A MANAGEMENT OVERVIEW OF COMPUTER POWER PROBLEMS

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"Power Problems" are probably the most mysterious and misunderstood problems which can affect the Data Processing user. This guide is presented to assist the DP manager in preventing power problems from interrupting operations.

The first portion of this article defines, "What is a power problem and how do I know if I have one?" The second portion reviews Hewlett-Packard power specifications for the 3000 family. The final portion addresses the resolution of those problems, along with an analysis of the different types of power conditioning equipment.

How can you tell if you have a power problem? There is no way to "see" a transient, a sag, a surge, or a frequency deviation. The only kind of power problem you can see is a power interruption (blackout). Unfortunately, blackouts do not cause the majority of "power problems".

The following questions reflect the classic effects of power and/or grounding/ wiring problems.

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*  1.  Do you have one device that always seems to be down, and   *
*      does not seem as if it can be fixed?                       *
*                                                                 *
*  2.  Is system reliability significantly lower than expected?   *
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*  3.  Do you have "intermittent software problems"?              *
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There are four generic categories of power problems. These problems are (1) Transients, (2) Sags or Surges, (3) Blackouts, and (4) Frequency Deviations.

All power systems have transients. A transient/impulse/spike is a short duration, high amplitude pulse, superimposed on the power sine wave. Transients are the most common type of power problem. Transients may be generated by improper grounding. A solid, computer-grade, single-point ground is a MUST for reliable system operation.

Transient/noise problems can be solved by putting the computers on individual circuits which have no noise-producing loads (dedicated circuits), by decreasing system sensitivity to power problems (with the vendor including additional power conditioning devices within the computer system), or providing some type of isolation from impulses on the power lines (power protection equipment).

Sags and surges are changes in the amplitude of the AC sine wave. They may last from several cycles to several hundred cycles. Voltage sags can come from external sources (the power utility "browning out" its users to help during power shortage periods), or internal sources (most commonly, an overloaded power panel).

A brownout is a scheduled long-term voltage sag. Brownouts force power supplies to draw more current. This can cause overheating and component stress. Brownout conditions may also cause certain devices to appear more sensitive to transient impulses.

Regardless of the origin of a voltage drop, short-term voltage fluctuation problems may be difficult to identify. Voltage dips may cause portions of the system to execute a pseudo-power fail routine that the operating system software cannot handle, with unpredictable results. High voltage surges can cause equipment damage, in addition to "baking in" long-term problems.

Frequency deviations are a shifting of the basic powerline frequency of 60 cycles per second. Frequency deviations are usually not a problem in the United States when using utility power.

Blackouts are complete voltage interruptions. These power discontinuities may last from sub-cycle events to seconds/minutes/hours/days. Blackouts can cause significant hardware damage because of the very large transients and voltage variations that can occur when the power grids are broken and re-established. Blackouts are usually never "clean".

Hewlett-Packard has incorporated circuitry within the CPU to detect an impending power failure and enter a power fail routine. When power is restored, the system will re-boot and processing will resume. During a "dirty" or miltiple power fail, the CPU may enter and exit the power fail routine several times. The software routines may not run to completion, and the system recovery attempt will fail.

Extremely large transients may be generated when power grids come on/off line. There may be significant voltage oscillations until the power grid is positively re-established. Power protection in areas subject to frequent blackouts or voltage breaks is a must. Both voltage and transient protection need to be provided. Larger systems users may front-end their systems with a motor-generator set, uninterruptable power system, or backup power generator to prevent hardware problems carried with blackouts.

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System grounding is very important to ensure a properly functioning system. The ground wire serves two purposes--as a safety path to ground and as a zero signal reference source for all the digital logic. No computer system can operate reliably without a solid, low impedance (AC + DC resistance) ground.

If the only concern were safety, any metallic path leading to ground would be satisfactory. Low-level, high-speed computer logic circuits require a solid electrical ground. There should be no short-cuts or com- promises when implementing computer system grounds. Building conduit, although it meets the requirements of the National Electric Code, is not reliable for use as a computer system reference ground.

