A GUIDE TO SOLVING POWER DISTURBANCE PROBLEMS RELATING TO COMPUTER EQUIPMENT

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Abstract

The probable causes of power-related problems with computer equipment are identified and explained, and a diagnosis of each effect is given. Recommendations of measures to reduce interference and a guide to selecting suitable equipment to reduce or eliminate the problems are discussed.

Introduction

One of the most common tools found in sugar factories today is the computer. These are used in a variety of applications such as programmable controllers, factory control, weighbridges, data capture and purpose built equipment. However, the most common uses are those of a personal computer (PC) and a local area network (LAN) workstation.

With sophistication and versatility come the problems of reliability and susceptibility to power line problems. Computers need an almost perfect electrical environment in which to operate. It is unfortunate however, that sugar mills do not generally meet this requirement.

Use of a computer in a hostile environment requires shielding and interfacing to separate one from the other as effectively as possible. Adopting the wrong measures will prove not only ineffective but costly. The specific problem must therefore be identified and analyzed before a solution can be found.

Causes of computer malfunction

It is estimated that as much as 95% of computer down time is the result of transient interference. Some years ago two IBM engineers (Allen and Segall, 1974) monitored numerous computer installations for power line disturbances. They divided the disturbances into four categories:

Undervoltage (sag) and overvoltage (surge)

Voltage sag is defined as the period that the supply voltage falls below 90% of the nominal root mean square (RMS) value for a period of a few cycles, i.e. if the RMS value is 22O V, the minimum = 198 V. A voltage surge corresponds to an overvoltage of 10% above the RMS value for a few cycles, i.e. if the RMS value is 22O V, the maximum = 242 V.

Oscillating transients

This kind of disturbance is both hazardous and the most common. It occurs in factories and office blocks and is caused by the operation of lifts, airconditioners, power factor correction equipment, thyristor drives, etc. as well as radiating devices such as two way radios.

In the office or home, interference is caused by airconditioners, fridges, washing machines and cordless telephones. Low frequency oscillations range between 4OO Hz and 5 kHz with initial amplitudes far exceeding the nominal voltage. The oscillations decay rapidly over one power frequency cycle.

Very high radio frequency oscillations (100 kHz - 200 MHz) can be carried through cables and the power supply of computer equipment. These may then be interpreted as data or control commands, with unpleasant results.

Voltage spikes

Spikes are induced in supply lines by lightning and sudden load changes. Load changes that are resistive in nature (as against inductive), i.e. furnaces, geysers, kettles etc. create spikes which can 'add to' or 'subtract from' the power frequency cycle.

The duration of a spike can be up to 0,1 msec and reach levels of thousands of volts. Lightning frequently induces voltage spikes in power lines and data cables from storms that may be some distance away. This phenomenon is more common than a direct strike on cables in the immediate vicinity of a computer system. These induced spikes are normally of short duration with very fast rise times (1 microsecond) and slow decay times (40 microseconds) (Geldenhuys, 1990). During this period they create transient inductions of tens of thousands of volts.

Power failures

Power failures can be categorized into three main types:

- Gradual decrease of voltage over a period of time, i.e. minutes or hours
- Failure of power for a very short period, i.e. when one sees the lights flicker, this is known as a 'brown out'
- A total power failure for minutes or hours.

The mains power supply that has one or more of the above problems is considered capable of causing problems in computers and electronic instruments. These problems may take the form of errors, memory loss, or total shutdown. A breakdown of occurrence is shown in Table 1.

Table 1

A breakdown of power line problems causing computer errors

	Type of problem	Percentage of total problems
1.	Under/Over Voltages	11%
2.	Oscillating Transients	49%
3.	Voltage Spikes	39.5%
4.	Power Fails	0.5%

Steps to avoid problems

There is a two stage approach that can be adopted to help prevent problems. These two stages should be integrated:

- Correct installation procedures
- Correct selection and use of protection devices.

