GE Consumer & Industrial
Power Protection

The Digital World and Electrical Power Supply
A Hypersensitive Imbalance

Contents:

GE imagination at work

A complete failure of utility power is a normal occurrence. A company's power supply may be interrupted briefly or for longer periods of time because of lightning, building work, or network overloading. Electrical power supply companies (EPSCs) cannot guarantee an uninterrupted supply. Many power supply companies promise a reliability rate of 99.997%. This alone means interruptions amounting to 14 minutes a year! It is high time to think about how to survive the next power failure unharmed.

1 UPS systems yesterday and today

Faults in utility power supply cause half of all inexplicable computer problems, whether hardware damage, loss of data or complete system failure. A UPS unit eliminates the problem – but careful, they are not all of the same quality. It is only when the correct system is combined with other important measures that system administrators can keep cool in the face of lightning; self produced power spikes, long or short power failures and other electrical faults.

The nominal voltage of our utility power network is 400/230 V. Most equipment is designed to tolerate an under- or over-voltage of about 15%. Anything higher or lower than this may result in unforeseen malfunction. Light bulbs are an exception; their life span is reduced rapidly if operated with over-voltage. When operated with an under-voltage of 5% they produce only about half the amount of light. Statistics show that most power failures are shorter than 300 ms. Light bulbs flicker briefly but computer systems often suffer considerable damage because data can inexplicably be lost or changed. Such short power failures are especially detrimental to database systems.

Furthermore, it is important to know that the most frequent power problems are not long-lasting power failures but over- and under-voltage, frequency deviations, short sags, or extreme spikes. What many computer specialists don't realise is that these problems are often not caused by the EPSC that is delivering the energy but by other equipment or systems that adversely affect the power network.

This paper will firstly explain the causes and effects of faults in the utility power and secondly the operation of Uninterruptible Power Supplies (UPS). The advantages and disadvantages of different UPS systems will be shown. An important topic will be that of redundant systems – because even UPS units can fail. Finally day and night maintenance needs to be looked at more carefully and here it is possible to use intelligently designed software that can monitor any UPS unit via the Internet.

Originally the use of UPS units was limited to the protection of larger computer network systems. In the last twenty years however the information technology world has undergone far-reaching changes. The emergence and spread of the personal computer gave rise among critical users to a boom in the use of small single phase UPS units. During the last 20 years big computers have been replaced by efficient PC networks. At this point many UPS manufacturers became seriously concerned about the future of medium and large sized UPS units. However, this fear was unfounded. In no time it wasn't enough to have just one computer in the office. Each office worker in the firm would be equipped with a PC and almost every industrial process would be controlled by computer. Hardly any computers would be working independently as they would all be part of a network. It was quickly realised that it wasn't enough to have a UPS unit for each working station and the server. When PCs communicate over a network, files are open. If one computer has a crash the file which is open can be lost even if the power supply of the server is backed up by a UPS unit. It isn't enough to make sure that the server is provided with an uninterruptible power supply. For important work all the computers in the network must be backed up by UPS units. Of course with many PC systems a small UPS unit isn't enough. It also isn't sufficient to provide an uninterrupted power supply for each PC in the network. A computer network also comprises components such as routers and switches. These also need to be included in the UPS system because switches won't work without electricity. Incidentally, switches are also a problem because their network part only bridges minute disruptions in the utility power.

Today we can't imagine our world without computer technology. The sending of data over the internet is important everywhere where computers are being used. More and more firms do their business over the internet. E-Commerce is no longer only for the few big firms. Many smaller ones are also using this new platform, which provides the customer with extra conveniences such as downloading of information and leaflets. If a firm uses e-commerce, it mustn't upset any of its customers through computer crashes. A firm offering quick service in retail, consultation or problem solution can't afford loss of image through computer crashes.

Deregulation of the power market

It isn't long since many European countries completely deregulated their electrical power markets. The intention was to move from the cumbersome state run companies to free enterprise in the production and distribution of electrical energy. Since then, however, disillusionment has set in. These fundamental changes in the distribution of electrical energy have meant that the production of surplus energy has disappeared. There is also hardly any investment in the development of the utility power systems since that only generates cost – not profit. In spite of economic stagnation the amount of electricity used rises annually. Because of this it will be impossible to avoid bottlenecks in the coming years. Many countries have also decided to stop using nuclear energy. However, no one knows how this energy source will be replaced.

In the year 2003 New York experienced a total power failure lasting several hours. The cost of this blackout was estimated at over a billion dollars. The loss of perishable foods alone amounted to 250 million dollars. The blackout in Italy wasn't any less dramatic! How did it happen? On that unfortunate day Italy, the biggest importer of electricity in Europe, had to import 750 MW more electricity than it had foreseen. France was the supplier. The electricity was delivered through the Swiss mountains because there the resistance was lower. The high voltage transmission lines were so overloaded that the heat caused the cables to stretch. They sagged deeper and deeper until they discharged onto a tree thus causing the immediate automatic shutdown of the line. It wasn't possible to reconnect because the Italian power system was now in disarray (acute phase displacement). All the power was now automatically transferred to the remaining high voltage transmission line leading to Italy. However here too due to the overheating there was a disruptive discharge on to a tree leading to the shutdown of that line. After the first breakdown the Italians should have immediately shut down all the pumps of their hydroelectric power stations. Because this didn't happen a chain reaction was unavoidable. The Italian power stations weren't able to meet the demand and so there was a complete breakdown in the power supply. A power system that has completely collapsed isn't so easy to resurrect and so it took many hours until the whole of Italy was again supplied with power.

Why this detailed account? When the deregulation of the electricity market began many years ago the EPSCs didn't really show any interest in redundancy, that is investment in extra capacities of production and infrastructure. However, power consumption has increased during the recent years of economic stagnation. Aside from this it takes years or even decades to obtain permission for new power stations and high-tension power lines. All these factors will lead to the quality of electrical energy supply deteriorating in the coming years. America has already sunk to the level of third world countries in terms of reliability of electrical supply. Experts had long been convinced of this and a study made by the government a short time ago confirmed this situation. In the coming years Europe will also inevitably have bottlenecks and hence more frequent electricity cuts.

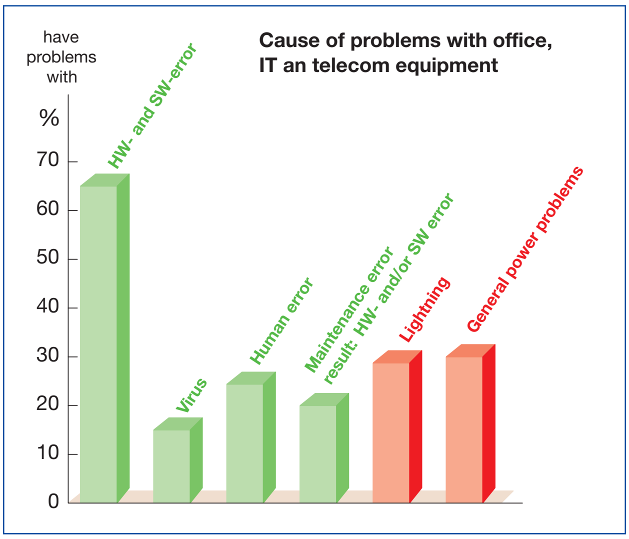
The expectation of cheaper energy through deregulation was made attractive to voters and it was cheaper at first. Since then, however, the trend has clearly changed. The most striking example is Sweden where power prices have doubled. In Germany prices have risen by 9.6% per year following deregulation. New firms requiring a lot of power to operate are now unable to set up business in Amsterdam because the EPCS is unable to

Picture 1 Lightning is a frequent cause of computer crashes.

increase its supply of power. It's a crazy situation when the job opportunities that everyone is demanding are already out of the question because of the power situation. In recent years in China there has been amazing economic growth of almost 10%. There have been power bottlenecks in 24 of the 31 provinces. However China has the advantage of being able to build, at short notice, power stations using fossil fuel. If the demand for power in Europe continues to rise at the present rate over the next 15 years, power stations with a total capacity of nearly 300 GW will have to be built. That would mean building a hundred large nuclear power stations. We should also not forget that some old power stations will have to be closed down. In Germany and other European countries it is practically impossible to get permission even for hydroelectric power stations. Environmental and other organisations campaign against every possible development of the electrical industry.

Attacks from heaven

Lightning is a beautiful natural phenomenon – at least for those of us who aren't afraid of it (picture 1). In a powerful storm, lightning strikes with half the speed of light and heats the air up to 20,000 °C. This heat is four times greater than that on the surface of the sun. The frightening noise – the thunder – is caused by the explosive expansion of the air around the arc. Lightning is a major threat to much modern electrical equipment. Only private people, if they happen to be at home, can pull the plugs out at the first signs of the approaching storm and sit back to enjoy the spectacle. Employees at work should, with clear consciences, be able to work on during the storm. Quite apart from that why should an Italian businessman be affected by a storm in Germany when he is just in the middle of e-commerce business? Meteorologists count approximately 750,000 occurrences of lightning a year in Germany, most of which occur in the months of July and August. This sort of natural phenomenon causes enormous financial loss. UPS units may help to avoid damage generally but not that caused by lightning. For this, lightning and surge protection must be included in the electrical installation. This needs to be done for both the power supply of the UPS and any cables transmitting data to the outside world. Finally there must be good potential (voltage) equalisation in the building combined with an effective lightning trap around the building (picture 2).



