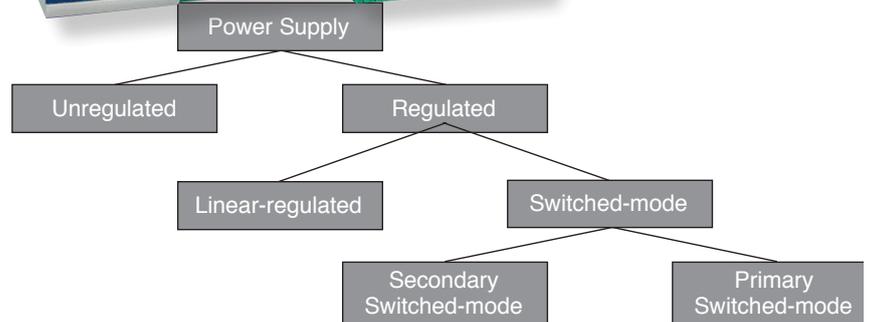


Working with switch mode power supplies in automation applications



A power supply has a decisive influence on the availability and operational reliability of electrical systems.

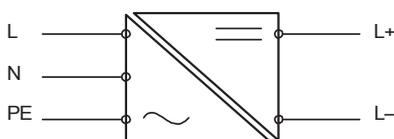
Consequently, the selection of the right power supply should be just as critically and carefully undertaken as that of the other system components.

1. General structure

Regardless of the technology employed, power supplies are devices with an input side and an isolated output side.

Input side

Output side



In technology terms, however, there are two different basic designs:

Unregulated and regulated.

The regulated variants are subdivided into linear-regulated and switched-mode power supplies.

The key criteria in selection of a power supply are: Input side: Output side:

Input voltage

Primary grounding

Current consumption

Inrush current

Input fuse

Frequency

DC supply

Power failure buffering

Power Factor Correction (PFC)

Output voltage

Secondary grounding

Short-circuit current

Residual ripple

Output characteristics

Output current

2. Safety

The safety of people and equipment is always the priority. Accordingly, power supplies must comply with unified regulations and standards.

2.1 Galvanic isolation

Galvanic isolation generally refers to the isolation between two conductive objects, such as metal plates or electrical circuits. In the case of electrical circuits it is consequently not possible for charge carriers to flow from one circuit into another, as there is no electrically conductive connection between the two.

In the case of power supplies this means that there is no electrical connection between the input and output sides.

2.2 Insulation

The different kinds of insulation are specified in IEC/EN 60950:

- **Functional insulation**

Insulation needed for the correct operation of the equipment.

- **Basic insulation**

Insulation to provide basic protection against hazardous structure-borne currents.

- **Supplementary insulation**

Protection against hazardous structure currents if the basic insulation fails.

- **Double insulation**

Insulation comprising both basic insulation and supplementary insulation.

- **Reinforced insulation**

Unified insulation system. Provides equivalent protection to double insulation.

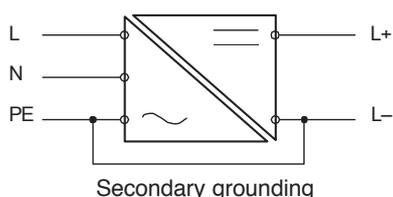
2.3 Safe isolation

Safe isolation according to EN 50178 is required for all interfaces between different electrical circuits, such as between a SELV circuit and a mains circuit.

Safe isolation means that no current flow can occur from one electrical circuit to another. This isolation has to be implemented either by double or reinforced insulation or by means of protective shielding.

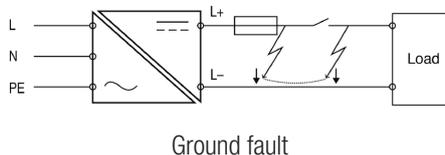
2.4 Secondary grounding

In case of secondary grounding, the output side of the power supply is connected to protective earth (PE) in order to prevent dangerous ground faults.

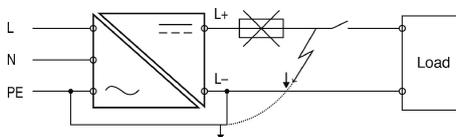


Secondary grounding

A ground fault occurs if a current-carrying line has contact to earth. In the worst case, two simultaneous ground faults can lead to a bridging of switches and thus can start equipment accidentally.