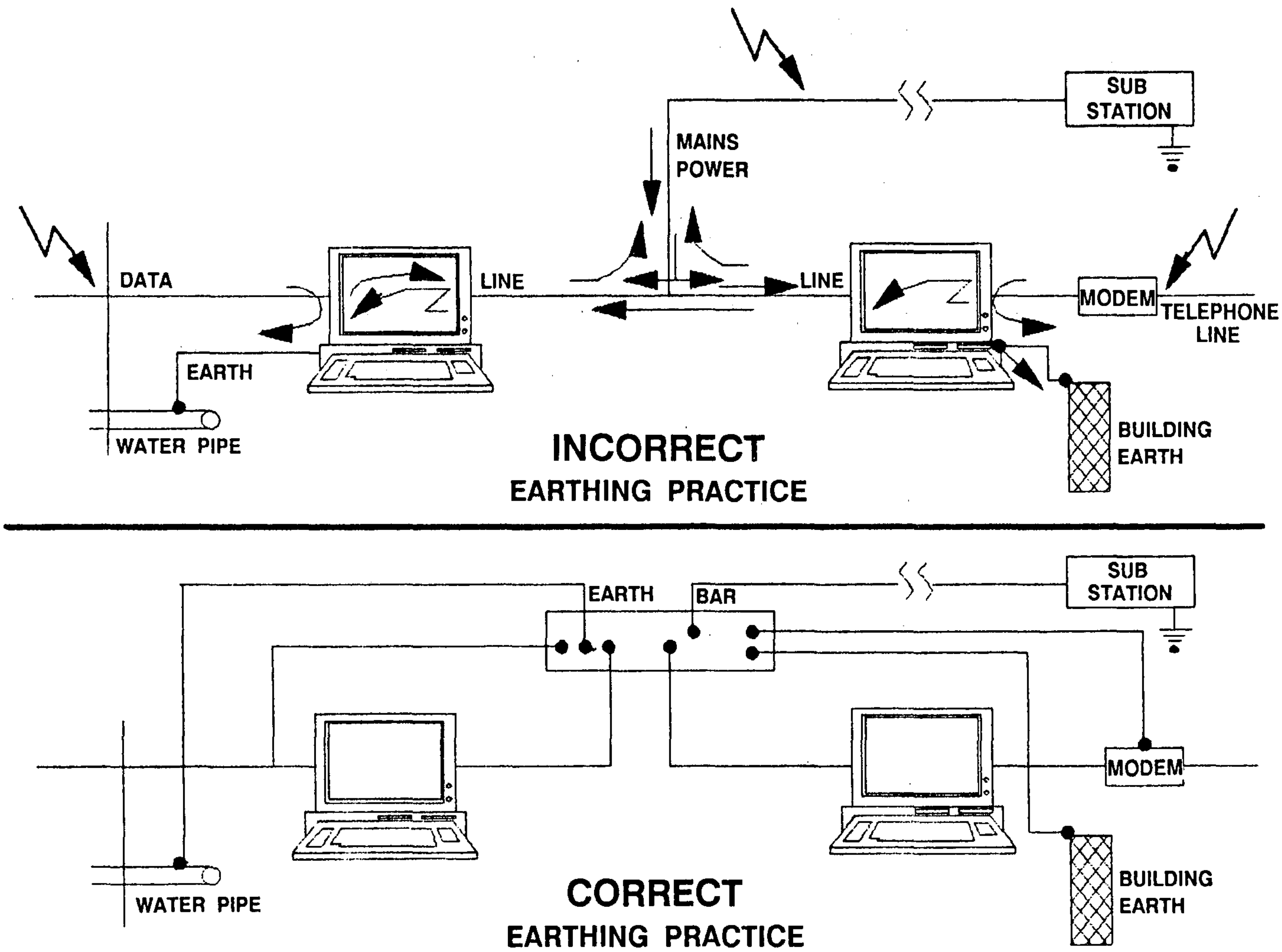

FIGURE 1 Examples of correct and incorrect earthing practices.