Picture 2 Causes of problems with computers and other equipment in offices and industry.

Industry – without electricity nothing works

In order to remain competitive, firms in all western industrial countries must computerise their manufacturing processes. The level of automation has constantly increased and become more efficient. PLC and PC systems are increasingly the order of the day. Industry is of course dependant on a top quality power supply. Critical processes are therefore dependant on a UPS because even the shortest power cut can have fatal effects on the process. There will be rejects and the machine will possibly be damaged if half-finished products get stuck in it. The more sophisticated the automation the more the process depends on an uninterrupted supply of electricity. Complicated networks used to control lighting, blinds, air conditioning, and entry and security systems in buildings also all depend on a continuous supply of electricity. Here too centralised UPS systems which keep at least the essential processes going are increasingly being used.

The consequences of a computer crash

It is surprising to see how careless even large firms are in securing a reliable supply of utility power. They should know how much the success of a company is dependant upon it. A power failure of only some few minutes may have fatal consequences such as:

- Loss of image
- Loss of contracts
- Loss of a customer
- Breakdown of customer service
- Backlog in production
- Loss of operational data

Very important! No insurance covers loss of image or loss of contracts. Also don't forget the loss of working hours caused by a crash of the communication system. Companies asked indicated costs of 13 000 € per hour in the case of system failures and the figure is even higher in the service sector. Many firms who have experienced a serious computer failure complained of months of increased economical difficulties.

To sum up

Before the deregulation of the electricity market, experts warned of difficult times ahead in terms of availability and quality of electrical energy. Their predictions have proved correct here in Europe more quickly than we would have liked. The requirements of the digital world have increased dramatically in the last two decades with regard to the availability and quality of electrical energy. There is a growing imbalance between the need for stable electrical energy and the situation as we have it on the energy market. A disquieting prospect – not for the manufacturers of UPS units though! They can reckon on a growing demand for their products.

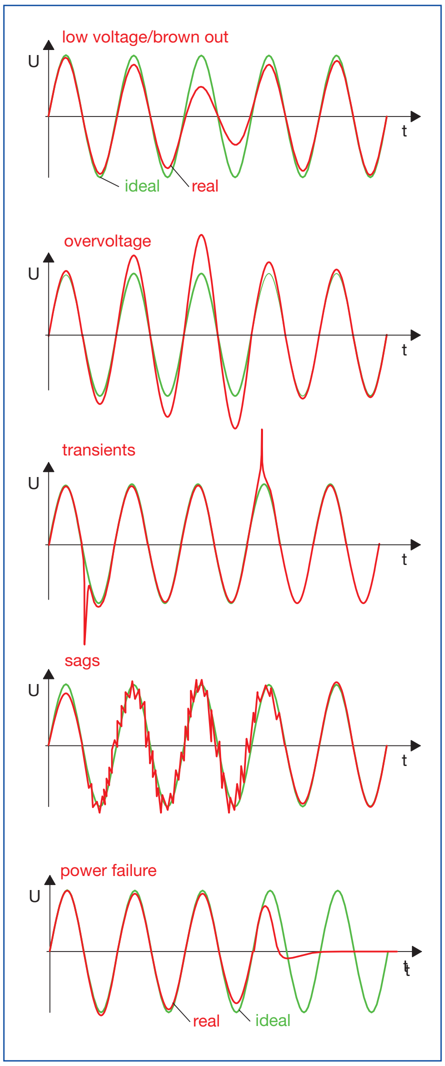
2 UPS technology – separating the wheat from the chaff

There is a wide variety of UPS system architecture. There are simple systems which are capable of providing power until the computer network has been shut down. There are more costly systems which offer a complete galvanic separation from the utility power supply and guarantee that 'spikes' never get through to the computer network and its components. For installations where power interruptions even of milliseconds must never occur – even if the UPS unit breaks down – redundant systems are important. This chapter looks at UPS technology more closely.

Typical problems in the utility power network

Problems are not only caused by power failures. Short interruptions that do not even cause a light bulb to flicker can have treacherous consequences for different sorts of equipment. In computers, network components and telecommunication systems, overvoltage can cause the electronics to become defective. Hidden effects are the most treacherous. In such cases a sensitive electronic device still functions but its power consumption rises, leading to overheating of the element and finally to failure. Picture 3 shows the typical problems in utility power.

Low voltage (brown out)
Approximately 60% of the disruptions. This is the most frequent problem and is usually caused by large consumers of electrical power, not by the user or the supplier.



Picture 3 Frequent faults in the utility power.

Over-voltage
Approximately 20% of the disruptions. It stems from switching operations performed by large consumers and can lead to hardware failure.

Transients
Approximately 8% of the disruptions. Transients (spikes) are extremely short occurrences of over-voltage. They can be several times higher than the rated voltage and get through the power supply units to the equipment, causing faulty transmission of data or leading to hardware failure.

Sags
These considerably distort the ideal sine waves of the utility power. The consequences can be 'inexplicable' system failures or faulty transmission of data. These problems are caused by pieces of equipment that do not draw a cleanly sinusoidal current (light controllers with phase shifting control or

utility power command guiding systems).

Power failure
It is common to distinguish between those failures lasting milliseconds and those lasting minutes or hours. The latter are much less frequent in Northern Europe than the former. Every UPS system must be able to cope with both types of power failure.

What types of UPS are there and how do they function?

What does a user expect of a UPS? It must:

- Bridge power failures for minutes and even hours.
- Protect from over- and under-voltage.
- Keep transients in the utility power from reaching the load.
- Provide failure-free and stable voltage for any kind of load.
- Provide careful recharging of batteries and protection from low discharge.

An important characteristic of a UPS is the signal form it produces. The power plant delivers a pure sine voltage with an effective mean value of 220–230 V and 50 Hz in Europe. America and other countries have 110–120 V and 60 Hz. The operation of simple loads, for example a light bulb, depends only on the mean value and the resulting power. But modern switching power supplies for computers are more demanding and require a much closer approximation to a pure sine voltage. Simple inverters deliver a square wave voltage with peak and mean values that are identical. This can cause a power supply unit to malfunction. An acceptable approximation is a trapezium where the peak and mean values correspond approximately to a sinusoid. The ideal is of course that a real sinusoidal voltage is generated, which is what high quality UPS do.

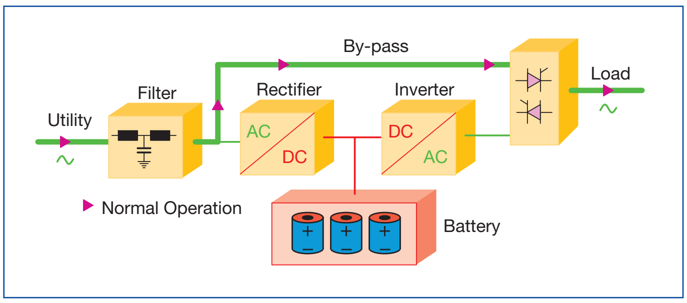
Off-line mode

This is also called standby mode (picture 4). This is the simplest type of UPS. It has two paths for the current. The concept of off-line technology is that when the UPS has utility power, the load is *directly* supplied with utility power voltage. The inverter remains in standby mode stepping into operation only when there is a power failure.

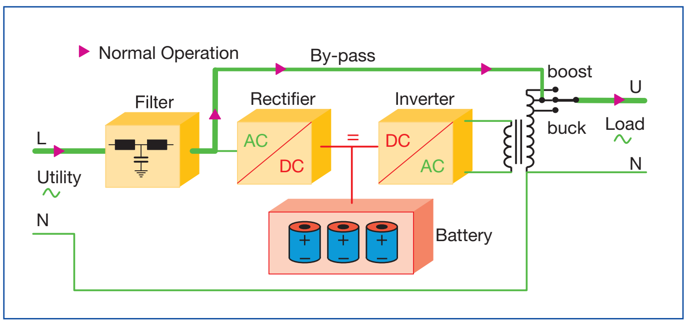
During normal operation (utility power voltage present) this type of equipment does not provide voltage regulation. The consequence of this is that in the case of fluctuation, the UPS must switch into battery operation in order to compensate for the fluctuation. This simple type of UPS is useful for single workplaces especially in private usage, but it should not be used to supply telecommunication equipment, network components or even server systems. The autonomy time ranges from 3 to 10 minutes, and the power range goes up to approximately 3 kVA.

Advantages:

- Reasonable in price.
- High degree of efficiency.



Picture 4 UPS with off-line or standby mode.



Picture 5 UPS with active-standby or line interactive mode.

Disadvantages:

- No suppression of non-sinusoidal injection back into the utility power.
- Short voltage fluctuations have no problem getting through to the load.
- Switching to inverter mode takes several milliseconds.
- Low-cost equipment does not provide sine form voltage when in inverter mode.