If secondary grounding is used, the occurrence of such a ground fault leads to a so-called short circuit to earth which causes the fuses in the secondary circuit to trip.



2.5 SELV

SELV according to IEC/EN 60950 is a safety extra low voltage, which thanks to its low level and insulation offers better protection against electric shock than higher-tension circuits.

Power supplies generating SELV, for example, must be designed to prevent shorting between the primary and secondary windings and their connections. The windings can only be overlaid if double or reinforced insulation is placed between them. This isolation is termed galvanic isolation.

Grounding of the secondary side is not required but permitted.

The peak value must not exceed 42.4 V in case of AC voltages and 60 V in case of DC voltages.

2.6 PELV

PELV according to IEC/EN 60950 is a protective extra low voltage with safe isolation. In case of PELV, the electrical circuits are grounded and (like SELV) safely isolated from circuits of higher voltages.

The voltage limits are identical to SELV.

PELV is used where active low-voltage conductors or the equipment structures have to be grounded for operational reasons. That is the case, for example, where potential equalisation is required to prevent sparking inside vessels and explosive rooms.

Thanks to the housing earth, hazardous leakage currents can be discharged via the structure independently of the low voltage when interference occurs on other equipment whose touchable conductive parts receive mains voltage.

2.7 Protection class

The standard IEC/EN 61140 defines protection classes for electrical equipment. The devices are classified according to the safety measures taken to prevent electric shock. The protection classes are divided into the classes 0, I, II and III.

- **Protection class 0**

Apart from the basic insulation there is no protection against electric shock. These devices cannot be connected to electrical installations with PE. Equipment of class 0 is not allowed in Germany. Protection class 0 will no longer be considered in future versions of the standard.

- **Protection class I**

In addition to the basic insulation, all electrically conductive parts of the housing are connected to PE. This guarantees that no electric shock can occur in the event of an insulation failure.

- **Protection class II**

Protection against electric shock is not only based on the basic insulation. The housing is equipped with reinforced or double insulation. If the housing is made of electrically conductive material, no direct contact between the housing and current-carrying parts is possible. The housings of class II devices are not equipped with a PE connection. It is important to note that the PE connection is not only used for the grounding of housings but also to connect filters for EMC measures (electromagnetic compatibility) to ground.

This is why even devices of which the housings are completely made of plastic material can be equipped with a PE connection.

- **Protection class III**

The device is operated with safety extra-low voltage (SELV) and thus does not require any protection measures. Power supplies are usually class I or II equipment.

2.8 Degree of protection

According to DIN EN 60529, electrical equipment is classified using so-called IP codes. IP stands for "International Protection" or "Ingress Protection". The IP code consists of two figures: The first digit specifies the protection against accidental contact and against ingress of solid foreign bodies; the second digit specifies the protection against ingress of water.

Since power supplies are mostly installed inside cabinets, their typical degree of protection is IP 20.

3 Input voltage ranges

3.1 Wide-range input

Wide-range input means that the device can be operated with any voltage within the specified limits. Lütze devices operate in the single-phase range from AC 90V to AC 264V or DC 110V to DC 370V and in the three-phase range from AC 340V to AC 576V or DC 480V to DC 820V. There is no loss of power, i.e. the device is able to deliver the specified rated power over the entire input voltage range.

3.2 Autorange

Power supplies that are equipped with autorange behaviour perform an internal measurement of the applied supply voltage and automatically switch between the available input voltage ranges.

3.3 Manual range selection

In case of manual range selection, the housing of the device is equipped with a selector switch for manual input voltage range selection. Lütze offers devices permitting operation at AC 115V or 230V.

The operating voltage range is then

AC 90 V to AC 132 V; AC 185 V to AC 264 V or DC 300 V to DC 370 V.