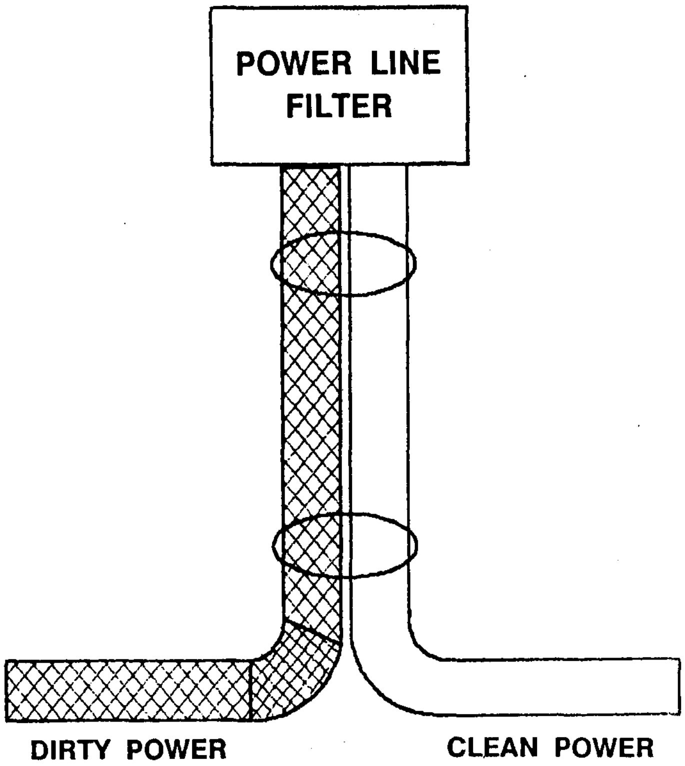

FIGURE 2 Incorrect cabling practice.

Installation procedures

These are as follows:

- All incoming cable shields should be connected to a common earth bar. Ideally this common earth should have a good ground connection, i.e. having low resistance and reactance characteristics. As it may not always be possible to do this, tying all equipment earths together will ensure that the same voltage potential exists at each piece of equipment and will prevent breakthrough from power earth to data ground (see Figure 1).
- Incoming power and data cables should be considered 'dirty'. These cables should not be bound together with cables that have been through a 'cleaning process' as interference can occur between them (see Figure 2) (Geldenhuys, 1990).
- Earth wires should be as short as is practical, and must not be gathered into a coil to take up slack. Insulated earth wire should not be routed in a metal pipe or steel conduit. If it is necessary to use steel conduits, then use bare copper wire (see Figure 3).

Correct selection and use of protection devices

There are numerous 'protection' devices available. They range in cost from a few to thousands of Rand. All of these devices claim to eliminate 'the problem', which they may do to a greater or lesser degree. Quite often the most difficult task is to select the correct protection device to eliminate the problems experienced, at the most reasonable cost.