Active standby mode

Also called line-interactive (picture 5). This is a refinement and improvement of the off-line mode (see above). During normal operation, the load is supplied directly with utility power voltage from an auto transformer at the output of the UPS. In many countries, the utility power fluctuates considerably depending on the load. The power supply units of computers and also other power supply equipment cannot take a fluctuation of more than ±15%. Active standby technology functions in such a way that a switching device at the level of the auto transformer can make the voltage increase or decrease depending on what is needed. If the supply voltage is too low, the switch turns into 'boost' mode, if the voltage is too high, it switches to 'buck' mode. This correction of the utility power voltage is not very finely tuned and thus – as will easily be understood – not particularly effective. But it has the advantage that the inverter does not need to step into UPS mode with every slight fluctuation of the utility power voltage, thus conserving the batteries.

In the case of a power failure, the switch changes the UPS to inverter mode operation. Then the load is completely supplied by the battery. This technology is often used for small networks and equipment that is not too sensitive. Certain loads, however, do not tolerate the switching time (reaction time) of this type of UPS unit. The autonomy time lies between 6 and 10 minutes, the power range reaches up to 3 kVA.

Advantages:

- The batteries are spared because the UPS does not switch into battery mode until the voltage goes beyond over- or under-voltage.

Disadvantages:

- Switching into inverter mode operation takes several milliseconds.
- Faulty frequencies can only be eliminated in battery mode.

- Low-cost equipment does not provide sinusoidal voltage in inverter mode operation.

Double conversion technology

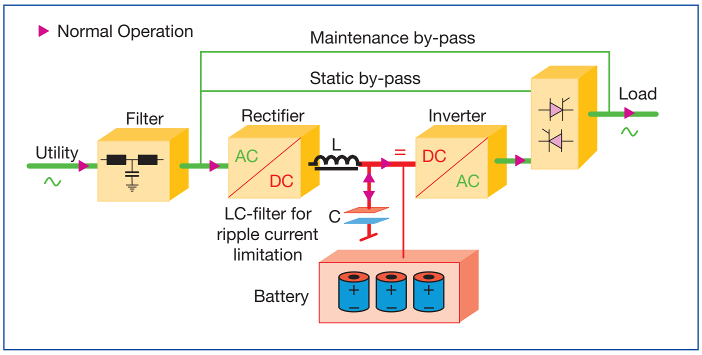
This type of UPS has two elements (picture 6). On the input side, the alternating current is rectified to direct current, which in turn charges the battery. An inverter which is on the output side of the UPS uses this direct current to produce an alternating current with the frequency of 50 or 60 Hz (depending on the user's network). The inverter permanently produces the alternating current. Filters at both input and output end successfully eliminate practically all faults coming from the utility power. Single phase equipment is available up to 10 kVA, three phase equipment up to 1000 kVA. Higher power can be achieved by connecting several UPS units in parallel.

Advantages:
- Steady sinusoidal voltage and frequency at the output.
- A secure protection from over-voltage because of the continuous conversion.
- No substantial switching delay in the case of a power failure. This is very important if sensitive equipment is being used in the area of network and telecommunication technology.
- Well defined and constant conditions throughout the network.

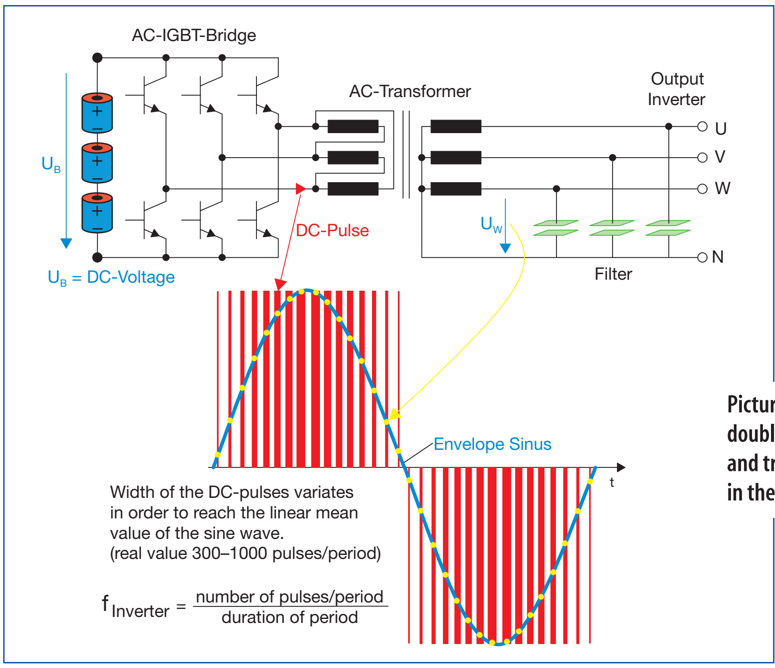
Disadvantages:
- The degree of efficiency of the whole system is low.
- The technology is more complex and therefore more expensive.

Is a complete galvanic separation necessary?

Online and double-conversion technology can be divided up in another way, namely into UPS units with or without galvanic separation. Many users repeatedly ask themselves which technology is the best for their application. Picture 6 shows double conversion technology. The inverter is available with or without galvanic separation. Both types have their advantages and disadvantages.



Picture 6 UPS with VFI or double conversion technology.



Picture 7 UPS with double conversion and transformer in the inverter.

With galvanic separation

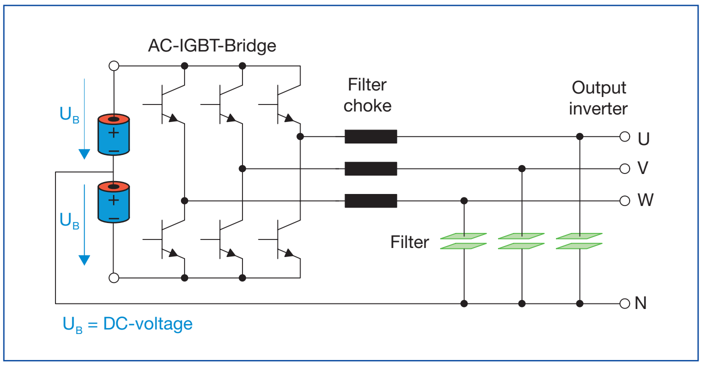
IGBT (Insulated-Gate Bipolar Transistor) transistors generate direct current impulses from the battery voltage (picture 7). One complete sine wave (one full period) is comprised of about 500 individual direct current impulses. Assuming that the output frequency is 50 Hz (duration of one period = 20 ms), it follows that the inverter frequency is 25 kHz.

The width of the direct current impulses varies in such a way that the linear mean value of the envelope corresponds to a sinusoid. This sinusoidal envelope comes from the filtering in the secondary winding in the transformer in combination with the capacitor at the UPS output.

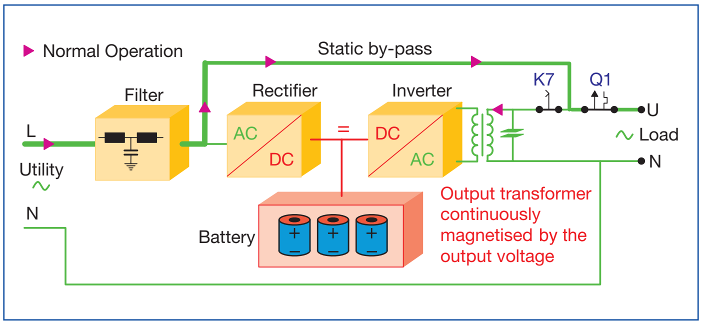
The higher the inverter frequency, the smaller is the physical size of the transformer. If the power stays the same, the size of the transformer diminishes almost in proportion to the frequency. The difficulty consists in finding materials for the core of the transformer which operate with minimal loss due to magnetic hysteresis and eddy currents. Laminated iron cores are problematic above 5 kHz. Ferrite cores are much better but also much more expensive.

Furthermore the capacity of the filtering capacitors at the output end of the UPS drops with higher frequencies. But a high frequency of operation results in better dynamic characteristics of the inverter. The narrower the direct current impulses, the quicker the reaction of the inverter to load jumps. Power supply units of computers, networks, telecommunication equipment and other electronic equipment draw a non-sinusoidal current. In simple inverters the consequence of this is that the curve deteriorates to a trapezoid.

IGBT transistors have the disadvantage of considerable energy loss when operated at high inverter frequencies. In recent years, the frequency has been increased due to the higher quality of IGBT transistors. Power-MOS-FET transistors are used for small power applications. The UPS manufacturer optimises the inverter according to technology and cost. In the area of high power applications it is possible to work with frequencies around



Picture 8 UPS with double conversion and without transformer in the inverter.



Picture 9 Output transformer magnetised by the output voltage, efficiency of 98%, switchover time only 2 ms patented by GE (Super Eco Mode).

12 kHz nowadays, and in systems up to 1 kVA with up to 30 kHz. The critical aspect of this optimisation is that the IGBT transistors must be operated in such a way that they reach a high degree of efficiency on the one hand and maintain a sinusoidal output (despite the non-linear load) on the other. A special quality characteristic of an inverter is its capacity to react to load jumps quickly. Another advantage of high inverter frequency is the fact that frequencies over 15 kHz are practically inaudible for the human ear.

Advantages of the transformer technology:

- The load is isolated from the utility power.
- No direct current in the load.
- Good dynamic characteristics even when non-linear load is connected.
- Good short circuit performance.
- Only one battery voltage needed, the level of which can vary greatly.
- Power capacity up to 1 MVA possible.
- The static bypass can be directly mounted thanks to galvanic separation.
- Fewer components needed.

