STO-P Technical Paper

Using d.c. Power Fault Protectors

Safe DC Power for Mobile, Marine and Industrial Applications




June 2000

Using dc Power Fault Protectors

Using the latest high tech electronic equipment in a mobile or marine environment is full of electrical hazards. This paper describes how nine classes of electrical system faults threaten equipment and how "dc Power Fault Protectors" are used to prevent damage and maintain the highest operating reliability.

If you design, install, or use electronic equipment in the 12, 24, or 28 Volt mobile environment, you will need to understand the hazards and consider the impact on equipment performance.

Arretec UK has been a pioneer in the design and development of dc Power Fault Protection devices for over ten years. Their line of STO-P protectors are used worldwide in military, industrial, mobile and marine applications.

Contents

Contents

Introduction:

Power faults in DC electrical systems are nothing new. They've been with us since the invention of the storage battery. They just weren't a significant problem. Shock, vibration, corrosion were the primary causes of failure in mobile and marine electronics. But, that's no longer true!

If you use electronic equipment powered from a dc electrical system, then you already know how unreliable it can be. High density silicon chips and micronization of other components has reduced the power fault tolerance of equipment to a point where susceptibility to common electrical system faults has become a serious concern.

At the same time, the use of wireless and mobile devices is growing exponentially and destined to 'explode' in the next few years. Many, if not most, of these devices are going to be connected to dc electrical systems and that's going to create expensive headaches for manufactures, retailers and users.

Monetary costs are usually cited to attract attention to a problem. But, when lives depend on navigation and communications equipment that may fail, the costs can be far greater that mere 'inconvenience'.

Arretec UK has dedicated the last ten years ensuring that mobile and marine electronic equipment gets the 'clean power' needed to operate reliably. Our 'STO-P Power Fault Protectors'^{tm} eliminate electrical supply problems before they get into your electronics.

STO-P Protectors are designed to provide the protection and high operating reliability demanded by the military and aerospace industries. Thousands upon thousands of STO-P's are in use world-wide in every imaginable application.

With the unique experience that comes from solving real world problems, we have put together this brief technical paper to ensure that designers and users alike are aware of the hazards associated with their particular application. It explains ***how*** Power Fault Protectors are used to achieve maximum reliability and economy. And, ***why*** you should use them.

Symptoms

Susceptibility to common Electrical System Faults results in:

- Premature Failures,
- Poor Reliability,
- Intermittent Operation,
- High Maintenance Costs,
- Degraded Vendor-Client Confidence

In the harsh Marine environment, a recent survey showed that over 50% of electronic equipment failures were traced to some form of electrical supply problem. Unfortunately many design engineers still think 12 and 24/28 Volt power systems provide 'pure DC' power because "the presence of a battery provides an infinite sink that absorbs all faults". Nothing could be further from the truth. And, therein lies the problem.

PREVENTABLE Faults

Mobile and Marine electronics fall prey to definable classes of faults found in DC electrical systems. The Fault classes are:

- **Spikes**
- **Transients**
- **Overvoltage**
- **Undervoltage** (brownouts, blackouts, low battery)
- **Surges**
- **EMI -** Electro-Magnetic Interference
- **IEMF -** Induced Electro-Motive Force
- **Reverse Polarity** (human-induced accidents)
- **Ripple**

Mobile and Marine power systems are more problem-prone than their AC mains powered counterparts. Details of each of these faults can be found in the section titled: “Common Electrical System Faults”.

Unreliable Operation

The first effect of these faults is unreliable operation of the installed equipment. For example, if you look at the section on 'UnderVoltage' you'll discover that even in 24/28 volt power systems, battery voltage will drop to 6 volts during engine cranking. Under MIL-STD-1275B specifications, this is considered normal for properly maintained and operating DC power supplies.

Likewise, Ripple from alternators, AC inverters, or main powered battery chargers can produce noise and hum that interferes with the operation of radio, sonar and audio equipment. Other faults, can cause memory loss, 'glitches', or lead to premature failures.

Damage to Electronics

In some instances, a single fault 'event' will cause the immediate failure of a component. More often, the damage is cumulative and thus more insidious and much more difficult to diagnose. Equipment performance is degraded slowly - often going unnoticed by those who use it everyday. Or, the damage may be manifest as unrepeatable problems that are often dismissed as 'glitches' or 'software bugs'.

Intensive post-mortems of failed equipment reveal that components were damaged and degraded by exposure to a long succession of high voltage events. The accumulated effects weaken semiconductors and other components. Eventually failure occurs. Often, these damaged components fail when stressed by other normal environmental factors - like increased temperatures. However, the real cause of the failure is not heat, but rather, the repeated effects of exposure to electrical system faults.

Standard 'Solutions' Lead to Further Problems

Many different devices and techniques have been tried by engineers in the past: MOV's (metal oxide varistors), zener and avalanche diodes, passive filters, capacitors, fuses, circuit breakers etc. Devices used to suppress surges from lightning strikes work well for that purpose, but cannot be used safely to protect low voltage power systems found in the mobile and marine environment. One reason is that these devices are generally rated for very small power levels (watch for devices rated in 'joules'). They tend to burst into flames when exposed to sustained overvoltages! To counter this catastrophic consequence, engineers have to select devices with very high 'clamping voltage' levels, which effectively removes any benefit from their use!

Applying one of the 'standard solutions' might work if all you had to worry about was fast rise time surges caused by lightning strikes. But, proper protection means that you have to suppress or remove ALL electrical system faults - not just one! Standard devices are not capable of doing this.

Yet, the alternative of leaving equipment unprotected is unacceptable when high reliability and low maintenance costs are of paramount importance.