If building conduit is the only ground provided for the system, the qual- ity of that reference will depend upon how tightly the conduits are mechanically connected. Any change in the integrity of those connections because of age, building movements, heat or cold, can directly impact the reference (and indirectly the safety) ground. These events may impact reliable computer operation.

There are three reasons for grounding electrical systems:

1. To maintain any non-current carrying exposed metal surfaces (conduits, equipment enclosures, etc.), at 0 volts, or ground potential with respect to earth - (PERSONNEL SAFETY/PROTECTION).

2. To provide an intentional path with ample fault current capacity to cause fuse or circuit breaker operation during a short-circuit condition - (EQUIPMENT SAFETY/PROTECTION).

3. To contribute to proper performance of the electrical system and equipment - (EQUIPMENT PERFORMANCE).

The five components of a grounding system are:

1. GROUNDED CONDUCTOR. This conductor is intentionally grounded. This is the neutral conductor (white wire). It carries return current back to the source.

   The neutral has two purposes: to permit utilization of power at the line-to-neutral voltage, and to provide a low impedance path for fault currents to return to the transformer neutral, thereby quickly opening a circuit breaker during a fault condition.

2. EQUIPMENT GROUNDING CONDUCTOR. This conductor is used to connect the non-current carrying metal parts of equipment, conduits, and other enclosures to the system grounded conductor and/or the ground- ing electrode conductor at the service entrance or at the source of a separately derived system. This is the "ground" (green wire). It will normally never carry current, except during a system fault con- dition.

   The ground has two purposes: to maintain 0 volts with respect to ground on the equipment enclosures during normal operation, and to provide a low impedance path for fault currents when a phase to ground fault occurs. The National Electric Code addresses itself primarily to safety, and does not specifically address situaions to reduce noise which could impact computer operations. Recent changes to NEC Article 250-74, Exception #4, have attempted to integrate safety and equipment performance.

3. GROUNDING ELECTRODE CONDUCTOR. This conductor is used to connect the grounding electrode to the equipment grounding conductor and/or the grounded conductor at the service entry or at the source of a separately derived system. This is the conductor which connects the ground/neutral bond to the building ground or the ground stake. It will normally never carry current, except during a system fault condition.

   The purpose of the grounding electrode conductor is to provide a low impedance path to connect the elecrical system to earth through the grounding electrode and also reference the neutral and ground wire to the same potential.

4. GROUNDING ELECTRODE. This item carries practically no fault current. During a fault condition, current flows back to the service transformer via the service neutral to complete the circuit. This is the building service entry ground, or a ground stake.

5. MAIN BONDING JUMPER. This is one of the most important connections in the entire power system. This connection is made between the grounded circuit conductor (the neutral) and the equipment grounding conductor. This jumper MUST be present at the main service breaker and the secondary of all transformers, especially isolation trans- formers.

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HOW CAN YOU DETERMINE IF YOUR SYSTEM HAS A POWER QUALITY PROBLEM?

Special devices are available from either Hewlett-Packard, consultants or power conditioning equipment vendors to monitor power quality. The generic term for these devices is "line disturbance analyzer".

High-speed line disturbance analyzers are the proper devices to use to qualify sag/surge/transient problems. These devices can quickly respond to short-term sags and surges and have the capability to "capture" transient impulses. These analyzers can also provide printouts of voltage abnormal- ities and summaries.

Because of their relatively slow response, the strip-chart recorders used by the power company are usually of limited help to identify short-term variations. They may be helpful in identifying long-term brownout conditions.

The first step in determining if you have a power problem is an in-depth review of the system wiring and grounding. If there are wiring or ground- ing problems, analyzers may falsely report conditions which are not present.

After the wiring and grounding have been verified, the next step is to con- nect a powerline monitor to your system power system to determine if your power quality is within the Hewlett-Packard specifications.