Disadvantages:

- The transformer is fairly large and heavy.
- Expensive in comparison to a design without a transformer.
- Especially in the low power range the energy loss is high when compared to a design without transformer.
- The realisation of Power Factor Correction (PFC, the current which the rectifier draws at the input is sinusoidal) in the rectifier is more difficult than with the solution without the transformer.

Without galvanic separation

This approach requires the use of two sets of batteries because a double supply of direct current is needed (picture 8). Single phase technology used this approach in the early nineties. The positive half-sine wave at the output is produced by the upper three transistors for all three phases. This is achieved in the same way as in a design with a transformer. The half-sine wave is comprised of direct current impulses of variable width.

It is clear that there is no galvanic separation between input and output. The negative side to this is that the output can be 'contaminated' with a direct current component. This component is caused by the fact that the linear mean value of the positive half-sine wave is different to that of the negative half-sine wave. It is very difficult to rectify this problem and consequently there is always a possibility of a direct current component at the output. This will not harm switched power supply units of computers, networks or telecommunication equipment, but it will harm supply units of toroidal transformers and AC motors. In this design the inverter frequency is higher than in the one with a transformer, lying between 15 and 30 kHz, because it only requires filter chokes.

Advantages of the technology without a transformer:

- Smaller in size
- Less expensive
- Higher degree of efficiency
- Less noisy

Disadvantages:

- No separation of the load from the power supply.
- Direct current component at output.
- If badly regulated, the neutral output line can carry a high current.
- Twice the number of boosters and batteries are needed.
- Limited to units up to 120 kVA.

Which technology is better?

It is pointless to ask this question because both technologies have their advantages and disadvantages. One or the other solution is more appropriate depending on the requirements. This is why leading UPS manufacturers build units with or without galvanic separation in order to meet the varying requirements of customers. However, the customer should make sure he knows which design is being offered to him.

When to use the transformer technology?

- When the load has to be separated from the utility power supply and the battery.
- When the load is sensitive to direct current.
- When the dynamic characteristics of the UPS have to be very good (also in case of high load jumps and short-circuit behaviour).
- When the application does not allow high currents on the neutral output line.

When to use a unit without a transformer?

- When the efficiency of the unit is important.
- When the price plays an important role.
- When the level of noise needs to be as low as possible (inverter frequency inaudible to the human ear).
- When galvanic separation is not mandatory.

- When the load is not sensitive to direct current.

Super Eco Mode

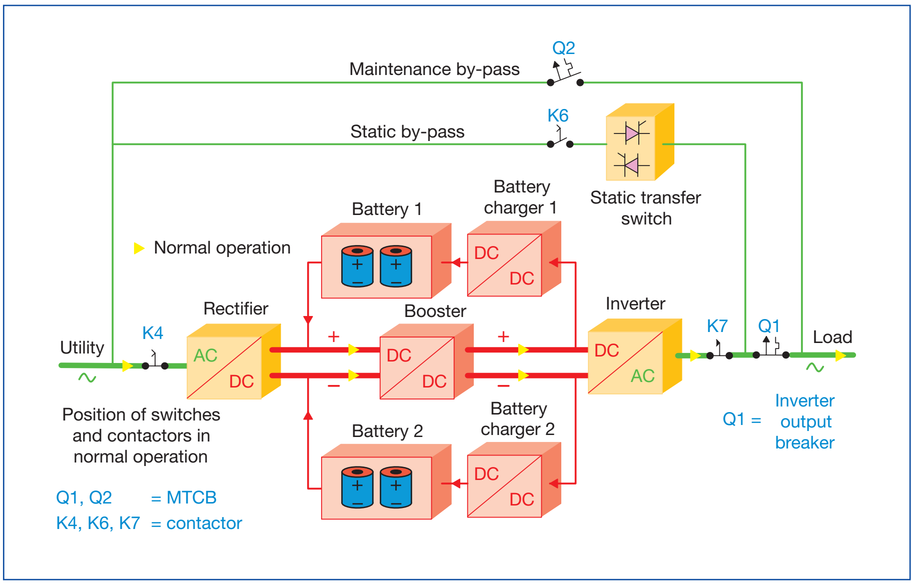
As mentioned previously, UPS units operating according to the off-line system are the most efficient because the utility power is normally led directly to the output via a static by-pass. The U I current on the silicon-controlled rectifier and the energy needed to sustain the charge of the battery are the only losses. The disadvantages of this system were given previously.

UPS units with transformers are naturally less efficient. The transformer alone absorbs approximately 3% of the power at full load and 1% at zero load. For safety reasons, however, UPS with transformers continue to be in use. The pros and cons are provided above.

In many countries in Northern Europe the tension and frequency of the utility power is remarkably stable. Hence it is obvious that the off-line system is the ideal UPS from various points of view. Unfortunately, however, this system does not satisfy the highest requirements regarding safety and stability. For very sensitive loads which do not tolerate direct current at all, users may have to resort to UPS with an output transformer. But such a unit cannot switch instantly from the ‘dormant’ mode of operation to the active one. The problem is the transformer, not the inverter. Even if the inverter can supply the output transformer instantly with the required tension, the load will not receive it instantly. The transformer has inductivity and this delays instant transmission. The delay mounts quickly to 20ms and in addition to that surges of tension are to be expected.

GE’s research division has provided a solution with the Super ECO mode (patent pending). In this system the load current flows in the ECO mode via a bypass as with the off-line system (picture 9), but of course only as long as the tension and frequency of the utility power lie within specified limits. The innovation is that the output transformer of the UPS is being ‘kept primed’ all the time by the load, i.e. kept magnetised. The benefits are as follows:

- If there is a power failure there is merely a drop in tension at the output, lasting less than 2 ms. There is no complete loss of tension.



Picture 10 Schematic diagram of LP 33 Series, trimmed for high degree of protection and highest degree of effectiveness.

- The output transformer and the filtering capacitors of the UPS act in the ECOmode as passive filters and thus improve the load parameters with regard to the utility.
- The inverter is turned off and the rectifier turned on occasionally in order to charge the battery.
- The user is sure that even with the worst case scenario of the UPS there will never be any direct current on the output side, since the unit has an output transformer.
- The efficiency of the unit is around 98% (the additional loss of 1% in comparison with the simple off-line system stems from the energy used for the permanent magnetisation of the transformer)

DSP technology

Analogue technology is nowadays used by well-known UPS manufacturers for the generation of the signal. The processing of the signal, as well as the controlling of the transistors of the rectifier and the inverter, is achieved through a DSP (Digital Signal Processor). DSP technology drastically reduces the number of parts needed since it measures the tension of the three phases as well as the current directly and calculates the width of the impulses of the direct current by way of a complex algorithm transmitted to the IGTB transistors. In this way the reliability of the electronic system is improved, i.e. the MTBF (Mean Time Between Failure). DSP is nowadays so efficient that at GE, for example, the total control of a UPS system is reduced to one single print-out and this print can be used for systems from 10 to 500 kVA. DSP also makes the application of a new technology for UPS possible, the so-called Space Vector Modulation (SVM). This technology makes it possible for only minute drops or rises in tension to occur when the load changes. DSP generates three sinusoid tensions as well as the modulated impulses for the three phases, taking into account the current required by the load in order to control the IGBT transistors. DSP and SVM greatly improve the performance of the UPS, also in the most demanding case of redundant and parallel circuiting of several installations.

The myth of a high degree of power efficiency

A high degree of power efficiency is often used as a sales argument. A UPS in off-line mode, operating normally and directing the current from the utility power supply directly to the ‘protected’ load, obviously has the best power efficiency of approximately 98%. For line-interactive units the figure is 97%. For UPS in online mode the efficiency is 89–96% depending on the size of the unit, this being the real online-degree of efficiency. In systems with transformers the efficiency can reach a maximum of 95%, in those without 96%. The brochures of UPS manufacturers always indicate the highest degree of efficiency. However, the efficiency is dependent on the utilisation of the unit, the power factor of the load, and the input voltage. For example, a UPS unit using the so-called Delta Technology (not explained in this article) has a definitely lower efficiency with non-linear loads, i.e. in the case of poor power factors.

The decision to purchase a certain model must be well thought out because the protection of the equipment connected to the UPS must be given highest priority. The question therefore is: is it worth taking a higher risk in order to save expenditure on energy? The money saved by buying a cheaper unit and saving energy never justifies the risk of damaging, for example, a sensitive server system. Just one single unnecessary shutdown per year (together with the resulting costs) exceeds any saving in energy costs.

To illustrate this, take the example of a large network with approximately 200 computers, including the monitors, printers and other network components, all of which are dependant on a UPS for their energy supply. Let's assume that the network is used for 12 hours per day. For this network a UPS supplying 100 kVA is necessary. At full utilisation and assuming 3% less degree in efficiency there is an additional loss of power of 3 kW. Assuming further that these 3 kW are lost for 12 hours during 365 days per year – which is unrealistically high – the additional cost of energy amounts to 1000 €, if one kWh costs 0.10 €. This then would be the amount saved by choosing a system with a lower level of protection. It would never cover the cost of rebooting a network of 200 computers after a crash. One daren't think of the cost of the time needed to reboot it.