PROBLEMS DUE TO NETWORK VOLTAGE VARIATIONS

Any power supply is defined by three main parameters:

Input rated voltage

Output rated voltage

Output rated current

About input voltage of power supplies

IEC and EN standards accept network voltage variations within $\pm 10\%$ of the rated value, which varies among the countries that have subscribed IEC-EN standards, as indicated in the following table:

World Wide network voltages acc. to IEC-EN

Single Phase Network

	Rated Voltage	min-max voltage
Europe	230Vac $\pm 10\%$	207 - 253Vac
England- UK	240Vac $\pm 10\%$	216 - 264Vac
USA	120Vac $\pm 10\%$	108 - 132Vac
Japan	100Vac $\pm 10\%$	90 - 110Vac

3 Phase Network

Europe	400Vac $\pm 10\%$	360 - 440Vac
USA	480Vac $\pm 10\%$	432 - 528Vac
USA	207Vac $\pm 10\%$	186 - 228Vac
Canada	575Vac $\pm 10\%$	517 - 632Vac

Rated voltage indicated on the label of a power supply:

IEC, EN, UL standards allows manufacturers to indicate the rated voltage of a power supply in many different ways, but always requires to refer indicated current absorbed by the input to the rated voltage indicated on the label. This is fundamental technical information for an accurate choice of connecting wire gauge and overcurrent protection fuses on AC line by the end user. So if the label gives 100-240Vac, the current absorbed by the input must be related to 100Vac and 240Vac. If the label indicates 120-230Vac, absorbed currents are related to 120 and 230Vac.

We prefer to indicate 120 - 230Vac and related current values, as these voltages are used by a wider number of countries and users than 100 - 240Vac.

The manufacturer must give the final user a clear indication on the min-max allowed input voltage limits of the power supply, and must indicate clearly if there are any output performance limitation related to input voltage variations allowed by IEC-EN, eg a certain output current limitation at 90Vac input voltage. For international IEC-EN-UL standards, any power supply, as any other device, must work within $\pm 10\%$ min-max variations of its rated voltage.

But as there are some technical difficulties in engineering a switch mode power supply that gives the same output performances within a very wide input voltage variations, such as between 90 to 264Vac, the manufacturer is allowed by IEC-EN-UL to reduce the output performances at the limit conditions, eg when input voltage is 90Vac.

The manufacturer must communicate to the end user any performance reduction, with clear technical information on product, or on data sheets or instruction manuals, about conditions or limitations to be applied to rated performance, also called performance derating.

Generally: the higher voltage stresses the isolation values of isolating materials, creepage and clearance distances on air and on PCBs, and isolation between primary and secondary coils of transformers.

The lower voltage causes a current increase on the input stage to keep the same output power, thus losses increase which overheats components and stresses the temperatures limits.

If the manufacturer does not give any specific different information on performances derating regarding either voltage, operating ambient temperature or both, when the mains voltage rises to the maximum allowed value eg. 264Vac or when mains drops to 90Vac, a power supply with an input range of 90-264Vac the device has to provide rated performances.

If input voltage rises over the maximum allowed value : over maximum allowed voltage limit, the input stage might be damaged depending on the value reached by the voltage and depending on its duration ; if a 100-240Vac input power supply is fed with 400Vac for more than a few ms, a failure on input stage is unavoidable.

What fails in this case? If the input of a power supply is fed with a voltage higher than the maximum allowed for more than a few ms, the immediate consequence is the short circuit of the overvoltage input protection Varistor connected between L and N on single phase models, between L1-L2-L3 on 3 phase models, and consequently it explodes or burns. When the varistor is shorted, the AC line overcurrent protection switches off. If the operator tries to switch on the protection, it switches off, or if the fuse is replaced it blows again as the line voltage is connected to the shorted varistor.

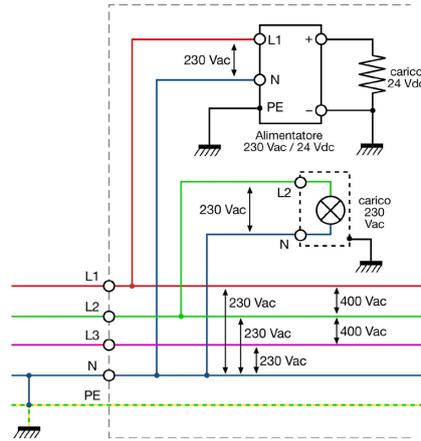
Greater reliability on 3-phase lines

Compared to single-phase power supplies, this series is more reliable in industrial applications.

The input stage uses components with 900V operating voltage, which are more resistant to voltage peaks in industrial power lines, compared to components used in single-phase supplies, whose operating voltage is 550V in high-quality power supplies, but often 400...450V in low cost products.