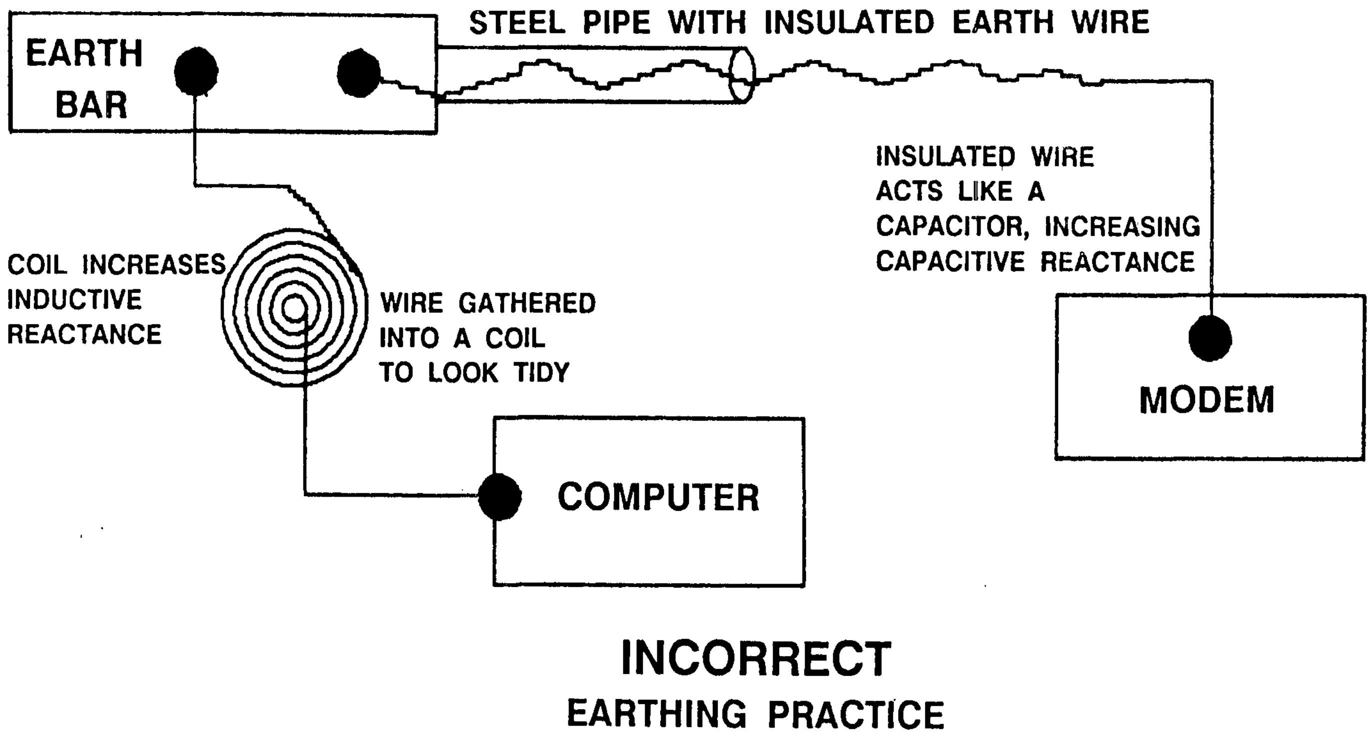

FIGURE 3 Incorrect earthing practice.

Table 2

Effectiveness of protection devices (1 = poor, 3 = good)

Common Power Line Problems	Spike Suppressors	Inline Filters	Isolation or Constant Volt Transformer	Line Conditioner	Standby UPS	Inline UPS
± 10% of Nominal Under/ Overvoltage	1	1	3	3	2	3
Oscillations	1	3	2	2	2	3
> 1 000 Volts Voltage Spikes	3	2	2	3	2	3
Brown Outs	1	1	2	3	3	3
Power Fails > 1 AC Cycle	1	1	1	1	3	3
V A Rating	N/A	330	250	?	350	500
Guide Price in Rands	35	50	900	?	1 500	3 000
Notes	1	2	3	4	5	

To begin, priorities need to be determined:

- If the problem is affecting a home computer the priority may be low
- If a LAN system is used to calculate salaries, the priority is high
- For anything in between these two examples it depends on the value of the data and the status of the user
- The priority of the problem will also determine how much money can be spent resolving it.

The next step is to identify the problem.

Notes on Table 2

Spike suppressors are connected between the line and neutral of a power supply, and normally have a high resistance. If the voltage exceeds a certain value the resistance decreases rapidly, presenting a low impedance path to the transient. The semi-conductor type of spike suppressor is required for computer applications, as the simpler spark-gap type gives insufficient protection.

Spike suppressors take two general forms:

- One is moulded into a 15 amp plug top, distinguishable by the raised bright coloured plastic back holding the suppressors. Note that the life of suppressors is dependent on the severity of the spikes with which they have to deal. When they fail, they burn out. This can be seen by deformation of the plug top, or when computer errors become apparent.
- The other can be mounted into the power distribution panel. This type is more robust than the other due to its size. Certain models of this type incorporate indicators that show whether they are still operational.

The above suppressors have a power dissipation rating determined by their physical size. However this power rating does not limit the size of the power load taken by the protected equipment, as they are connected across the supply lines and not in series with them.

It is important to note that the voltage value on a spike suppressor is the peak to peak and not the RMS value.

Since one spike suppressor plug attached to the cable feeding a multisocket outlet will protect all the outlets, it is not really necessary to have one on each piece of equipment.

Inline filters are most effective for getting rid of oscillatory noise in the high frequency bandwidth of 100 kHz to 200 MHz. These filters must be located close to the equipment they are protecting. Being in line, all load current has to pass through them, therefore consideration should be given to voltage drop and heat dissipation on full load. Earth leakage current is a factor that may also need consideration.

Isolation/constant voltage transformers (CVT) are constructed in such a way that they incorporate static screens and capacitive filtering.

The CVT is designed to run with a magnetically saturated core which acts as a reservoir during sags and surges. These transformers may be individual or incorporated devices. The prevalent characteristic of isolation or constant voltage is determined by link selection in the unit.

General specification is that a maximum 15% voltage input variance will change the output by 2%. They attenuate noise in the 5-500 kHz range, and correct voltage surges and short duration brown outs.

Undesirable characteristics are:

- The output voltage varies approximately 1,5% per Hz change of the input frequency, even with a steady input voltage
- They can induce a large voltage spike into equipment if the machine is on when power is restored to the transformer
- They should be used as close to the rated value as possible for best performance, in which case they run fairly hot and need ventilation
- Both generate fairly strong magnetic fields, therefore the use or storage of magnetic discs/tapes nearby should be avoided.