GE's LP and SG Series units – examples of the most up-to-date technology

Taking the example of these ultramodern units, both designed for a power range of 80–100 kVA, let us examine the differences in the realm of technology. The following data is given for a 120 kVA system. Picture 10 shows the schematic diagram of the LP Series Model which incorporates the feature of galvanic separation. Both models satisfy the highest level of UPS standards. They are VFI units, i.e. units operating in online mode. Both can be switched to redundant parallel function by means of RPA (see below) and both are equipped with the Super ECO mode. The LP Series model, however, is a unit without transformer. The SG Series model has a transformer.

The first difference is a purely external one: the LP Series requires 0.52 m^2 ground surface, the SG Series almost double – 0.96 m^2 – which still makes it one of the most compact units on the market. The difference in size is somewhat balanced out when we take into account the number of batteries needed. The LP Series needs forty 12 Volt units, the SG Series needs only thirty.

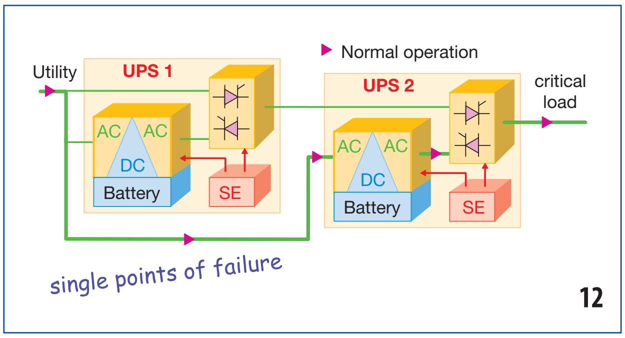
The values of the output tension are almost identical. Both units overcome a load jump of 100% with less than 2% fluctuation of the tension. Both have a total harmonic distortion of less than 3% with 100% non-linear load. There is a small difference in the efficiency of the units: the LP Series reaches 93% in VFI mode and 99% in ECO mode, the SG Series unit reaches 92–98%. This small difference is the price paid for galvanic separation.

At a first glance the two models are similar, both fulfilling the standard range of expectations (pivture 11). Why then does GE offer two models? Just as big car producers offer different ranges of power and comfort, GE has produced two models for the important power range up to 120 kVA. One can view the LP Series model as the open sports car, and the SG Series as the luxury four-door four wheel drive. With the LP Series unit you can add up to four elements in parallel redundant setting – with the SG Series (thanks to SVM) you can add up to eight. Furthermore the SG Series is equipped with a whole range of additional conveniences and safety devices, e.g. redundancy ventilator, optimized soft start, greater capacity of the batteries and a convenient control panel.

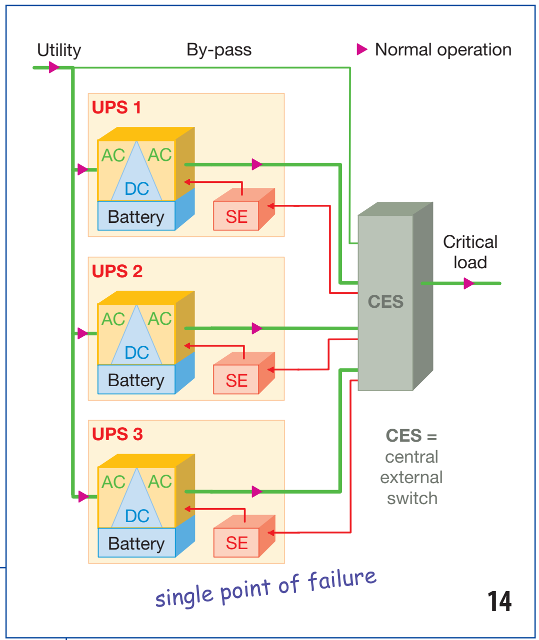
Picture 11 LP Series on the left – an ultra-modern UPS without transformer, SG Series on the right – units with transformers using very little floor space, 120 kVA each.

3 Assess your partner firm – avoid being left in the lurch

The need for upgradeable UPS systems with highest fail-safe record has increased enormously. Computing centres of internet providers, banks, telecommunication companies and all those using large computer networks demand a high degree of availability. Many customers are now less cost-conscious when it comes to power supplies. Yet some firms still entrust their complex server systems to a low-cost UPS. Upgradeability, that is the possibility of adding power and autonomous time, is more and more in demand. On the UPS market GE offers a unique failure-tolerance of N + 1 redundancy.



Picture 12 Cascaded UPS system.



What is a redundant system?

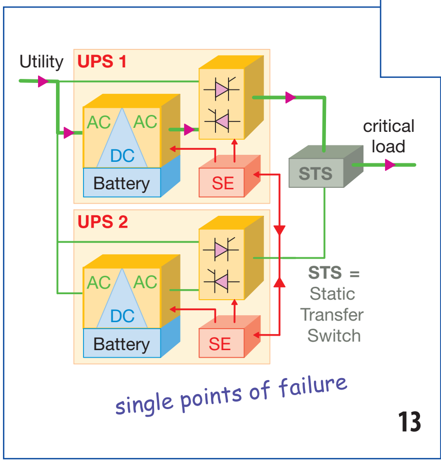
Important business activities and high-tech control systems require an uninterrupted power supply. The installation of a UPS unit makes this possible. Such a unit is made up of electronic components, batteries and mechanical parts, all of which can break down. Hence it is clear that *you cannot depend on a single UPS unit only* when supplying computing centres or other important systems with electrical power.

A redundant system can cope with the failure of one of its parts without normal operation being impeded. An example will help to explain this. An aeroplane used for the transport of passengers has at least two engines. If one of the two fails to operate, the aeroplane must nevertheless be able to fly on to the next airport and land there. In an N + x redundancy, the N stands for the number of units operating in parallel. X stands for the number of units that can fail to operate without affecting the operability of the entire system. In our example we have an N + 1 redundancy. In the case of a plane that has three engines it can lose two and still continue its flight; here we would talk about an N + 2 redundancy.

However, this does not mean that the aeroplane with three engines necessarily has an N + 2 redundancy. If there is one element in the plane upon which all three engines depend then this plane does not have redundancy at all! Here is the problem with most of the global UPS manufacturers. Individual UPS units in parallel may provide redundancy – or may not, depending on whether there is an additional component in the system upon which all the UPS depend. There must not be the possibility of a single point of failure in the system. Because of the importance of this point, several concepts of parallel architecture will be presented, highlighting their advantages and disadvantages.

Picture 13 Parallel system with automatic switch (STS).

Picture 14 Parallel system with external switch.



Hot-standby systems

Here, as picture 12 shows, two UPS units are connected in series. In normal operation, unit 2 takes over the supply of the critical load. If unit 2 fails to operate, it switches to bypass mode and after 2–8 ms unit 1 automatically takes over the supply of the load.

Advantages:
- Reasonable in price since no additional components are necessary.

Disadvantages:
- There are many single points of failure.
- There is no distribution of the load. If one UPS fails then the other one has to take on the whole load. This means that it must be able to cope with an increase of power supply from 0–100% within approximately 8 ms.
- Overload is limited to the capacity of one single unit.
- The MTBF of the whole system is lower than the MTBF of a single unit.
- The loss of energy is relatively high because one unit is only 'idling along'.

Parallel system with automatic switching mechanism

This architecture operates with two or more UPS units as well as an automatic transfer switch (STS static transfer switch). The sensor in the STS monitors the output voltage of each unit and immediately switches to a different UPS (or several) as soon as a failure is registered. Picture 13 shows that the system is not redundant because of the STS. If this component fails then the UPS are of no use.

Advantages:
- When one UPS fails to operate, a different one can take on the load.

Disadvantages:
- There is no distribution of the load.
- Additional expenses: an STS costs roughly what a UPS unit without batteries costs.
- Additional loss of 1% of the energy.
- If the STS fails then the whole system collapses (a single point of failure). The UPS units which actually still work are of no use.

Parallel system with external switching mechanism

UPS normally have an internal switch to change from inverter mode to bypass mode. Some manufacturers situate this switch externally for manual operation in order to facilitate the use of several UPS units in parallel (picture 14). The advantage of this configuration is that there is a distribution of the load and losses are minimal due to the fact that the load current does not run through two switches. Yet it is also clear that the external switch is the critical element in this configuration. If it fails, there is no redundancy. This configuration is comparable to a jet plane with a central hydraulic system. With regard to the UPS units that are aligned in parallel, the system is redundant, but not with regard to the central external switch.

Advantages:
- When one UPS unit fails to operate, a different one takes on its load.
- There is a distribution of the load.

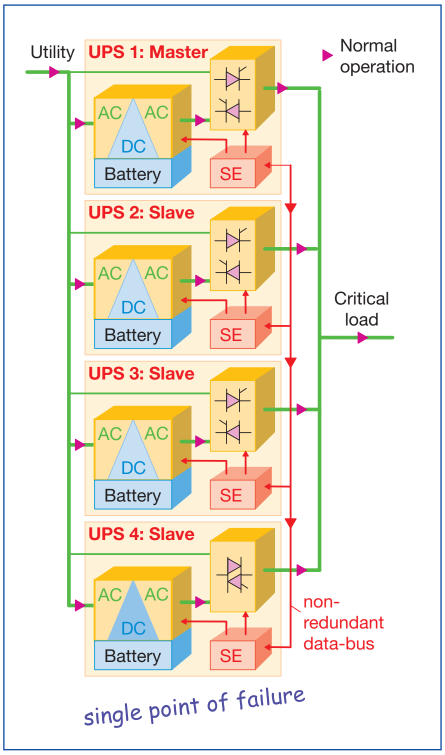
Disadvantages:
- If the external switch (ES) fails (a single point of failure) then the whole system fails. The UPS units which actually still work are of no use.