STO-P's Time Domain Approach

STO-P works in the 'time domain' and applies different techniques to 'trap', 'block', 'dissipate' or 'fill' (TBDF), or otherwise remove, each event as it occurs. For example, a fast rising high voltage transient usually occurs just prior to a charging system failure. But, a few hundred microseconds later an extreme Overvoltage condition follows. The first event is detected and suppressed by STO-P, but as the fault continues and transforms into a dangerous overvoltage condition, other 'trap', 'block', 'dissipate' or 'fill' (TBDF) methods are successively used to protect the equipment. We divide Fault Events into time domains:

DOMAIN 0: 1 nanosecond to 1 microsecond
DOMAIN 1: 1 us to 1 millisecond
DOMAIN 2: 1 ms to 15 ms
DOMAIN 3: 15 ms to 1 second
DOMAIN 4: over 1 second

Then, depending on the 'fault characteristics' detected, we use different TDBF techniques to remove or suppress the fault.

This broad spectrum Time-Domain approach allows us to achieve maximum possible suppression of fault conditions. The downside is that it costs more than the 'standard' ineffective methods, but that cost is spread over the entire bank of electronics carried on the vehicle or vessel. So overall it is extremely cost effective to install, and yields great savings in maintenance and repair costs.

UPS Reserve Power

Computer users are familiar with the problems of 'brownout' when AC Main voltages dip to a level where memory is corrupted. The same undervoltage effect occurs in 12/24/28 volt d.c. powered systems. The momentary starting of an engine, or the sudden increase in load due to some other equipment can cause small voltage dips that can destroy the memory on a GPS or onboard computer system. STO-P is 'UPS Enabled' - when voltage levels dip, the backup battery will automatically supply power (up to 45 amps!) to your equipment.

The Bottom Line!

Downtime due to premature failures, and costly service calls are eliminated. For the Vendor, it means better Client relationships and far less frustration for field technicians! For the 'End-User', it means years of reliable equipment operation, free from 'bugs' and 'glitches'.

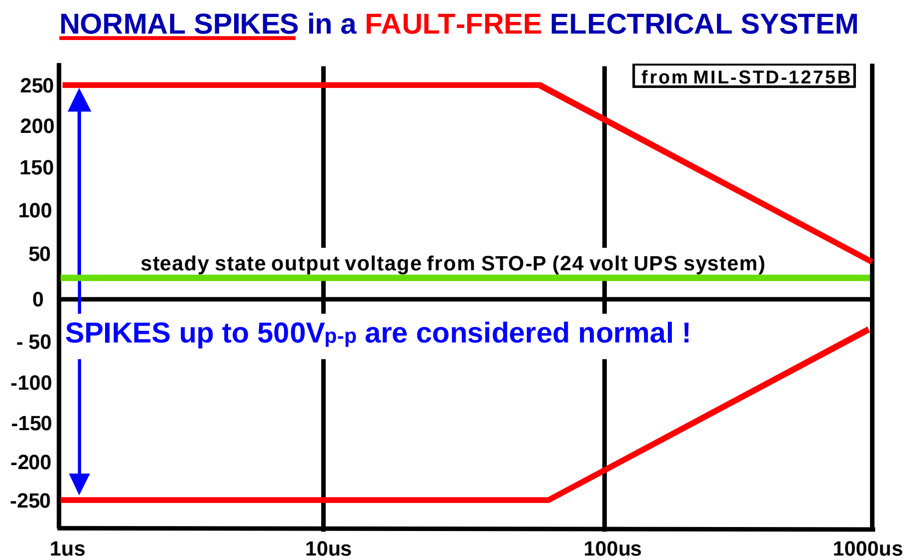
If you need a clean source of power - STO-P will meet or exceed your expectations.

Common Electrical System Faults

Spikes

SPIKES are high frequency oscillatory variations from a steady state level generated when reactive loads are switched.

In a properly operating electrical system, spikes can be expected to reach +/- 250 volts for durations up to 70 us decaying slowly to a steady state voltage.



In vehicles, windscreen wiper motors, lamp flashers and ignition sparks are typical sources of spikes. In the marine environment, bilge pumps, relays and solenoids produce spikes capable of damaging semiconductors.

For example, the small (and sometimes not so small) blue spark that occurs when the contacts of a switch are opened are a good example of this. Current flowing through the switch is interrupted but the inductance of the load AND wiring tries to keep the current flowing by charging stray capacitance. This can also happen when the switch contacts bounce open after its initial closing.

When the switch is opened (or bounces open momentarily) the current that the inductance wants to keep flowing will oscillate between the stray capacitance and the inductance. When the voltage due to this oscillation rises at the contacts, breakdown of the contact gap is possible since the switch opens slowly compared to the oscillation frequency and the distance may be small enough to permit 'arcing'. The arc will discontinue at the zero current point of the oscillation, but as the oscillatory voltage builds up again and the contacts move further apart, each arc will occurs at a higher voltage until the contacts are far enough apart to interrupt the current.

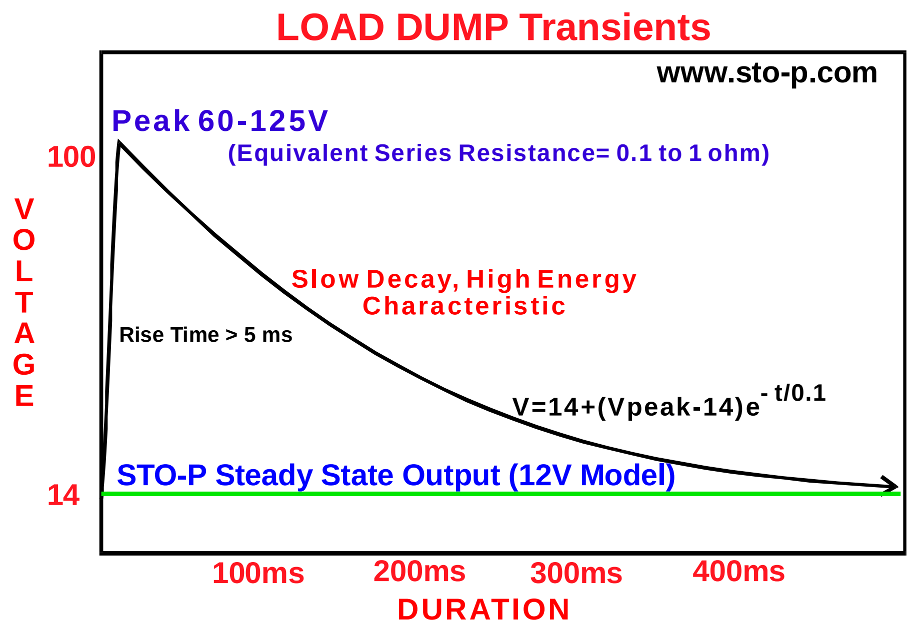
The arcing is usually visible as a small blue arc even in 12 volt systems. It reaches levels that will damage integrated circuits and other components. This damage tends to be 'cumulative' by nature and does not cause immediate failures. Successive exposure eventually leads to component degradation and complete failure.