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WHAT ARE THE HEWLETT-PACKARD "POWER" SPECIFICATIONS, AND HOW DO THEY RELATE TO THE POWER QUALITY AT YOUR INSTALLATION?

HP has published power specifications for the 3000 family in the site prep manual. The system specifications are as follows:

1. VOLTAGE SPECIFICATIONS -

   a. SYSTEM III, 30, 33, 40 and 44: Between 108 (-10% low) and 124 (+4% high) as referenced to a nominal input voltage of 120 volts.

b. 3000/64: Between 187 (-10% low) and 220 (+6% high) as referenced to a nominal input voltage of 208 volts.

If your input voltage remains within these two limits, you are operating within the HP voltage requirement specifications.

2. TRANSIENT IMPULSES - LESS THAN 100 VOLTS

If the transient impulses (spikes on the powerline) are less than 100 volts, you are within specifications.

One important exception - the HP64B contains an integrated conditioner. Because of the integrated conditioner in the CPU, you can obtain significant installation cost savings by not having to purchase three-phase power conditioning equipment to protect the CPU. Only the peripherals require protection.

"-db measurements" are a method of specifying transformer high frequency noise rejection characteristics. The higher the "-db", the greater the noise attenuatin capability of the transformer. A -60db transformer seeing a 20KHz, 1 volt spike in, will output a .001 volt spike. A 1000 volt transient will result (ideally) with a 1 volt output at the secondary. Note that these are only mathematical calculations, and usually have NO actual relationship to what the system may actually see under a live load. Proper wiring and instal- lation are a must to ensure correct power conditioning equipment performance.

Understanding the specifications and how they specifically relate to you and your system can prevent many problems. Providing proper wiring, grounding, and in-spec power is your responsibility. Provid- ing the information you need to ensure that the specifications are met is HP's reponsibility.

Service engineers are trained to solve equipment problems, not elec- trical problems. Vendors may be able to provide you some limited assistance in helping determine if you have a problem, but the final selection of the proper equipment, and ensuring that it has been properly installed is ultimately yours. It's your installation.

Knowing what type of conditioning devices can provide the proper, most cost-effective protection for your site can possibly prevent an expensive mistake, and help ensure a smooth DP operation.

POWER PROTECTION EQUIPMENT

The first thing to do before any power protection equipment is purchased is DETERMINE WHAT THE PROBLEM IS. Power problems are solved by addressing two separate but related areas:

(1) Correct wiring configuration and grounding, and

(2) True power problems (transients, sags/surges, blackouts, and frequency shifts).

Wiring and grounding MUST be correct before anything will work properly. It is generally the case that poor equipment performance is a result of poor wiring/gounding and/or true power problems. System reliability cannot be achieved without addressing both concerns.

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* PERSONNEL SAFETY  **    ***      POWER     *
*        +         ***     **                *
* WIRING PROBLEMS  ****     *      QUALITY   *
*        +         ***     **                *
* GROUNDING PROBLEMS **   ***      PROBLEMS  *
*                    *   ****                *
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ISOLATION TRANSFORMERS

As a general rule, no stand-alone isolation transformer, when actually installed, will meet its published isolation specs. This is because of the many installation variables and non-standard wiring practices which cannot be controlled by the transformer manufacturer. Isolation transformers can be installed improperly, causing unknown safety problems or continued poor system performance.

Proper connection and grounding of the transformer is more important than a high db rating. An improperly installed isolation transformer may in- crease, or do nothing to alleviate, common mode noise problems.

1. Isolation transformers will usually resolve transient problems if they are properly installed. They cannot resolve voltage fluctua- tion problems.

2. A standard power transformer will transfer both power and "noise" from the primary to the secondary. Because the windings of a power transformer cannot respond to high frequences, transients will easily pass from the primary winding to the secondary (output) side.