Parallel architecture with master and slave

In this configuration, one UPS (or special circuitry) takes on the role of the Master and the other units take on the role of Slaves. The Master is responsible for the load to be evenly distributed among the UPS which are aligned in parallel. If one of the UPS units fails to operate the Master automatically redistributes the load to the other Slave UPS. It is clear from picture 15 that this configuration also has its weak points. If the Master UPS fails to operate, then it switches into bypass mode, but if the circuitry that controls the Master unit fails, then the whole set-up is without a Master and therefore no longer controlled. This configuration has at least two single points of failure.

Advantages:
- No casing with an external switch necessary.

Disadvantages:
- If the circuitry that controls the Master UPS fails, the whole configuration is out of control.
- The data bus is not redundant. If it fails, the whole system collapses.



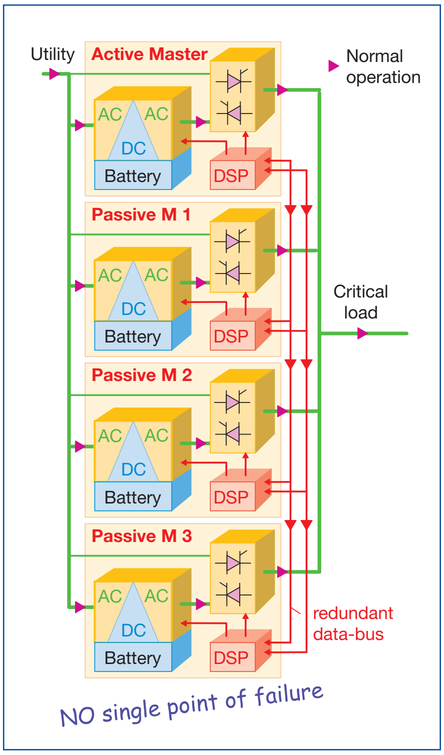
Picture 15 Parallel system without external controls or switch, but with at least two single points of failure.

Real redundancy parallel architecture without a single point of failure

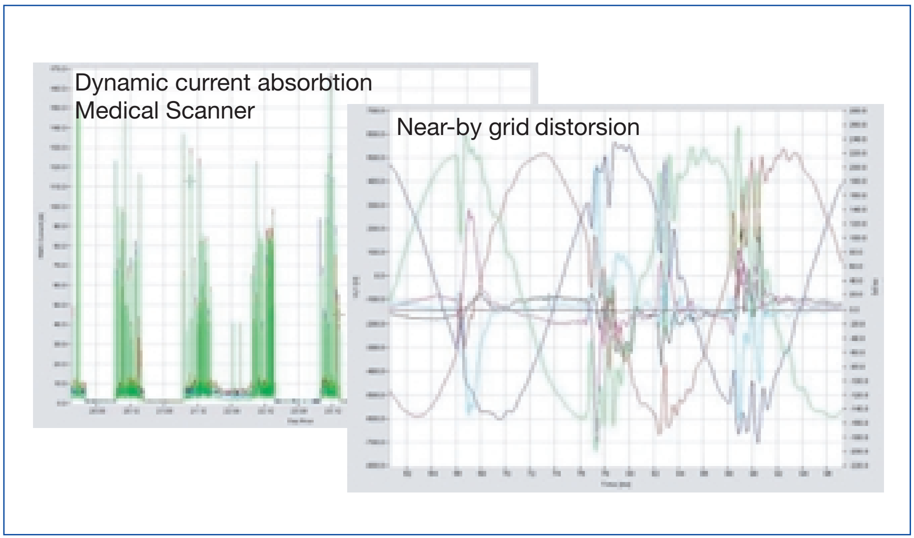
GE is one of few manufacturers on the market producing UPS units with real redundancy. The system is called Redundant Parallel Architecture (RPA). In it there is no need for external electronics or switches to control the UPS in parallel arrangement (picture 16). With RPA, using so-called Active-Active-Technology, one of the UPS in the system temporarily takes on the role of the Master and the others follow, as in a democracy in which one person takes on the role of leadership. However, all UPS have access to all control parameters. The system is equipped with a redundant bus (featured twice) which ensures constant distribution of the load. If one UPS unit fails to operate, the load is automatically redistributed among the other units. If the Master UPS fails to operate, then a different UPS automatically takes on the role of the Master. If necessary, any of the UPS in this democracy can take on the role of leadership.

If there is a need for more protected power, it is possible to simply add further UPS in parallel to the existing ones. Furthermore, a UPS can easily be switched off or another one switched on. And here is the unique feature of GE's RPA: *your critical load is always protected.* As soon as a UPS is switched off, its load is taken over by the other units without the load even 'noticing' a change of voltage. The addition of a UPS unit is a more complex operation. The new unit must first be synchronised with the load voltage, and then the Master UPS must take care of the integration into the whole system requiring a new distribution of the load. In the designs offered by other manufacturers, a change in load distribution necessitates a change into bypass mode. This means that the critical load is connected to the utility power without protection in case of power failure.

The critical point of this GE technology is the exact synchronisation of all the UPS that are aligned in parallel. The reference value is the load voltage, and depending on the load, individual UPS will need to provide more or less current. The supply of the necessary load current is the control-condition reference value. The distribution of the load with RPA technology is so precise that all the UPS in the system provide substantially the same current (it varies by only a few amperes). Finally, the excellent dynamic behaviour of this architecture needs to be mentioned. It guarantees a negligible fluctuation of voltage even in the case of a sudden, big load jump e.g. a short circuit.



Picture 16 GE real, redundant parallel system, without a single point of failure.



Picture 17 Pulsating power consumption of a medical appliance.

The cost advantage of a completely modular system

The need for upgradeable UPS systems with highest fail-safe operation has increased dramatically. Few companies operate without having their own server, quite apart from all the internet service providers, banks, telecom companies etc. All of these need UPS systems. They are ready to invest capital in order to obtain a maximum of operability. Important criteria in the choice of a system are the questions of the expansion of the system later and the length of time that the UPS system can provide power during a power failure. It makes little sense to install an over-specified UPS system just because there might be a need for more power in the future. An over-specified UPS system produces unwanted heat and costs more.

For the above reasons the upgradeability and failure-tolerating N + 1 redundancy is important for sensitive loads. The modular approach also makes for cheaper production and running costs. There are different versions of the modular system on the market such as strict separation of the UPS into individual casings or into drawers in a main casing. Both versions have their advantages and disadvantages, which are not discussed in this brochure. The customer has to make sure that he is given the pertinent information.

UPS – only a part of a safe power supply

In a high-standard set-up the UPS with its set of batteries represents only part of the whole. The quality and correct installation of other parts such as the connection to the mains, the connections to the output, the type of fuses used and the selectivity of the different circuits all play a vital role.

The above points highlight the fact that the UPS is by no means the only element in getting a secure supply of electricity to your critical load. The experience of recent years has shown that integrated solutions are called for. Market research shows that manufacturers of UPS should offer integrated systems in the future. In other words, offering a high quality UPS is no longer sufficient. An overall solution is what is called for. This solution comprises all the parts between the connection to the utility network and the load.

The future: advantages through integrated solutions

If a UPS manufacturer offers an approved overall concept, a whole range of problems is eliminated. Here is an illustration: if you ask an architect to build your house you will get a house that is unique. If you chose your house from the catalogue you'll get something which is well-planned but off the shelf. In this house everything should work. Teething troubles, which one would have to expect in the case of a 'prototype house', should be eliminated. It may be that for your own special house you'll put up with 'teething troubles'. With regard to a secure power supply it is completely different. Here it does not make sense to develop the whole system from scratch again for each new application. For an every-day application this is less important. The parts simply have to be wired up correctly according to an existing diagram. It is rather like putting railway carriages in the right order on the rails. For a complex application, as required in the office or telecommunication sector, the design of an individual power supply system would be a demanding and time consuming job for a highly qualified 'architect'. To go for an individual special solution obviously does not make sense in this case. Here one must go for the proven solution off the shelf – one comprised of tested elements which can be put together in different ways.

Such a system should not only include switch cabinets with excess tension protection, power switches, automatic fuses, input and output connectors, distributors, the obvious UPS unit with its set of batteries, but also a comprehensive control and service programme. Ideally a comfortable design programme greatly simplifies the work of the system designer. The advantages are striking:

- Achieving greater reliability of the whole system.
- Saving through the use of standard modular elements.
- Testing of the entire system beforehand made possible.
- Shortening of the installation time.
- Dealing with only one partner.
- Permanent monitoring, making visual checks unnecessary.
- Discovering potential problems in advance.