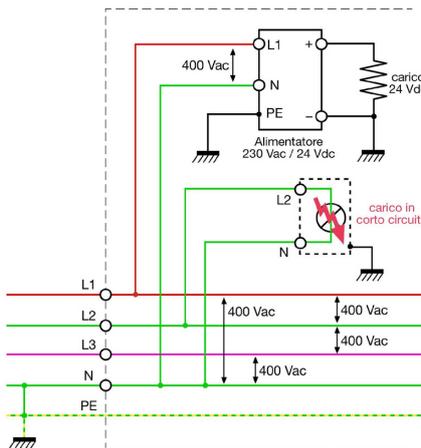
Being able to work from 185 to 550Vac, these power supplies are immune to power failures. At 230Vac input (L1-N), when another device connected to L2-N goes short, the neutral rises up to approx 400Vac, and the input is supplied phase/phase until the protection is activated, which takes place – at best - in 300 ms. This is one of the most common causes of damages to 230Vac single-phase power supplies in industrial applications. Another example of faults in 230Vac single-phase devices powered between phase-neutral is due to the disconnection or accidental interruption of the panel's neutral from the system's neutral: failing to return to the neutral point, the neutral rises up to phase voltage applying approx. 400Vac to single-phase loads, inevitably damaging the system.

Figure 1



Typical application with three-phase network and neutral. The latter is used to obtain a 230Vac voltage in order to supply power to loads (in the example, a simple lamp) and power supplies.

Figure 2



A simple short-circuit on the load causes a rise in the neutral's potential, all the devices connected to it will be powered between two phases, i.e. with a value of approx. 340...400Vac instead of 230 Vac.

How to solve the problem

Use a 3 phase primary // single phase secondary transformer to provide isolation and voltage reduction to get a single phase 120 or 230Vac from a 400 or 480Vac 3 phase line and do not connect the secondary to ground.

Use a 3 phase power supply, where 340-550Vac is the operating voltage.

Use a super wide range power supply with an operating input voltage range of 90-550Vac ; this new technology allows the power supply to continue to work even if it is connected to a single phase line that rises to 500Vac when there is a failure somewhere in the system.

If mains voltage drops under the minimum rated or allowed value

If AC line voltage drops under the minimum value allowed by IEC-EN or by the manufacturer, depending on the value reached by the drop and depending on its duration, the immediate consequences are:

- A shut down of the power supply output
- A high increase of input current
- A ripple increase: the higher the load, the higher the ripple increase.
- A voltage drop of output DC voltage: the higher the load, the higher the voltage drop.
- For switch mode power supplies, the minimum input voltage and full load are the worst working conditions.

Where ripple reaches the maximum value and DC stability is the lowest. Nevertheless, also in such difficult conditions, ripple and stability keeps normally acceptable in good quality power supplies.

If low AC line voltage has a long duration the consequences are:

If AC voltage drops under the minimum allowed value eg some minutes, and if the output is supplying rated current, on the input stage flows a current higher than rated, thus input components overheat and this might cause a failure or an over temperature protection switches off if this function is included, and if it is located to detect input stage temperature.

Minimum line voltage along with maximum output load are working conditions to

be avoided. This can occur as they are consequences of the life reduction of any device. If an isolation-transformer is to be adopted for other reasons, we recommend to choose its secondary voltage corresponding to the higher rated input voltage of the adopted power supply eg. 230Vac.

AC line undervoltage definitions

Undervoltage: when the voltage value is lower than allowed by IEC, EN, UL for a long period of time.

Sag: when voltage drops to zero for some AC cycles

Flicker: low frequency modulated variations of mains under rated voltage

The above events lower quality and performances of electric power and are very frequent in industrial electric systems and can be dangerous for any electronic devices. A poor quality of AC voltage is very often the real cause of the failures of AC powered electronic devices.

Surge (high overvoltage): A high voltage peak, which can be single or multiple (burst) on AC line; surges are due to lightning strikes, failures on power lines, commutations of high current loads, switching off of circuit breakers; when a sag occur, it's often followed by an overvoltage.

How to prevent failure due to surge voltages:

As required by IEC1000... , EN61000-4-2, 4 - 4 , 4 - 5, the input stage of a power supply must withstand 2.5kV surge voltage between the phases, phase and neutral, and 4kV between phase to ground. The surge test applies pulse waveform 1.2/50 (voltage pulse) and 8/20 (current pulse). To withstand such high energy pulses, input stages are usually protected by varistor connected between L-N on single phase power supply and between, L1-L2-L3 on 3 phase.