3. If the transformer manufacturer installs a "Faraday Shield" in the transformer (consisting of a grounded, single sheet of conductive copper foil, spanning the full width of the primary and secondary windings), this shield will shunt the majority of the noise impulses to ground. This type of transformer is also called a single- shielded, or elecrostatic transformer. Electrostatic transformers will generally reduce common mode noise by a factor of 1000:1 (-60db), or greater.

4. Two additional steps can be taken to produce ultra- or super- isolation transformers. A "box shield" can enclose the primary and secondary windings. This shield provides a second path for shunting noise on the primary (input).

5. The next step in the "ultra-isolation" process is to wrap each indi- vidual coil in another layer of conductive shield and enclose the entire transformer assembly in a shielded enclosure. These expen- sive, very high isolation units are also known as triple-shielded transformers. Their common mode noise rejection (UNINSTALLED) can be greater than 10,000,000:1 (-146db). It is HIGHLY unlikely that these figures will ever be met (or even come close) in an actual installation, because of the many installation variables. These numbers are test lab figures.

6. Before you attempt to solve a "noise" problem, make sure that you have accurately identified the problem that really needs solving. Most computer power supplies can effectively filter normal power- line noise.

7. The logic for solving noise problems with an isolation transformer is exactly opposite that for making an audio frequency transformer work. In the isolation transformer, the 60 cycle hum is the desir- able component, and other frequencies are undesirable.

8. An isolation transformer MUST be installed safely and properly. Manufacturer's instrucions must be followed precisely, or noise may bypass the transformer and go directly into the load. The neutral on the secondary must always be grounded. "Floating" the neutral is a code violation, and can cause many problems with switching type power supplies. If you (or your CE) measure greater than 1 VAC

between neutral and ground, you are facing a situation that requires immediate attention.

POWER LINE CONDITIONERS

A powerline conditioner is a device that reduces noise and compensates for voltage fluctuations. There are two primary types of devices on the market that will do this. Each type of unit has its advantages and disadvantages.

One type of powerline conditioner uses ferro-resonant technology. Ferro- resonant units are very reliable, and provide smooth voltage regulation. This type of unit is usually initially less expensive to purchase than tap-switching powerline conditioners.

Ferro-resonant line conditioners have some inherent deficiencies which should be carefully considered. Ferro devices work best when they are heavily loaded (70-90%). This may leave little room for future growth. A lightly loaded ferro-resonant regulator's voltage output may be higher than 120 volts. The voltage can go as high as 126 volts. These types of devices need heavy loading to saturate the transformer and obtain the ferro resonant/voltage regulating effect.

Perhaps the biggest problem with ferro-resonant devices is that the output voltage may collapse if the power units are approximately 150% overloaded. This can happen when discs are spun up, or line printers powered on. Some sites have had to modify their operating procedures to accommodate the powerline conditioner. To alleviate this problem, some manufacturers sug- gest the installation of two units--one for the CPU and peripheral, and one for the discs. This can increase installation costs significantly.

The second type of line conditioner on the market today is an SCR (Silicon Controlled Rectifier--a type of elecronic switch) tap-switching isolation transformer. This type of unit uses SCR's to electrically change the length of an isolation transformer in response to voltage variations. This stepped up/down voltage is then filtered to reduce powerline noise. Tap- switchers are usually initially more expensive than ferro-resonant devices.

Voltage regulation is performed by electronically switching the transformer winding taps on and off. Tap-switchers are not sensitive to loading. The output voltage will vary in step functions.

A bypass switch is a must to ensure continued operation should the voltage regulator fail.

Tap-switcher output voltages are not affected by high overloads. One properly sized unit can usually power the entire system.

Tap switchers cost more than ferros. However, this initial cost is usually recaptured in less than one year by power savings. A lightly loaded ferro will be about 65% efficient. A tap-switcher is about 95% efficient. Considering a 15 KVA load, this difference in efficiency is about 3 KVA per hour. With power costing about $.06 per kilowatt hour, this savings could be as much as $5 per day. In larger installations, the ferro cannot be put in the computer room because of the heat and noise. Tap switchers are quiet and run much cooler.