Common Electrical System Faults

Transients

These are faults which cause the voltage of the power supply to go outside normal limits for a period of time. Many transients are capable of causing immediate equipment failures. But, most of the time they cause minor damage to semiconductors, degrading their performance. This damage is cumulative and eventually reaches a point where sudden and complete failure of the component results. Because of the subtlety of the fault process, equipment failures are often incorrectly blamed on other 'perceived' causes. Equipment is repaired, the 'perceived' cause of the problem is fixed, but failures continue. The only cure is to keep transients out of equipment!

Load Dump Transients



Destructive 'LOAD DUMP' transients occur when a battery is disconnected from the charging system during moderate or high charging rates. Load dump transients typically reach peak voltages of 60 to 125 volts in 12 volt systems with relatively slow rise times. Their duration usually exceeds several hundred ms and can extend out to 1 second or more depending on the characteristics of the charging system.

Load Dump transients also occur when heavy loads are switched off although their magnitude and duration will be lower. These transients are capable of destroying semiconductors on the first 'fault event'.

Field Decay Transients

These are high energy, high voltage NEGATIVE transients. These typically occur if an ignition switch is turned off while current is flowing in an inductive load such as an electric motor or alternator field coil. Therefore, it can occur several times per day.

A negative voltage transient appears on the supply rail on the same order of magnitude as a field dump transient, i.e. -60 to -125V. These transients tend to oscillate between negative and positive values, decaying slowly.

Because typical integrated circuits are highly susceptible to negative voltages, this is a potentially devastating (but all too common) fault.

Other Transient Sources

The following are typical of transients found in the automotive industry:

Transient Source:	**Typical Voltage:**	**Length:**
Failed 12 Volt Regulator	+18V	Continuous
Booster Start (12V systems)	+/- 24V	1-5 min.
Load Dump	60-125V	5-400+ ms.
Inductive Load Switching	-300V to +80V	up to 320 ms
Alternator Field Decay (each engine turn-off)	-125 to -60V	up to 200 ms
Ignition Pulse (battery disconnected)	up to 75V	90 ms typ.@ 500 Hz
Mutual Coupling in wire harness	up to 200V	1 ms

Common Electrical System Faults

O v e r v o l t a g e

OVERVOLTAGE is a sustained voltage that exceed normal steady state limits. In a 12 volt system, this is defined as any voltage that exceeds 15 volts. In a 24/28 volt systems, the limit is 30 volts.

Overvoltage is caused by malfunctioning alternators, voltage regulators, poorly adjusted 'fast charge' controllers, battery chargers and solar panels.

Another source, often overlooked, is the jump starting of vehicles during cold weather. This is usually done using a 24 volt battery to jump start a 12 volt system.

Overvoltages are continuously applied to the DC power system. The total energy produced is extremely high and very destructive. Ordinary 'surge suppressors' available from many manufacturers are only able to handle a few joules (watt-seconds) of energy for periods of 100 to 500 milliseconds or less. When an overvoltage is applied to these devices, they quickly heat and are destroyed often bursting into flame in the process!

So what started out as an overvoltage fault can quickly escalate into the loss, or severe damage, of the entire vehicle or vessel - not to mention the potential for loss of life.

Operator-Induced OVERVOLTAGE Problems

In the marine world, 3 and 4 stage battery charging systems have become common. One of the selling features of these systems is their ability to 'fast charge' batteries at high current rates. In theory, this sounds quite reasonable - charge the battery bank with a minimum of engine running time. In reality, ohmic losses in battery cables, and poor battery maintenance mean that the system never quite achieves a 'full charge' rate when properly installed.

Customers who were oversold on the benefits of the system by the local sales clerk want to see their ammeters register all '100 amps' from their 100 amp alternator flowing into the batteries! So the hapless tech who installed the system, or a 'knowledgeable' boater, adjusts the output voltage level to 18 volts or more to achieve 'proper' charge levels. Batteries heat up to near meltdown conditions, electrolyte is rapidly boiled away, battery plates buckle, and system voltages skyrocket to dangerous overvoltage levels.

As a result, the batteries are cooked and must be replaced every 6 months while the electronic gear suffers from endless failures. But, for some odd reason, the owners of such systems refuse to acknowledge the electronic failures are due to their own actions!

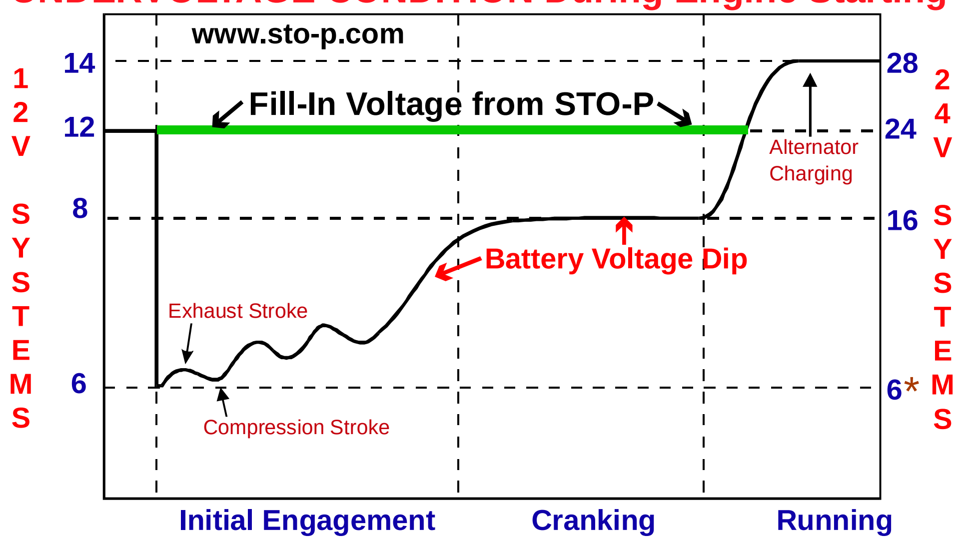
So, if you're an equipment dealer and find yourself in this type of ‘no-win’ situation, get your customer to install a STO-P UPS system. Then the overvoltage condition won't get to the electronic gear and the boat owner can continue to cook his batteries without costing you warranty repair time and money!

