-Stage Surge Protection of Sensitive Airport Equipment

advertise lower and lower clamping voltages of secondary SPDs, which are called *surge suppressors* or *transient voltage surge suppressors*. However, tests have shown that clamping voltages around 500 to 600 volts—rather than the 330 volts currently promoted by some manufacturers—are quite appropriate to protect most devices. In some cases, adding a line choke to the power terminals of equipment will also mitigate the effects of overvoltage transients.

When equipment such as a modem, fax machine, or television is connected to both the power system and a communication system—such as a telephone, local area network, or cable TV system—the equipment should be protected with a surge reference equalizer (SRE). An SRE is a single-package SPD that is plugged into both the electrical receptacle and the communication system used by the equipment. The equipment power cord and communication cable are then plugged into the SRE, which equalizes the grounds of the two systems to protect each against surges occurring in the other.

Surges can also be avoided by maintaining the building wiring and replacing faulty contactors and switches. Good maintenance practices can reduce the occurrences of surges originating within an airport while improving the overall reliability of the power system. Constant-voltage transformers also mitigate surges. As shown in Figure 7, a CVT will damp both oscillatory transients caused by capacitor switching and impulsive transients, such as those created by lightning and motor switching.

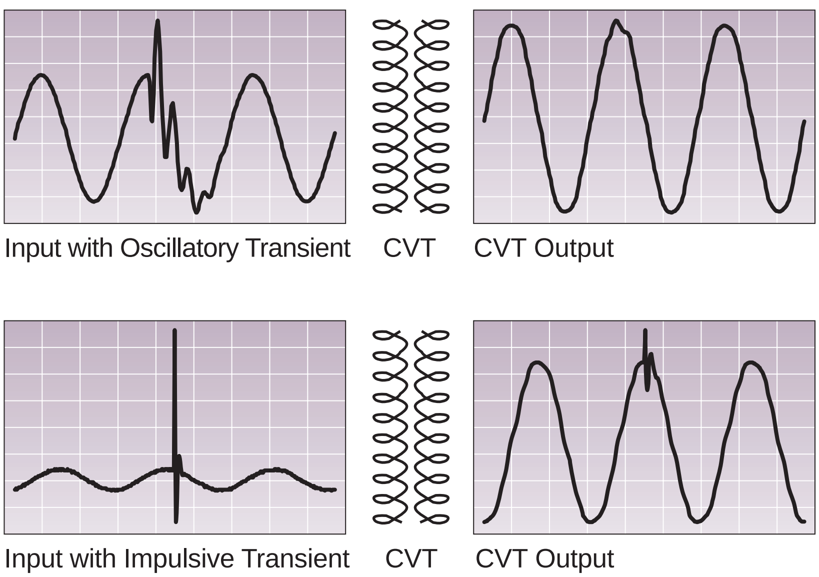


Figure 7. The Response of a CVT to Oscillatory and Impulsive Transients

Before purchasing airport equipment, specify a high immunity to surges. The increased equipment tolerance may entail some added cost, and some manufacturers may be reluctant to provide increased tolerance unless the need is clearly identified in the purchase specifications. Further, not all manufacturers perform tests required to characterize the surge-tolerance of their products. The equipment purchaser must insist upon documentation from the manufacturer that demonstrates enhanced surge tolerance.

Conclusion

As in any other complex industrial or commercial environment, electronic equipment in airports may be vulnerable to common electrical disturbances. Many of these electrical disturbances are predictable, and the response of the equipment to these events is known. By following the guidelines in this TechCommentary, airport facility managers can identify and solve most existing incompatibilities between airport equipment and the airport electrical environment. Moreover, by understanding how susceptible types of airport equipment react to common electrical disturbances, facility managers can anticipate future power quality problems and their solutions as power electronic devices continue to proliferate in airport systems and as new power-conditioning technologies emerge.

Where to Get Help

- Equipment vendors and manufacturers
- Vendors and manufacturers of power-conditioning devices
- Your local electric utility

For Further Reading

Publications from the EPRI Power Electronics Applications Center:

- PQTN Application No. 1: Mitigating the Effects of Line-Current Unbalance on Adjustable-Speed Drives
- PQTN Application No. 3: Avoiding Temporary Blackouts of Metal Halide Lamps
- PQTN Application No. 5: Sizing Single-Phase UPSs To Match the Load
- PQTN Brief No. 2: Residential Service Entrance Meter-Base Surge Protectors
- PQTN Brief No. 3: Plug-In Transient Voltage Surge Suppressors
- PQTN Brief No. 4: Plug-In Transient Voltage Surge Reference Equalizers
- PQTN Brief No. 9: Low-Voltage Ride-Through Performance of 5-HP Adjustable-Speed Drives
- PQTN Brief No. 10: Low-Voltage Ride-Through Performance of AC Contactor Motor Starters
- PQTN Brief No. 13: Ferro-Resonant Transformer Output Performance Under Varying Supply Conditions
- PQTN Brief No. 14: Ferro-Resonant Transformer Output Performance Under Dynamic Supply Conditions
- PQTN Brief No. 15: Ferro-Resonant Transformer Output Performance Characteristics During Various Loading Conditions
- PQTN Brief No. 16: Ferro-Resonant Transformer Input Electrical Characteristics During Linear and Nonlinear Loading
- PQTN Brief No. 19: Evaluation of Incompatibility Between Electronic Ballasts and a Hearing Aid
- PQTN Brief No. 26: UPS Mitigation of Capacitor-Switching Transients
- PQTN Brief No. 27: UPS Mitigation of Oscillatory and Impulsive Transients
- PQTN Brief No. 28: Input Performance of ASDs During Supply Voltage Unbalance
- PQTN Brief No. 29: Input Performance of an ASD with AC and DC Reactors During Supply Voltage Unbalance
- PQTN Brief No. 30: Ride-Through Performance of Adjustable-Speed Drives with Flying Restart
- PQTN Brief No. 33: Shared-Neutral Current in Branch Circuits Serving Office Appliances
- PQTN Brief No. 34: Performance of an ASD Ride-Through Device During Voltage Sags
- PQTN Brief No. 35: Power-Conditioning Performance of Uninterruptible Power Supplies
- PQTN Brief No. 39: Ride-Through Performance of Programmable Logic Controllers
- PQTN Brief No. 40: Ride-Through Performance of a Web Process Enhanced by a Constant-Voltage Transformer
- TechCommentary Vol. 1, No. 1: Power Conditioning Equipment: An Overview
- TechCommentary Vol. 3, No. 2: Applying Power Conditioning Equipment
- TechCommentary Vol. 3, No. 3: Principles of Low-Voltage Surge Protection
- PQTN Commentary No. 1: Harmonic Currents in Building Wiring

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