What happens if a surge is higher than 4.5kV:

Surge currents higher than 4.5kV 8/20 damages the varistors and often the devices.

Solutions:

If frequent failures of input stages of power supply and other AC powered devices are detected, overvoltage protection devices Class C, 10kV 8/20, must be connected between phases and gnd; install the overvoltage protections where the AC line is connected to the AC main terminal blocks of the cabinet ; this is also required by IEC-EN EMC standards that must be applied also to electric systems, control panels and cabinets.

4 Self-protection

In case of overload, the power supply needs to be switched off as quickly as possible.

There are basically two types outside of nominal operation. Overload, which can occur sporadically or continuously, and short-circuit.

Overload means that the current required by the loads exceeds the nominal current of the power supply.

A short-circuit is a special form of overload. In this case, the outputs of the power supply are interconnected at very low resistance, as a result of which the output current may assume extremely high values.

State-of-the-art Lütze power supplies offer the following protective functions:

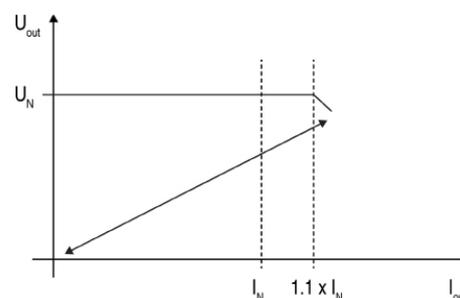
Fold-back characteristic/Hiccup mode

Lütze power supplies supply a current typically up to 1.2 times the nominal output current. They automatically switch off if the current consumption of the connected loads exceeds this value or if a short-circuit occurs. After a defined period of time, the power supply tries to restart the load. If the overload or the short-circuit still exists, it switches off again. This procedure repeats until the fault is cleared. The power supply has "hiccups". In applications requiring high starting currents, it must be ensured that the overload current capacity is higher than 1.2 I_N . To do so, Lütze also offers devices with overload capacity of 1.5 I_N featuring Hiccup mode. Another aspect is response to short-circuit. The output

voltage is cut very rapidly. Whereas the use of conventional line protection equipment in the secondary circuit is very critical in any case, the function under Hiccup mode is not. Electronic overload protection units such as the Lütze LOCC-Box should always be used in such cases. They provide safe protection in all circumstances.

U/I characteristic

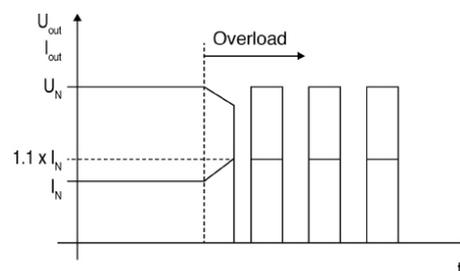
Lütze power supplies with a U/I characteristic perform current limiting to typically 1.2 times the nominal current at constant output voltage. This current is still available in case of an overload or a short circuit. The voltage is slowly lowered, while the output current may rise further (triangular current limiting). Since the current does not sag in case of an overload, this method enables reliable starting of high loads.



Power supply protection against overcurrent and fire risk

If power supplies are not provided with proper protection fuse, they absolutely must be protected providing external overcurrent protections on the AC line.

3 phase power supplies usually are not provided with proper internal fuses, so external protection on the AC line is absolutely necessary to prevent electric shock and fire risk.



Even if the power supply is protected with proper fuse, for safer working conditions it's as well recommended to provide external fuses or overcurrent switches.

Mains cable protection

Even if the power supply is provided with proper input overcurrent protection fuse, AC line cables feeding the device have to be protected to prevent overcurrent through them if their length is longer than 4m from the main busbar (for EN standards); nevertheless, for better electric shock and fire risk prevention, external overcurrent protection of AC line cables is always recommended.

If protection fuse blows

Usually the input of single phase power supply is protected by a fuse to prevent overcurrent and fire risk. Often the fuse blows as a consequence of mains overvoltages that cause failures to input circuitry. In 99% of the cases, a blown fuse is a sure sign of internal failure on input stage, and even if the fuse is replaced normally the power supply doesn't work. If a power supply seems to work after the fuse replacement, it might be stressed by high current and voltage and thus no longer safe for this reason, an internal protection fuse should be replaced by the factory or by authorized and skilled personnel.