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Assume a 50% load (7.5 KVA fed from a 15 KVA conditioner):

If 7.5 KVA (out) = 95% efficiency (tap switcher), then 100% (input power required) = 7.89 KVA power required to operate the conditioner and the system.

If we have 7.5 KVA (out) at 65% efficiency (using a ferro device), then 100% input power required is 11.54 KVA.

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 11.54 KVA
- 7.89 KVA
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   3.64 KVA/hour difference X $.06 per KWH = approx. $.21 per hour
        X 24 hours = approx. $5 per day X 365 = approx. $1825 in
        additional energy expense.
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All power conditioning devices must be properly installed. The power input and output leads should be kept separate. There must be a single- point, electrical (not mechanical) ground. Only the critical load should be connected to the power conditioner.

The load on the conditioner should be balanced.

COMPUTER POWER CENTERS

Computer power centers offer many advantages. They are most cost effective with multiple System III/44 or 64 installations. They are a good way to completely eliminate workmanship variables and power system design inter- pretations. They give the DP manager control and monitoring capabilities over the power system. They offer a standardized integration scheme for incorporating safety items. Relocation and upgrades become much easier. Power centers provide the end user with a standard engineered power system which effectively takes care of the majority of power problems--wiring, grounding and transients.

If available, use a dedicated 480 volt feeder to supply the power center. 480 volt services are relatively "stiff" and have a tendency to resist voltage sags. System installation costs can be reduced because the wire and circuit required for 480 volt services is about half the size of those required for 208 volt installations. These feeders should ideally originate at the building service entry. It may be possible to eliminate an additional voltage regulator requirement if 480 volt lines are used.

The powerline feeder will terminate in a J-Box, supplied by the manufac- turer. The power center is then plugged into the J-Box. The power center should contain a copper core, electrostatically shielded transformer (to remove transients), power distribution panels and flexible, shielded, waterproof cables with the connectors attached, and power/voltage/monitor- ing capabilities. Any device in the computer room can be easily relocated without an electrician. New circuits can be added as desired. Safety equipment (halon, emergency power off, etc.) can be integrated in the power system.

All power centers, although they may appear on the surface to do the same thing, are, in fact different. Many engineering differences exist between different vendors which cannot be determined from sales literature alone. Examine various units before making your final decision.

Ensure that your unit can be easily serviced without system shutdown if the power center elecronics should fail. Ensure that the power center has a copper, not aluminum, transformer. Are service contracts available? Is there sufficient room for additional future cables? Who will install addi- tional breakers and cables as your system grows? Will it be necessary to power down to add new circuits (this sometimes has to be done when bolt-in breakers are used)?

Is the unit efficient? Will it add significant heat load to the computer room? Look inside the unit. Are the input and output lines separated to minimize noise transfer? Does the unit construction seem to be of high quality? Does installation and integration of the power conditioner into your existing alarm and sensor system seem as if it will be a straight- forward project?

Computer power centers are an excellent complement (not replacement) for motor-generators and UPS. Some manufacturers now offer units with voltage regulation. A bypass is a must for continued operation should the voltage regulator fail.

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MOTOR GENERATOR SETS

A motor generator (M/G set) consists of an A/C motor which is mechanically coupled to a generator and integrated with the appropriate control cir- cuitry.

M/G sets are very resistant to transients, brownouts, and voltage surges. They contain sufficient mechanical (rotating) energy to "bridge" short-term power outages. An M/G is not an Uninterruptable Power System. When the input power stops, the output voltage will continue to stay up for a short period (typically, 1/4 to 1/2 of a second).

Most power interruptions in the Los Angeles area are short-term breaks-- light flashes. If your requirement is the ability to "ride-through" a short-term power break, and also desire power protection and voltage regulation, an M/G set can be a good selection.