Common Electrical System Faults

Undervoltage

UNDERVOLTAGE: A sudden dip in voltage caused by engine starting or other heavy loads. This is one of the primary causes of memory loss in GPS navigation systems and crashes in mobile computer systems.

UNDERVOLTAGE CONDITION During Engine Starting



Voltage levels for 12 Volt Systems shown on the Left and corresponding levels for 24 Volt Systems shown on the Right.

*** Note that voltage can drop to as low as 6 volts in BOTH systems.**

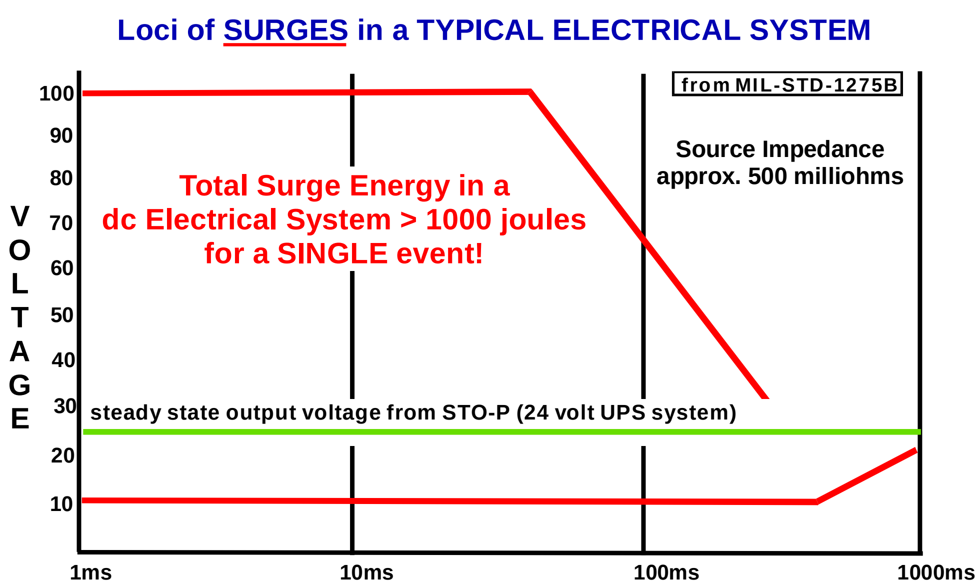
Cranking voltage with a fully charged battery can drop to 6 volts during the initial engagement of the starter motor. With the engine OFF, battery voltages can be expected to drop to 10 Volts in a 12V system, or 20 Volts in a 24/28 volt system under normal use.

Frequent events, like a fuse blowing on a lighting system, will drop system voltages below this for a few seconds before the fuse or circuit breaker opens.

Common Electrical System Faults

Surge

Technically, a 'surge' is a variation from the controlled steady state level of the DC power system. In a properly operating 24/28 Volt system, the 'permissible' level of surges is 100 Volts for up to 50 ms and 70 volts for 100 ms from a source impedance of 500 milliohms (from MIL-STD-1275B).



This illustrates the danger for equipment connected to mobile and marine electrical systems. Most engineers looks at data supplied by manufacturers of MOV or Surge Suppresssor diodes and are misled into thinking they are capable of protecting dc powered equipment. These devices are designed to suppress remote lightning strikes on power lines. They exhibit an 8/1000 us characteristic - meaning they are designed for surges that reach a peak at 8 us and have decayed by 1000us, or 1 ms. **In dc electrical systems, surges last several hundred times longer!** The power ratings of the protection devices are quickly exceeded which causes them to fail - short circuiting the power supply section of the equipment. Excessive current flows causing printed circuit board traces to vaporize *(see Reverse Polarity photo).* An expensive trip to the repair shop follows.

CONCLUSION: If your equipment has built-in surge protection, it is more likely to be damaged by your dc electrical system! Use a STO-P Power Fault Protector to prevent this from happening.

AC SURGES

In common 'usage', a SURGE has been equated to AC power line variations due to lightning strikes or other faults on the distribution system. These 'AC SURGES' need to be considered in the design of DC power systems, since at some point a mains powered battery charger is likely to be connected. For marine systems, AC battery chargers are routinely used to keep batteries fully charged whenever the vessel is at a dock.

AC Surges are coupled into the DC power supply causing severe fault conditions.

The table below indicates the frequency of surge transients on 120 Volt AC power lines in the United States. The corresponding voltage levels coupled to the DC power system will depend on the design of the charger and the characteristics of the AC distribution network. But, the table clearly shows that significant surge voltages can be applied quite frequently even in geographical areas considered to be at 'low risk'.

Typical Surge Voltages Measured on 120 VAC power lines

Surge Risk	Frequency	Voltage Level
Low	50 hits/year	350 V
	10 hits/year	500 V
	1 hit/year	920 V
Moderate	50 hits/year	2100 V
	10 hits/year	2700 V
	1 hit/year	4900 V

Even in low risk areas , one can expect surge levels at the ‘serious’ or ‘dangerous’ level at least several times each year. Since many, if not most, battery chargers DO NOT have any form of output filtering to suppress them, high voltage surges can enter the 12/24/28 volt power bus at unpredictable levels.