Line conditioners are devices which use electronic circuitry and magnetics. They approximate the electronic equivalent of CVTs. Their output voltage regulation and attenuation specifications are considerably better than the CVT and do not share the same undesirable characteristics.

Uninteruptable power supply (UPS) is a device that continuously supplies clean power to the load despite sags, surges, noise and power failures on its input.

It basically consists of three parts:

- A rectifier that converts AC into DC
- A set of storage batteries charged by the rectifier
- A converter that is continuously fed by the batteries; this changes the DC back to AC. If there is an input power failure to the UPS the batteries will continue to supply the converter for a given period (usually ten minutes) and ensures the power supply necessary for the computer to be shut down in the required manner.

Standby uninteruptable power supply (UPS)

This is not a UPS in the true sense, as it operates by monitoring the mains voltage. If the mains voltage is within certain limits, it is allowed directly through to the computer.

When the mains voltage moves out of limits, the standby UPS switches over to its own power, which is supplied via internal storage batteries. When the supply voltage returns to specification, the standby UPS transfers the computer load back to mains power. However this is not an instantaneous change-over and may affect certain computers depending on their type of power supply.

Inline uninteruptable power supply

An inline UPS is situated between the incoming AC power supply and the computer load. This forms a barrier which is highly resistant to extraneous spikes and oscillatory noise. Input power failures can be tolerated for extended periods, depending on storage battery capacities and load demand. The device supplies clean and continuous power output to the load.

Selection of a UPS

Points to note in the selection of a UPS are:

- Some UPSs have a square wave or a quasi sine wave output (reduces cost). This is not normally a problem when feeding into a computer which has a SWITCH MODE power supply. However older models of computers, computer monitors and electronic equipment with conventional power supplies could be damaged.
- The overload capacity of a UPS is important. A computer load (especially on older models with large disc drives) is extremely high when switched on, and may reach 200% of normal operation for a very short duration. A UPS should be able to withstand a 150% overload for approximately 10 seconds to overcome start-up surges without causing protection circuits to shut the system down. A standby UPS does not have an initial overload problem as it will be allowing mains power through to the load.
- To determine the size of the UPS required, add all the loads that are to be supported. This figure can be found on the back of the individual item, or in the respective handbook. An XT or AT machine with mono screen, 640K memory and a hard disk normally consumes about 50 to 70 W. An AT machine with one megabyte memory and colour screen takes approximately 100 W. A 500 VA UPS will support up to five monochrome PC workstations. Each work station should be switched on/off separately to prevent massive load variations.

A UPS should contain the following features:

- Over and under voltage protection for its storage batteries
- Visual and resettable audible alarms for power failures and battery supply voltage
- An output signal for incorporation into a local area network supervisory card that enables the system to be shut down in a controlled manner when the batteries are no longer able to sustain the system.

Further points to note in the selection of a standby UPS:

- By allowing mains power through to the load via the incorporated mains filter, severe electrical noise spikes and power surges may be allowed through to the PC load.
- The standby unit switches over to its battery supply when the mains fall below a pre-set value. The unit does not usually switch back to mains supply until this has improved by approximately 5%, therefore long duration sags (over say 10 minutes) become a problem.
- Some standby units monitor voltage and frequency, and switch in accordingly. This compounds the problem of low voltage and unstable frequency supply, causing the standby unit to run on batteries more often.

- Some standby units have a facility to adjust the input voltage operating range, and this may look promising. However, when operated in the mid setting (182-198 V) the computer load may become unreliable at the low end of the input voltage limit. This can occur before the standby supply comes in. At the higher input setting (196-212 V) the standby supply comes in at below 196 V and never switches back to mains power, as it may not rise above 212 V.

  The standby unit will only supply power for a relatively short period, say about 10 minutes at full load, before switching off completely to protect the batteries.
- In computers that do not use switch mode power supplies, automatic change over from UPS to mains and *vice versa* is not recommended. The transfer method used will probably be a mechanical relay, and this is not fast enough to prevent the computer from crashing.

Storage batteries used in UPS systems

The smaller type standby and inline UPS systems normally have their storage batteries built into the unit. These batteries are of a maintenance-free gel type, and can be mounted in any position without leaking. The average battery life is between three and five years and replacement should be of the same type. It is not recommended that motor car batteries be used as an inexpensive alternative as they may corrode equipment due to gassing. They are not designed for float charging and would therefore probably fail within 12 to 18 months.