Reliability is important. A properly designd M/G power system should have a "bypass", so that if the M/G set fails, the entire computer system will not have to wait until it is fixed.

M/G sets usually cost about 1/3 to 1/2 of a UPS. M/G sets also have the advantage of slowly "winding down", and preventing the large transient and power surges experienced during power breaks from reaching the critical load.

M/G sets have some disadvantages. The larger units are very loud, and are typically installed in separate rooms. Doors and entryways should be carefully measured before the equipment ships. Floor loading must be checked to ensure that the floor (or roof) can support the weight of the equipment. Bearings may need to be greased and occasionally changed.

M/G sets can be a good solution for customers who need power bridging and have the space and money. They are not a UPS, but they do provide many of the advantages of a UPS. M/G sets are about 80-85% efficient--comparable to most Uninterruptable Power Systems.

M/G sets can be provided with diesel generators to provide power during extended blackouts.

UNINTERRUPTABLE POWER SYSTEMS (UPS)

A UPS provides uninterrupted power for a limited time, after a power interruption.

When the incoming AC power utility fails, the storage battery system pro- vides a source of DC power to the inverter, which in turn provides a source of no-break AC power to the critical load. This "incoming power off" time is limited by the capacity of the storage batteries. Five to fifteen minutes of standby power is usually provided. This will generally provide the user with sufficient time to start an engine generator or other alter- native input AC source. Fifteen minutes is typically the time it takes for the temperature in the computer room to rise to a level where continued operations will be impossible.

After the normal utility power returns, the critical load will contunue to see no-break power and the batteries will be recharged.

UPS is complex and expensive. Large systems usually require the assistance of a consulting engineer specializing in UPS.

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Article 645-3 of the National Fire Protection Code requires specifically for Data Processing Rooms, that a disconnecting means be provided as part of the main service wiring which can be controlled from locations readily accessible to the operators and at the principle exit doors. This "shunt- trip", or Emergency Power Off, or Contactor, when activated, disconnects power to all electronic equipment in the computer area and shuts down the air conditioning. The room lights should remain on.

All computer rooms should have an Emergency Power Off as part of their disaster planning effort.

STATIC

All digital circuits can fail as a result of static discharge. Although the actual currents involved with static discharges are small, the dis- charge voltages developed can easily reach 20,000 volts or more. There are primarily two things which can be done when dealing with static problems. You can attempt to make the device more tolerant of high voltage dis- charges or you can attempt to prevent high voltage discharges from occurring.

Line printers generate static as the hammers strike the paper. As the hammers hit the paper thousands of times, high charges are developed. In low humidity areas, it is possible to generate 500 volts per printed page. Putting 20,000 volts+ on a stack of paper is not uncommon. When that voltage discharges, the results are unpredictable.

Static control can take many forms, but they all have one thing in common--providing some type of conductive pathway to ground is necessary to prevent high voltage from accumulating. Devices commonly used for static control are antistatic sprays, conductive mats and rugs, humidifiers, and tinsel and corona discharge devices. Good grounds are a must for static suppression devices to work effectively.

All these devices work, but some work better than others. Line printer tinsel strips are very common. There is nothing to break, and they are easily checked by visual inspection. A tinsel strip will remove about 90% of the static charge on a sheet of paper. The charges continue to accumulate--they just take longer to manifest themselves. Using a grounded paper stacker with tinsel generally does an adequate job.

Proper power grounding plays an important part in eliminating static. Poor grounding compromises the reference needed by the peripheral. If the static voltage discharges through a poor ground, noise may be generated, which may travel directly to the CPU via the peripheral cable through a CRT. This may directly affect system operations.

BIO SKETCH - ED MUXO

1980 - Present: Founded Computer Power Solutions, Inc., specializing in computer power consulting services and power conditioning equipment sales.

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1969-1972: Field Service Engineer with Burroughs Corporation. Respons- ible for Bank of America data processing center.

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