STO-P UPS responds to AC Surges that pass through the battery charger in the same manner as Transients - they are detected and removed within the first few nanoseconds. It’s important to remember that the only real protection in DC systems is having power ‘scrubbed’ clean just prior to entering the equipment.

Note: The use of standard 'surge suppressors' on AC lines must be applied with caution. Most low cost suppressors use MOV's (Metal Oxide Varistors) which have a limited working life. A single high voltage surge can render them inoperative! Unfortunately MOV's produce no indication that they are no longer functioning. The user is left with the false impression that his system is protected when the opposite may be true.

Common Electrical System Faults

Electro-Magnetic Interference (EMI)

EMI is noise and interference from electrical appliances and nearby transmitters. EMI from VHF/UHF radios, Cellular phones, SSB marine or ham radio transmitters effect mobile equipment and degrade performance.

The RF voltage levels present at equipment terminals varies over a wide range depending upon frequency, proximity and power output of the interfering device. Installations cause even more variability. The length of power supply wires and cables often determines whether the fault is a 'minor annoyance' or a major cause for failure within the equipment. If the wire becomes 'resonant' at the operating frequency it can absorb significant amounts of power from the transmitter and present very high voltages at the equipment power terminals.

STO-P Power Fault Protectors incorporate passive filters to suppress EMI to levels that do not threaten damage to equipment. Typical suppression levels are 15 to 20 db (100 times reduction in power levels) over a broad band of frequencies.

Common Electrical System Faults

Induced Electro-Magnetic Force (IEMF)

INDUCED EMF are excessive voltages induced into electrical wiring (which acts like an antenna) by nearby lightning strikes. Particular care should be exercised when using solar panels since their large conductive surface area acts like an antenna that couples lightning induced EMF directly into your electrical system.

Mutual coupling in wiring harnesses of vehicles and vessels can induce voltages in circuits that are electrically isolated from one another. A typical example of this is where dual batteries are used. One battery is used to supply high loads to start the engine or run a heavy motor, while the other is used for electronic equipment. The theory is that heavy transients generated when starting an engine will not affect the electronics powered by the second battery. But, most often, the wiring for both systems is run adjacent to each other and this allows coupling of spikes from the 'starting' power system to the 'electronics' power system even though there is no physical or electrical connection between the two.

In the marine world, people often claim they have been hit by lightning which caused the loss of all electronics on board. However, further investigation usually finds that there was no direct strike to the vessel but rather damage was caused by induction from a nearby strike. "Nearby" is usually defined as 'within 1000 metres' (approx. 0.6 mile), but damaging voltage levels have been measured in electrical storms at ranges of 1.5 miles or more.

Polarization is also a factor. A horizontal strike from cloud to cloud induces a greater voltage in an electrical system cable that is laid horizontally. Peak voltages are measured when the wire is parallel to the direction of the lightning strike. Likewise, a vertical lightning strike from cloud to ground induces maximum voltage in vertical wires - like those run up a mast to navigation lights.

Several hundred volts of lightning induced EMF are frequently measured in moderate electrical storms. In areas of severe thunder activity, higher levels have been measured.

Common Electrical System Faults

Reverse Polarity

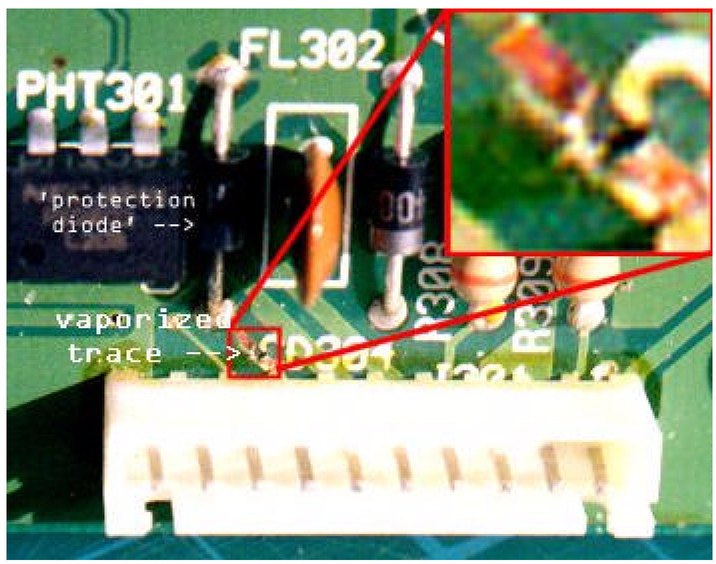
Reverse Polarity faults typically occur while jump starting vehicles or installing new batteries. While these are the result of 'accidents', their damaging effect can be devastating. Because of poor design techniques, much of the electronic gear brought into the marketplace over the past several years can be severely damaged by reverse polarity. STO-P protects your equipment.

POOR EQUIPMENT DESIGN?

There is one area where manufacturers are at fault. Of late, we've noticed a trend in equipment design that makes 12 Volt and 24 Volt electronic equipment prone to expensive damage.

Ironically most equipment has some form of reverse polarity protection built in. Usually in the form of a diode and fuse. The 'theory' is that if a reverse polarity fault occurs, the diode will conduct, short the power supply to ground and cause the fuse to blow - thus protecting your equipment. It works. But, there’s an expensive catch.

An alarming amount of 12 Volt and 24 Volt electronic gear has a basic design fault. The copper traces on the printed circuit board are made very small. The 'protection' system pulls so much current through the diode (trying to pop the fuse) that it VAPORIZES the printed circuit board power trace before the fuse can blow. (see photo) So, instead of replacing the fuse, you have to replace the entire printed circuit board! Or, find a competent tech who can repair the damage. In either case, the accident requires expensive repairs when it should only result in a blown fuse costing 15 cents.



Beware! This problem has been detected in equipment from a wide range of manufacturers.