Rated Output Current

The current that the power supply can provide keeping all performances and parameters within the manufacturer's data sheet and product approval. Rated current has to be supplied within the min - max input voltage, keeping output voltage no lower than -10% of rated value, below which the power supply is considered to be in "overload protection".

Current and operating temperature

If an output current rating is not referred to the operating temperature range at which that current can be given, it is almost useless.

Current flowing through components, conductors, PCB paths etc., causes a voltage drop. The voltage drop multiplied for the current flowing through the component, gives the power that it dissipates for Joule effect, that causes its temperature to increase above the environmental temperature.

Power supplies operate inside panels and cabinets, where the maximum allowed temperature is 45°C (113°F). So as a minimum condition, rated current has to be referred to 45°C.

NOTICE: Even if some manufacturers declare operating temperatures higher than 45°C (113°F) eg 60°C (140°F), we suggest this information be treated as a 'reliability or ruggedness' statement, because if the device operates for a long period of time at 60°C, this drastically reduces the life of the power supply.

Power dissipated by power supplies increases surrounding air temperature

When a certain electric power is dissipated inside a cabinet, air temperature inside the cabinet increases compared with external air temperature. Air temperature increase gets higher as the dimensions (or volume) of the cabinet gets smaller.

Operating temperature of power supplies

With 25°C (77°F) environment temperature, generally a good and efficient power supply, feeding rated current, has a temperature increase of 25°- 35°C (77-95°F) over 25°C (77°F), so it reaches 50-60°C (122-140°F) at its hottest point.

With 45°C (113°F) air temperature inside the cabinet, the same power supply reaches 70-80°C (158-176°F), which is to be considered the maximum limit for an acceptable life duration of electronic components - eg. life of electrolytic capacitors are rated 105°C (221°F) operating limit temperature, reduces 50% every 10°C (50°F) temperature increase, this is why "the cooler the better".

Overtemperature protection (ovtp)

A circuit that prevents failure, if temperature limits of the components are overheated; ovtp protection is a second back up protection, that works when currents are higher than rated for a long duration, but still under overload protection limit, together with a high environment temperature or reduced cooling conditions.

Ovtp protection can be achieved detecting the temperature on a key component and setting up a point where the ovtp circuit starts limiting output power, or shuts off the power supply.

In the case of ovtp, ovtp protections that shut off the power supply are better than ovtp that reduce output power.

If the power supply shuts off, it makes immediately clear that something is wrong. A power supply where ovtp limits output power

under a certain current, will not feed the system any more, but this only happens after a long period of stress that shortens the power supply's life.

What to do when ovtp protection shuts off the power supply

When ovtp circuit shuts off the power supply, it indicates that working conditions are abnormal. Verify that output current supplied by the power supply is not higher than rated.

Make sure that air temperature inside the cabinet during full power operating conditions keeps within operating limits

Make sure that the temperature of air surrounding the power supply is lower than the limit allowed by the manufacturer; usually 45°C is the limit for continuous operating rated power.

If the power supply is mounted right over a power device eg motor drives, inverters that generate heat, the power supply might be heated by hot air ascending, increasing its temperature instead of being cooled.

The power supply must have 5 cm (2 inches) free space above and below, and 1 cm at the sides.

Clean the power supply from dust to assure free air passages.

Verify the efficiency of the cooling system: Fans efficiency, air filters efficiency etc.

Mains voltage has not dropped lower than the minimum allowed by manufacturer.

Power supplies efficiency

Any electric and electronic device dissipates a certain amount of total absorbed power as heat. This increases the temperature, and therefore increases surrounding air temperature.

A higher efficiency means a lower power dissipation that saves on the costs of electric power and reduces the temperature increase inside cabinets They can work inside smaller enclosures without exceeding the maximum temperature, and finally are more reliable in the same given operating conditions. Today's technology makes it easy to get 90% efficiency on single phase power supplies and up to 94% on 3 phase.

Power dissipated by power supplies

A 100W output power supply with a 85% efficiency, absorbs 117.6W total input power, thus 17.6W is dissipated in heat. Manufacturers usually do not indicate input power, but indicate the efficiency. To calculate the total power and dissipated power:

$$P \text{ dissipated in } W = P_{\text{out}} : R - P_{\text{out}}$$

eg: 100W (output power) : 0.85 (efficiency) = 117.6W total input absorbed power

117.6W (P input) – 100W (Poutput) = 17.6W power dissipated in heat by the power supply.