Critical loads that overtax an ordinary UPS system

There are extraordinary demands on UPS systems in the area of telecommunication, medicine and also industry. Particularly critical are loads that must under all circumstances be supplied with electricity. Here a redundant system is imperative. But there are also other kinds of critical loads, namely those that draw power in an extremely pulsating manner (picture 17). Medical scanners, computer tomography and x-ray machines fall into this category along with certain machines in industry. These consume large amounts of electricity for short periods of time. On the right in the picture the effect on the utility power can be seen clearly i.e. sags and peaks of tension. These adversely affect the operation of the instruments. It need hardly be said that a power failure in a hospital is extremely critical if some diagnostic process or operation is in progress. Which patient would be pleased about a power failure while he is being examined or while the computer is evaluating his data?

What is the problem in this case? Ordinary UPS systems have great difficulty in supplying loads that use electrical power in a fluctuating manner. Here are the resulting problems: the tension drops sharply and this in turn causes the instrument to work improperly. The simple sort of UPS system may not even be able to supply a current that is higher than the nominal one, not even for a short time. What can the customer do? He could opt for a (highly) over-rated UPS so that it will be able to cope with the fluctuations. However, the problem is not yet solved. For a short interval of time his unit is likely to deliver undertension, because it cannot cope with the dynamics of fluctuation. When a load is switched on, i.e. starts operating, the initial current causes the tension of the UPS to drop, the switching off of the load causes the opposite, i.e. a rise in tension. The other loads connected to the UPS may suffer harm. The European standard EN 50091 for UPS defines variation in tension in terms of dynamic changes of the load. The UPS units of manufacturers which guarantee this standard are, however, far from being able to supply critical medical machines adequately. Class 1 standard allows a drop of tension of 30% during 6 ms while the load rises from 0 to 100%. The same is true for a drop of the load: the tension may rise up to 30% during 6 ms. 30% fluctuation in tension during 6 ms is a lot for average electronic equipment. GE systems offer ten times better values. With a change of load of 100% the tension fluctuates a mere 3%. It is to be noted that greater changes of the load occur with certain medical instruments. It is worth the purchaser's while to make a very careful comparison. A cost comparison alone with a standard unit (which would have to be an over-rated one) simply isn't sufficient. In the medical sector the difference in price is a relatively insignificant one when a high quality UPS is being purchased – it amounts to 3–30%.

How does GE achieve these superior values (compared to EN 50091)? GE achieves them through the use of an inverter with highly dynamic characteristics in combination with special output wiring. In particular through the following three features:

- The output transformer has zigzag windings, thus distributing a change of load on one phase to two phases of the output inverter. For very critical loads an output transformer is usually installed in the UPS unit for safety reasons so that even in the worst case no direct current gets through to the load.
- The output tension as well as the output current are monitored directly and are evaluated with regard to the tendency to change (i.e. in a differentiating manner).
- The highly dynamic SVM technology (Space-Vector-Modulation) is used for the control of the inverter. Most equipment on the market still uses PWM technology (Pulse Width Modulation).

These three measures allow the unit to discern changes of the load ahead of time, and react through the inverter within microseconds. The three features together with elaborate DSP technology (DSP = Digital Signal Processor) have resulted in GE producing a UPS unit with 10 times better dynamic values than those of the European specification for Class One UPS.

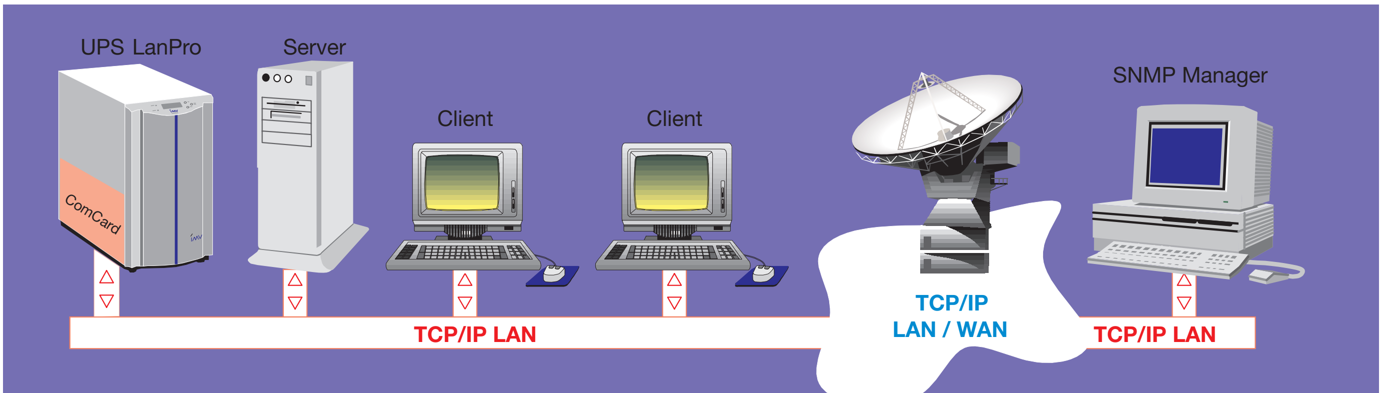
4 Intelligent software makes the difference

Worldwide there are hundreds of UPS manufacturers, but most offer only a very limited range of units. If you start looking for manufacturers who produce units for a few hundred watts up to the megawatt range, the number shrinks to a mere dozen. And if you start looking for companies that offer efficient monitoring and maintenance software, the figure drops to a mere handful of names.

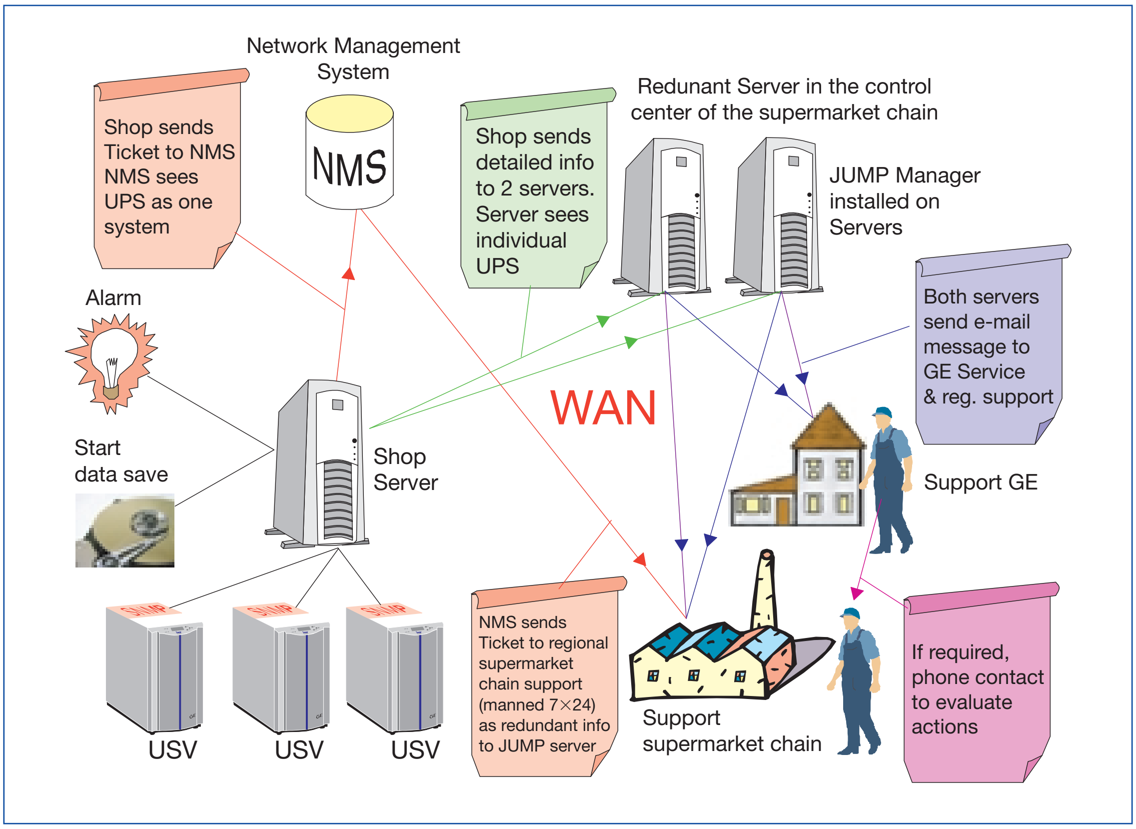
Installing a UPS correctly is one thing. Shutting down all the computers in case of a power failure is another – especially if no one is around. Programmes that are running have to be stopped, open files have to be shut down, and unsupervised systems have to be shut down in a controlled way. When the utility power is on again, the UPS software takes care of rebooting the system again. This is the straightforward task of the so-called shutdown programmes which most UPS manufacturers offer free of charge. The operation becomes more difficult where a complex IT-system with different operating systems and hardware from different suppliers is in use (Multi-Platform and Multi-Vendor). The most difficult case is a decentralised system that has to be monitored by remote control.

Functionality of the UPS software

This is best explained by giving an example. Picture 18 shows in a simplified way the computer/UPS system together with the server and various customers online. By means of SNMP the UPS units are integrated into the IT-network (Simple Network Manage-



Picture 18 Typical network configuration of UPS units and computers.