Common Electrical System Faults

R i p p l e

RIPPLE is defined as the regular or irregular variations of a voltage about a fixed DC voltage level during steady state conditions. Under MIL-STD-1275B, ripple should be 2 volts or less in a 24/28 Volt system within the range of 50 Hz and 200 KHz. That's for a properly operating system!

Ripple sources are commonly the alternator system (heard as 'alternator whine' on radio or audio equipment), the ignition system, and hum generated by battery charging equipment.

STO-P Power Fault Protectors incorporate highly effective filtering to provide a very low impedance to ground. Typical values are 20 milliohms or less at 1 KHz. This extremely low impedance level removes virtually all traces of ripple from the power supply feeding electronic equipment.

An unexpected benefit of this is the tendency to improve the audio quality of communications and entertainment systems.

Land Transport Applications

Mobile applications abound in the wireless environment. Unfortunately the moment you connect electronics to the vehicle electrical system, you begin a spiral of problems that will effect the operation, reliability and longevity of the equipment.

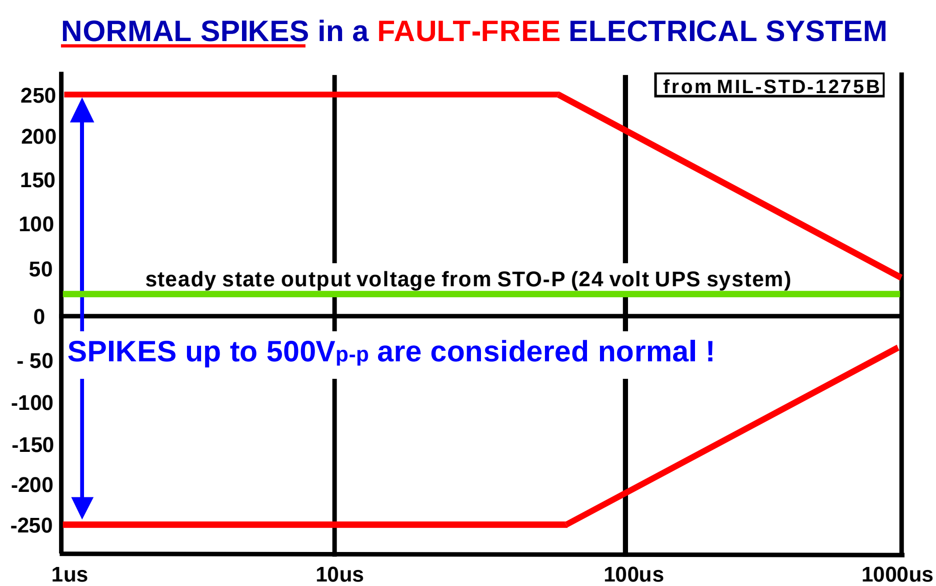
ISOLATION:

Computers, Communications, Navigation and Entertainment systems MUST be isolated from the vehicles electrical system. In the past, installers have recommended that a separate battery be installed to power this equipment. Unfortunately, that doesn't guarantee reliable operation since the second battery is usually charged by the vehicle's alternator. 'Isolation' diodes do not prevent electrical faults from reaching the electronics either.

CONSTANT DANGERS:

Each time the engine is started, high voltage spikes are generated by the starter solenoid and starter motor. Contact bounce aggravates the problem by creating a series of positive and negative spikes that can reach several hundred volts. In 24 volt systems, spikes can reach 500 volts peak-to-peak!

For example, the following chart is extracted from MIL-STD-1275B and shows the 'normal' loci, or limits, found in a properly operated and maintained system:



Each time the engine is switched OFF, a **'Field Decay Transient'** occurs as the electromagnetic field collapses in the alternator. These are high energy, high voltage NEGATIVE transients. They also occur if an ignition switch is turned off while current is flowing in an windshield wiper, or power window motor. Negative voltage transients of -60 to -125V are generated. *See the section on TRANSIENTS for more details*

UNDERVOLTAGE or 'Brownout':

Perhaps the easiest to understand fault is UNDERVOLTAGE. Each time the starter is engaged, battery voltage can be expected to dip to as low as 6 volts. This causes havoc with embedded computer systems and other electronic gear.

OTHER PROBLEMS:

All of the problems noted previously in the *'Common Electrical Systems Faults'* section can be found in vehicular power systems. There is little difference between the modest passenger car, a diesel powered bus, an ambulance, or military APC. ALL suffer from these problems.

The bottom line is thus: if you MUST HAVE RELIABILITY, you MUST keep electrical system faults out of electronic equipment. That was the reason for STO-P's development nearly 10 years ago. Today's dependence on mobile communications and navigation makes it even more important!

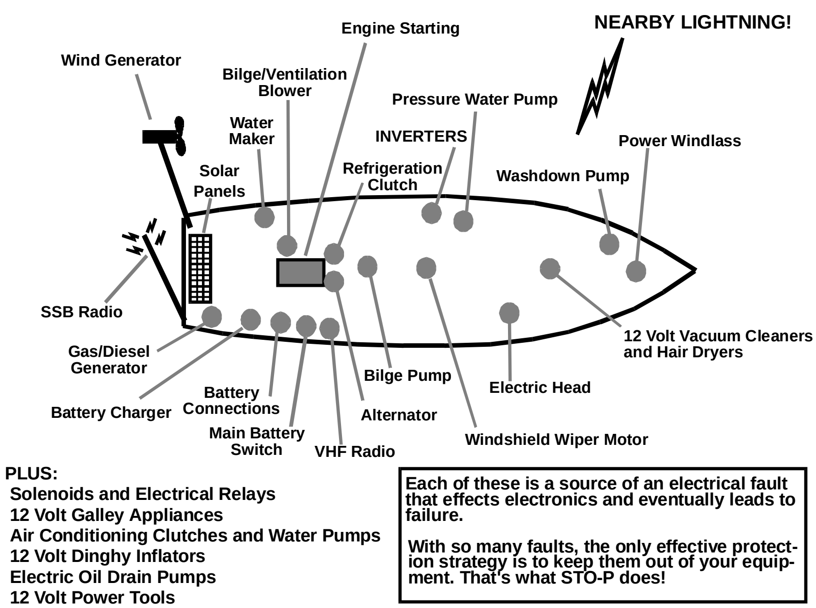
Marine Applications

STO-P was originally designed for the demanding marine environment where electronics and navigation equipment is essential for safety at sea. Nowhere else are the problems of power reliability so important. As we pointed out in the 'Common Electrical System Faults' section, high voltage faults damage electronic components making them more susceptible to environmental stresses. The more they are exposed to high voltage faults, the more likely they are to fail - the effect is cumulative.