Power supplies operating inside small cabinets or enclosures

The power dissipated by any electronic device, increases its temperature and increases the temperature of surrounding air.

So, if a device operates inside an enclosure, the temperature inside the enclosure increases.

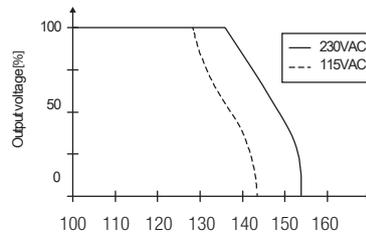
Rule : the smaller the volume of the enclosure with the power supply, the higher the increase of air temperature inside.

Practical parameter: one W dissipated inside 1dm³ (1 decimeter = 10cm) volume enclosure, increases inside temperature 10°C (50°F).

UL508C Power Conversion Equipment standard, makes performance approval tests on devices at 45°C while devices are operating inside an enclosure with a volume that must be communicated by the manufacturer.

When selecting a power supply, its rated current and the current derating versus temperature, must be selected and calculated, considering the final operating volume and the environment temperature of the application, and also the power dissipated by other devices inside the same cabinet.

Consider also, that if a part of or all of the output power of the power supply feeds a load located inside the same cabinet, the power dissipated by the load must be considered as it increases temperature too.

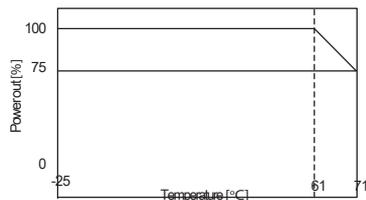


5 Influence of ambient temperature

The ambient temperature has a direct influence on the maximum possible output power of a power supply and so on its response to short-circuit or overload.

Temperatures inside cabinets may be over 60°C as a result of internal or external influences. Power supplies still have to operate reliably even at such high temperatures.

Due to the components used, however, there is a point as from which the output power has to be reduced. That point is described by so-called derating. The Delta series from Lütze is rated for ambient temperatures up to 70°C for example, with derating beginning at 60°C. The reduction in output power is 2.5%/°C.



Example: Derating curve of Lütze of Delta series

6 Thermal protection

When operating a power supply under extreme conditions for a long duration, e.g. in case of permanent operation within the power limits or in case of very high ambient temperatures, the power supply can heat up to a degree where safe operation is no longer guaranteed. There are a number of techniques for protecting the power supply against destruction due to overheating.

- The maximum output power is reduced, allowing the power supply to cool down.
- The device is switched off completely and cannot resume operation until a manual reset is performed. Depending on the manufacturer, the reset is done either using a corresponding switch or by disconnecting the supply voltage.
- The device only switches off the output and does not switch it on until the temperature

falls below a certain limit value. This is the most frequently used method nowadays, and is the one used by LÜTZE.

7 General parameters

7.1 Open circuit resistance

Open circuit resistant power supplies require no minimum load in order to provide a stable output voltage. This is important, for example, in the case of time-critical applications in which a load is applied which has to be immediately supplied with voltage. Power supplies which are not open circuit resistant often require up to the seconds range until an actual supply takes place.

7.2 Resistance to reverse feed

The resistance to reverse feed specifies up to which voltage a power supply is immune against the feeding of voltages into the secondary side. Such a current flow can occur if power supplies are operated in parallel or inductive consumers are connected.

7.3 Overvoltage protection (secondary side)

In case of an internal error of the power supply, this protection mechanism prevents the occurrence of overvoltage on the secondary side that could possibly damage or even destroy a connected load or exceed the SELV voltage limit.

7.4 Power failure buffering

Power supplies must be able to maintain their output voltage for a certain time in case of supply voltage dips. Usually, a power failure buffering time of at least 20 ms is applied in order to provide buffering for one complete cycle of the mains voltage. In the semiconductor industry, a longer time is required. The devices must then comply with the requirements of Semi F47.

8 Line cross-section and protection

8.1 Input-side protection

If power supplies have their own input protection, such as a safety fuse, no further protective measures are necessary. However, standards stipulate that a power supply must be capable of being disconnected from the supply mains by external means. Line protection equipment can then be used. For the relevant characteristics refer to the Lütze data sheets.