It is not recommended to use larger capacity batteries than those supplied, nor to add further batteries in parallel to increase backup time as this may overload the battery charger section of the UPS, especially after a long power failure has been experienced.

Recommendations

Power line protection is an insurance against data loss. The cost of this insurance must be weighed against potential loss and inconvenience. Before paying out large premiums in the form of a UPS, the nature of the problem should be established, i.e. spikes, oscillations, power failures etc.

It is recommended that assistance be requested from an electrical or instrument department. Voltage at the point where the computer is to be used should first be measured. As an instantaneous reading may not provide much information, it is recommended that a voltage recorder be used to monitor the voltage over a period. A frequency meter, even a simple panel mount type with a scale of 45-55 Hz, connected at the same time as the recorder will help.

Voltage between the earth and neutral wires should be checked with a volt meter. There should be very little voltage between them (about one volt or less). If it is higher then the supply is unbalanced, the earth wire is damaged, or there may be a bad connection between earth and neutral at the supply transformer. A bad earth is worse than no earth at all, as it creates a false sense of security.

Spikes and oscillations are much more difficult to detect. An oscilloscope may be used in their detection (with an isolation transformer and extreme caution), but to monitor a spike or oscillation as it occurs is virtually impossible. It is possible to hire power line disturbance monitors which will do all of the above and print out a log of problems, with the time of their occurrence. This is most useful when trying to determine where the problems originate.

If the problem is indeterminate, begin with good installation practice. Use spike suppression plugs to feed multiplug outlets. Small inline filters are best used in individual equipment as they stop electrical noise being fed back into the supply from inherently noisy devices such as printers.

If the problem is voltage fluctuations (with stable frequency), spikes and occasional noise, then a constant voltage transformer would eliminate the problem.

It should be noted that none of the above will protect against power failures.

A standby UPS will protect against power failures as well as spikes and, to an extent, noise through the built in filter. As a cost effective answer to a total solution, the standby UPS is excellent. However some units may be unsatisfactory if their supply is too erratic or deviates about 10% from its nominal value for extended periods (e.g. 10 minutes).

An inline UPS is the ultimate answer to power line problems. It isolates the computer or electronic load from the power line problem, thereby eliminating all extraneous noise. Power to the load is continuously maintained even during change over from mains to battery and back again. It should be noted that a standby or inline UPS will safeguard a number of computer loads if it is strategically placed. However the need for good wiring practice should be remembered.

Final comment

Power line precautions may resolve many computer errors, but should not be seen in isolation. Attention should also be given to data line cables, telephone or telefax modems and interdepartmental or interbuilding connections. Lightning is also a hazard to be considered (Calboutin, 1989).

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Glossary

Common mode noise

This is the mode in which interference occurs between the live, neutral and earth wires.

Differential mode noise

This is the mode in which the interference occurs between the live and the neutral wires.

Volt amp rating (VA rating)

The VA rating (apparent power) of a device is equal to the supply voltage multiplied by the current drawn. If the device is resistive with a power factor of 1,0, the VA rating is equal to the true power rating in watts. If the device is inductive (e.g. a transformer) the power factor may be about 0,8, in which case the VA rating will be equal to the true power divided by 0,8.

Switch mode power supply

This consists of a rectifier, an electronic circuit to 'chop up' the direct current at a high frequency and an output transformer to supply the relevant low voltages. It can be fed with an AC or DC supply. Its internal reservoir capacitors are usually sufficient to sustain power output during a change over in input supply, as in the case of a standby UPS.

Conventional power supply

This normally consists of a transformer, a rectifier with capacitors and a series pass element with an electronic regulator. The conventional supply presents a reactive load to a supply device (e.g. a UPS). Its efficiency is fairly low, and it does not have sufficient capacity to tolerate any interruptions of the input supply.

Local area network (LAN)

A LAN consists of a number of PCs connected via a cable. These PCs are connected to a common filing system which is known as a file server. All application programs and data files are stored on this central file server. Each individual PC, or workstation as they are known, completes its calculations and then sends the results to be stored on the file server. The link between PCs enables direct communication and the sharing of expensive peripherals.

Root mean square (RMS)

RMS is a measure of the effective value of a sine wave. It is the value quoted when referring to the AC mains voltage. In South Africa, the RMS (mains) voltage is 220 V. The peak value is the maximum voltage of the sine wave, i.e. 220 V * 1,414 = 311 V.