For example, marine radar often fails when it is needed the most - in the midst of a thick fog, or when approaching an unfamiliar port at night. There's a logical explanation for this. In low visibility situations, radars operate for long periods of time. Continuous use generates heat within the equipment. Heat stresses components which have already been weakened by exposure to electrical system faults. A component fails and the radar ceases to operate - at the worst possible time.

Many marine operators are aware that engine cranking causes high voltage spikes as the solenoid and starter motor engages and disengages. But, there are many other sources of high voltage spikes and faults as the diagram below shows:

Sources of Electrical Faults on Boats



HIGH VOLTAGE WORRIES

Transients of several hundred volts peak-to-peak can be measured using a high speed digital oscilloscope at various points in the electrical distribution system. See the sections on transients, spikes and surges for details.

LIGHTNING

Lightning is another hazard. A direct hit is quite rare if you remain near land, or are berthed in a marina or port. But, nearby hits (within 1 KM or so) to buildings, radio towers, etc. can induce large voltages (i.e.m.f.) in boat wiring where it is distributed to equipment.

RADIO 'RF 'INTERFERENCE (EMI)

Electromagnetic interference from high powered SSB radios pose another problem for many types of electronic equipment. Boat wiring acts like an antenna. Power leads, which are rarely shielded, can pick up large induced voltages as their length approaches resonance at the operating frequency. Autopilots wander off course, GPS waypoints are scrambled, NAVTEX stops working, and instruments give wild readings. The effects vary according to transmitting frequency. It may be terrible at 4 MHz and non-existent at 12 MHz, or vice versa. Each installation is different because of such variables as power lead length and the peculiarities of the radio installation.

BATTERY CHARGER PROBLEMS

Using a battery charger when at the dock is a necessity for most vessels but it causes problems. AC mains surges due to the operation of heavy equipment in port, and by distant lightning strikes, are coupled onto the ship's DC power system. A look at our section on 'Surges' shows that voltage spikes of a thousand volts, or more, are frequent even in 'low risk' areas.

Many of today's high tech battery chargers use a pulse charging technique which generates substantial amounts of Ripple which can be heard as a buzz or whistle in audio entertainment and communications equipment. The 'theory' is that the battery bank will act as a filter. In the real world, ripple can be substantial and it affects equipment. While unlikely to damage equipment outright, it does produce annoying 'hum' and 'noise' on audio equipment and is often heard on VHF radios. At the very least, it sounds very 'unprofessional'.

WHAT STO-P UPS DOES

The key to reliable marine electronics is to keep electrical fault OUT! Installing STO-P in-line on power leads accomplishes this. High voltages are sensed and treated the instant they exceed the 'safe' level. STO-P's response time is typically 1 nanosecond (one billionth of a second) or less!

The STO-P UPS series is designed to maximize suppression of EMI and Ripple by presenting a very low impedance to ground at frequencies above a few Hz. For example, The typical output impedance at 120Hz is 0.03 ohm, falling to 0.02 ohm at 1KHz. Ripple and EMI are reduced significantly. In some cases, this low impedance will also improve the overall audio quality of brand new communications radios.

Industrial Applications

Where ever DC powered equipment is used, it needs protection.

ENGINE CONTROL SYSTEMS

One manufacturer incorporated STO-P as standard equipment on one of their advanced engine control systems. STO-P solved persistent engine faults that had been blamed on software bugs in the engine control computer. After spending countless man-days scouring computer code for bugs and timing errors, an alert engineer placed a STO-P in the power supply line and the problems ceased!

REMOTE SENSING & SOLAR POWERED INSTALLATIONS

Remote sensing sites often rely on 12 or 24 volt battery power supplies recharged by solar panels. While this seems like a reasonably foolproof way of supplying power, engineers often find that equipment failures are abnormally high. One cause has been induction caused by nearby lightning. Solar panels present a large conductive surface area which is a very effective antenna for coupling high voltage transients into equipment.

Battery failure, regulator failure, or batteries nearing the end of their service life create overvoltages as solar panels drive a 12 volt system to 20 volts or more.

STO-P UPS series protectors solve both problems.

CUSTOMIZED POWER FAULT PROTECTORS

Arretec can supply STO-P UPS and Power Fault Protectors over a wide variety of voltages and power handling capabilities. We can also package to meet your needs. Over the past ten years, our engineering department has successfully diagnosed hundreds of power related problems for clients around the world.

Contact us with your requirements.

STO-P Specifications

STO-P UPS 40 Specifications

Power Fault Protector and Uninterruptable Power Supply that provides up to 40 Amps of safe power. The backup battery is built in. The entire unit is housed in a rugged die cast aluminum case, sealed to IP65 standard.

Technical Specs for Model:	STO-P UPS 4012-x	STO-P UPS 4024-x
Nominal Voltage:	12 VDC	24/28 VDC
Operational Range:	0-15 VDC	0-30 VDC
Max. Continuous Current	40 Amps	30 Amps
Short Term Current	60 Amps (30 seconds)	40 Amps (90 seconds)
Overvoltage Limit:	+15.3 VDC (adjustable)	+30.5 VDC (adjustable)
Reverse Polarity Clamping	-0.5 VDC (typical)	-0.5 VDC (typical)
Transient Response time	1 nanosecond (typ.)	1 nanosecond (typ.)
Internal Backup Battery	4.0 Ah	1.2 Ah
Peak 'Fill-in' Current	45 Amps	45 Amps
External Battery Option?	Yes!	Yes!
Operating Temperature	-40C to +85C	-40C to +85C
Input/Output Leads	8 AWG/7mm^2 FlexCopper	8 AWG/7mm^2 FlexCopper
Dimensions LWH (mm)	190L x 110W x 120H	190L x 110W x 120H
Availability:	Stock to 30 days	Stock to 30 days

A separate set of control leads can be routed to an external switch to place the UPS in ‘sleep’ mode where it will draw less than 10 microamps from the main battery supply.