Picture 19
Supermarket chain with 1000 UPS units, monitored by central remote control.

ment Protocol, a worldwide standard language for the communication between components of IT networks). The UPS jumps into action as soon as the utility power fails.

Taking the example of the GE software 'Suite' the comprehensive functionality is easily understood. The software packet consists of two parts, which can be used individually or together.

JUMP (Java Universal Management Platform) affords high flexibility and wide ranging independence from the differences of the IT operating systems. JUMP jumps into action when the UPS are integrated into the IT network and when an orderly shut-down of the whole system has to be carried out, e.g. open communication links having to be closed.

IRIS (Internet Remote Information System) makes, as the name says, remote monitoring of UPS possible. Wireless systems such as GPRS and UMTS are used to supplement the link through the internet. IRIS has its place when an independent structure for monitoring is needed and when people who are not part of the internal network have to be contacted, e.g. service technicians of the UPS manufacturer.

JUMP will call on the person responsible for the software, IRIS on the person responsible for the technical infrastructure. Both software users can adapt the programme and receive the information in their own language. The person responsible for the software will receive it by means of SNMP right into his network management system (NMS) – the person responsible for the technical side of the set-up will receive it in the form of Volt and kW information.

Big supermarket chains – maintenance of 1000 UPS

A chain of supermarkets may have 1250 shops and 160 restaurants. The entire supply of goods is computer controlled. In total this chain may have 6600 cash points and 2600 computers to support the cashiers in their task. In most of the markets no UPS are planned for the server, the network and the scanner cassettes. If a UPS does not work properly no one is likely to notice it. After all you cannot expect the personnel, in the rush of serving customers, to take notice of a warning signal coming from a UPS. In an individual branch of a supermarket chain it's highly unlikely that someone is responsible for the computers and the software. Therefore no-one will do anything about the problem with the UPS. UPS are there to bridge power failures and these don't happen according to plan – but a faulty UPS will in that situation not be of any use. This calls for a solution. If there is a fault in a UPS or if there is a utility power failure the service centre of the chain would like know what has happened and where (picture 19). Then, when the case arises, the service centre will be able to act, i.e. send instructions to the particular branch. In this way the problem can be solved or the damage limited. Causes for faults in UPS can be high temperature or unauthorised connecting of new equipment. UPS units do require maintenance! The batteries at least have to be checked regularly. To do this for 1250 supermarkets is a major job, requiring personnel. Therefore GE has worked on a system to monitor the state of UPS by remote control thus reducing the number of breakdowns.

All the UPS are connected to the local area network (LAN) by means of a SNMP card. This card gives access to remote maintenance. The UPS reports any fault automatically. The report goes to the regional centre as well as the headquarters of the supermarket chain. In addition, the technical service centre of GE is notified. Depending on the kind of fault reported it will be decided whether a GE technician has to go to site or not. At the moment this particular market chain has 300 UPS of 600 VA–400 kVA in operation, all supplied by GE. In addition to this it has 500 UPS in operation from various other suppliers, all of which will shortly be replaced. The new UPS are fitted with a device which calls the service technician of the market through a visual or audible signal. Thanks to maintenance by remote control and a warning system at the main service centre it seldom happens that one of the UPS in a branch of this chain breaks down.

Level of security	Type of UPS? Characteristics of the UPS?	Protection from what? Used for what?
1	**Off-line:** Dependent on utility power with regard to tension and frequency, switchover time 2–8 ms. Battery operation needed in case of under-voltage. Square, trapezium or sine wave voltage, shutdown and diagnosis software optional.	Protection from power failures, **NO** protection from over-voltage. Single work place.
2	**Active Standby or Line-Interactive:** Dependent on utility power with regard to frequency, over- and under-voltage is adjusted in steps using the auto-transformer. Switchover time 2–8 ms. Square, trapezium or sine wave voltage, shutdown and diagnosis software optional.	Protection from power failures, and from over-voltage. Single workplace and small multiple-workplace situations with network.
3	**Double conversion (VFI):** Double voltage conversion, load-stable sine voltage independent of utility power, quartz-controlled frequency, no switchover time, galvanic separation from utility power.	Protection from power failures and all faults in the utility power, such as over- and under-voltage, distorted frequency and spikes. Server and multiple workplace with network.
4	**Double conversion (VFI) with RPA:** Double voltage conversion, load-stable sinusoidal voltage independent of utility power, quartz-controlled frequency, no switchover time, galvanic separation from the utility power, parallel redundancy, upgradeable with regard to power and autonomy, system exchange without shutdown.	Protection as in **3** with additional system availability thanks to Redundant Parallel Architecture (RPA). Computing centres, internet providers, mainframes, demanding multiple workplace computer systems, very sensitive industrial applications.

5 Other things that users of UPS systems need to know

How can I calculate the correct power requirement for a UPS system? How can the UPS be tested to see whether it actually works when there is a power failure? What maintenance work is required? And last but not least, what set-up suits the needs of my enterprise?

The right choice

Where you have one server with network stations (probably not backed-up by UPS) a unit providing a long autonomy time in the case of power failure doesn't make sense – continuing work is out of the question anyway. What is important is that the components of the network can terminate their application in a controlled fashion before the battery power is gone. Normally a server should be shut down within five minutes of a power failure.

In order to provide a fully automatic shutdown of the above system the right kind of UPS needs to be combined with the right sort of software. This software must be installed on the server and possibly on other computers in the data network. When the server is booted up after a power cut, the batteries are still not recharged. A second power failure could then lead to a tragic collapse of the system. A feature of sophisticated UPS systems therefore is that the load can only be turned on again after the batteries have been recharged.

In computer centres in hospitals, where shutting down the system is not an option, the UPS is mainly there to bridge the time between the beginning of a power failure and the emergency power generator (petrol or diesel) providing (synchronised) power. In this case a few minutes of autonomy time are sufficient, but it must be kept in mind that the back-up system has to provide several hundred kVA of power because the entire installation is running on the UPS.

UPS are available from 300 VA rated power up to 500 kVA. In the case of more complex projects it is advisable to consult a UPS expert. As already stated, computer systems and industrial plants that require a high level of energy availability need a redundant UPS system. The electrical planning of such a project together with software that is needed on different computers requires considerable knowhow. In simple situations the customer can chose the UPS himself. In order to do that he first needs to calculate the power requirement.

What power does a UPS need?

1. The first step is to define all the different loads that will be connected to the UPS. It is important to remember that it is not enough to only connect the server. An operating system such as Windows NT requires that the computers in the network be shut down in a specific sequence if the rebooting after the power failure is not to last hours or even days. It is also clear that the monitors and external accessories such as hard drives, tape drives and active network components like switches or routers must be taken into account.
2. The next step is to determine whether any subsystems need special protection.
3. The complex power S* (VA value) of each piece of equipment is to be determined.
4. Is any system or network expansion foreseen in the not too distant future?
5. The UPS is to be rated according to the addition of all the VA values.

Is the UPS functioning correctly?

Modern UPS units are equipped with an automatic battery test that is performed once or twice a month, but the customer should perform his own test once a year in order to verify the ca-

* Where the active power P is indicated, S is approximately 1,4 × P. The result is the approximate VA value. Or, where the voltage and current consumption is known, then S = U × I.

pacity of the batteries. Customers of GE can leave this to GE specialists who do the test via the internet. A battery test monitors how the battery voltage behaves with time and load. If the voltage sinks too quickly, the batteries are defective. The time taken for the batteries to discharge must not be lower than the specified autonomy time. If this is the case, all the batteries must be replaced.

Is the UPS system adapted to the level of protection needed?

UPS systems must fulfil very different needs depending on the application. In practice different security levels are distinguished in UPS systems. For example there are computer users who simply want to protect their computer from crashing in the case of a power failure. Such users are at the lowest level of security. A highly complex computer network with a central server is at a high security level. This network must remain in operation 365 days a year and round the clock in spite of power failures, and any other problems.

Protection from lightning

A direct impact by lightning is very rare, but the spin-off effects of lightning are devastating none the less. Once lightning current has found its way into the building, the computer network is going to suffer major damage. However, as just mentioned, a direct lightning impact is very rare. Most cases of damage stem from indirect impact, i.e. when lightning strikes somewhere in the vicinity. These can be prevented, because an electrical installation or a computer system can be protected, even from a direct impact. *But this is not possible simply by using a UPS.* Over-voltage because of lightning (far or near) can reach the building via the utility power network, the telephone line or data-cables. In order to protect a building from this, several options are available: a good potential equalisation arrangement, Surge Protection Devices (SPD), and of course a good lightning trap.

And finally

Not all UPS are of the same kind and quality. Many users have had to learn this the hard way. In the case of complex systems in the computer sector and industry in general, basic electrical knowledge is no longer sufficient to chose a reliable – and at the same time adaptable – solution or even to evaluate it. Reliability, professionalism and performance of the manufacturer are at least as important as the technical specification of the system itself.

Article and illustrations
Raymond Kleger, BSc.
Editor of the Swiss periodical
"Elektrotechnik"

GE imagination at work

Digital Energy SA
Via Cantonale 50
6595 Riazzino (Locarno)
Switzerland
T +41 (0) 91 850 51 51
F +41 (0) 91 850 51 44
E gedeinfo@ge.com

Visit us online at:
www.gedigitalenergy.com