STO-P Specifications

STO-P PFP15xxxx or EFP15xxxx Specifications

PFP15 Power Fault Protector is compact in size for tight installations. It is 'UPS enabled' with switching and charging controls but requires user supplied backup battery mounted externally. Provides a total of 15 amps of safe power to two separate outputs. The UPS output can supply up to 10 Amps of backup power.

Technical Specs	**PFP151224**	**PFP151224**
Voltage Setting (user selected)	12 VDC	24/28 VDC
Operational Range	0-15 VDC	0-30 VDC
Max. Continuous Current	15 Amps	15 Amps
Overvoltage Limit	16.5-17.5 VDC	30.5-31.5 VDC
Reverse Polarity Clamping	-0.5 VDC (typ.)	-0.5 VDC (typ.)
Transient Response Time	1 nanosecond (typ.)	1 nanosecond (typ.)
Max. 'Fill-in' Current	10 Amps	10 Amps
Operating Temperature	-40C to +85C	-40C to +85C
Dimensions LWH (mm)	50L x 50W x 30 H	50L x 50W x 30 H

STO-P Installation Notes

STO-P UPS 40 Series:

The new STO-P UPS40 Power Fault Protector is amazingly easy to install. Just insert it between the battery system and the electronic equipment to be protected. There are a pair of Input leads (positive and negative), and a pair of Output leads (positive and negative). The power leads from the STO-P are #8 AWG ($7mm^2$) wire. These are extremely flexible and easy to fit into existing installations.

The Diecast aluminum box may be mounted in any position via 4 - 3/16” (5mm) diameter mounting holes. While sealed to IP65, it is best to mount the box in a clean, dry environment. There are no operator controls and no periodic maintenance is required, so the STO-P UPS40 may be located in what otherwise might be wasted space.

STO-P PFP 15 Series:

The PFP15 series is designed for applications where space is at a premium. It performs the same functions as the UPS series but requires a user installed battery and is slightly more complex to install. It is completely sealed with seven wire leads providing connections to the electrical system.

Installation can be as simple as cutting an existing power lead and fitting the STO.P between the equipment to be protected and a suitably 'fused' power source. It should be placed in a location away from intense heat sources. It will be most effective when placed as close to the equipment as possible. Generally, a position somewhere in or near the existing electrical panel will suffice.

<u>**INPUT SIDE (Power Source):**</u>

RED: Positive side of Battery. Must be connected through a fuse, or a circuit breaker.
BLACK: Common or negative side of Battery.

<u>**OUTPUT SIDE (Equipment):**</u>

GREEN: *PROTECTED OUTPUT* ‘+’ for equipment that does not require 'low voltage fill-in voltage' during engine cranking.
YELLOW: *UPS OUTPUT* ‘+’. Maximum 10 Amps.
ORANGE: Standby Battery ‘+’ side.
BLUE: Standby Battery ‘-’ side.
BLACK: Common or negative to equipment.

Appendix:

Ordering Information:

STO-P dc Power Fault Protectors

STO-P UPS 40:

Power Fault Protector and Uninterruptable Power Supply providing 40 Amps of safe power. An internal backup battery is supplied - housed in a rugged diecast case sealed to IP65 standards. An external battery may be used for even greater backup capacity. Available in 12 Volt and 24/28 Volt models.

STO-P PFP 15:

Power Fault Protector, UPS enabled but requires user supplied backup battery mounted externally. Provides a total of 15 amps, 10 amps from UPS output. Voltage is user selectable for either 12 Volt or 24/28 Volt operation.

Small Quantity Price List: (For OEM or Volume Quantities, please ask for a quotation)

Item #	Description	Price Each + Shipping ($US)
EFP-151224	15 Amp STO-P 12/24/28 VDC	**$ 149** + $10
UPS4012-4	40 Amp STO-P UPS 12 VDC 4Ah Battery	**$ 495** + $40
UPS4024-1	40 Amp STO-P UPS 24/28 VDC 1.2Ah Bat	**$ 525** + $50

Prices shown valid as of 1 June 2000. Subject to change without notice. Check website for latest pricing.

Orders may be placed online for next day shipment (stock permitting) at:

http://www.sto-p.com/pfp/online.htm

Alternatively, contact us for payment details

sales@sto-p.com

Appendix:

Volume Quantities and Customized Versions :

Please fill in the form below and we will contact you immediately about your needs.

Contact person **Title**

Company name

Street address

Street address

City **State/Province** **Zip/Post Code**

Country

E-mail

Fax Number

Model

Date Needed

Quantity Needed

Nominal Voltage **Capacity (Amps)**

Special instructions (if any):

FAX to:

United States:	**1-415-704-3134**
United Kingdom:	**(0207) 681 3134**
Europe:	**+ 44 2076 813734**
International:	**+ 1 415 704 3134 or + 44 207 681 3734**

ONLINE:

Quotes: **http://www.sto-p.com/pfp/pfp-quote.htm**
Customized: **http://www.sto-p.com/pfp/pfp-customize.htm**

Appendix:

Additional Information:

Check our website for additional information and downloadable files.

http://www.sto-p.com/pfp/lit.htm

Contact Details:

internet: **www.sto-p.com/pfp**

fax:	***United States:***	**1-415-704-3134**	
	United Kingdom:	**(0207) 681 3134**	
	Europe:	**+ 44 2076 813734**	
	International:	**+ 1 415 704 3134**	**or** **+ 44 207 681 3734**

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