8.2 Output-side protection

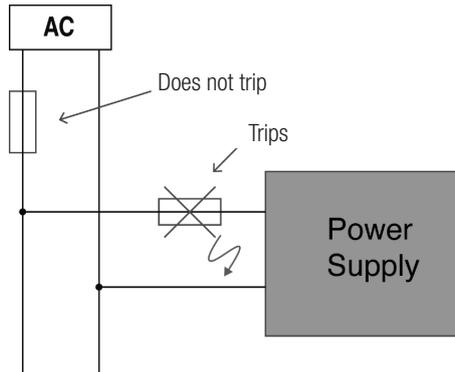
Alongside the output behaviour described in section 4, there is a U/I characteristic with an additional power reserve. However, all these output behaviour modes are ultimately not suitable for safe activation of standard line protection equipment. The reason lies in the technical design of the equipment. Only electronic protection devices capable of reacting fast enough to overload or short-circuit offer a solution. These devices also feature a high degree of repeat accuracy across the entire temperature range. With the LOCC Box Lütze offers intelligent DC protection modules which can also be integrated into field bus communications systems.

8.3 Selectivity

Selectivity means the tripping coordination. In electrical systems, distinction can be made between “series selectivity”, which means that individual fuses connected in series are selective against each other, and “parallel selectivity”, which means that electrical circuits connected in parallel are selective against each other.

Series selectivity

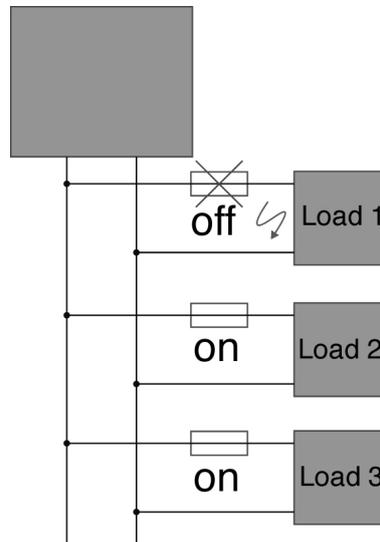
In case of series-connected fuses, the tripping coordination of fuses is considered as selective if only the fuse installed nearest to the fault trips. Fuses that are located nearer to the energy feeding point do not trip. This guarantees that as many system parts as possible remain operative in the event of one single fault, resulting in an increased availability of electrical systems.



Rule of thumb: The fuses must differ by two nominal quantities

Parallel selectivity

Based on the self-protection, the output voltage is switched off or reduced in the event of a fault. If multiple loads are carried on one power supply, a voltage drop will occur throughout the entire application. To prevent this, protective devices are installed in the individual lines to the consumers. If a fault occurs, the protective device concerned must trip fast enough so as to disconnect the faulty consumer reliably from the rest of the system and such that the other consumers remain available.



8.4 Connection cross-sections

The line cross-sections are selected dependent on the maximum output current. The following table provides an overview of the current capacities of multi-core flexible copper cables with different conductor cross-sections at a temperature of 30 °C and up to a nominal voltage of 1000 V (to DIN 57100-523).

Cross-section in mm ²	A
0.75	12
1	15
1.5	18
2.5	26
4	34
6	44
10	61

9 PFC (Power Factor Correction)

Since 1 January 2001, the European standard regarding the limits for harmonic current emissions (IEC/EN 61000-3-2) is in force. This standard defines the maximum allowed intensity of harmonic currents fed back into the supplying mains system. It is applicable for consuming devices with an active power input between 75 and 100 W that are directly connected to the public electricity supply. Power supplies for industrial applications often do not require PFC, since large installations are equipped with a central PFC, installed between the internal electrical system and the public electricity supply.

9.1 Passive PFC

For passive PFC, a reactance coil is connected to the input circuit. This reactance coil buffers energy from the mains and thus reduces the current pulses. The lower the pulses, the less harmonics are produced.

The advantage of this solution is its easy implementation into existing circuitry.

However, the drawback is that it is not able to reduce all harmonics.

9.2 Active PFC

Active PFC is able to deliver considerably better results. In a very simplified consideration, one could say that the actual power supply is preceded by another power supply that performs a regulation of the current consumption from the mains.

This consumption is oriented towards the sinusoidal supply voltage. Using this technology, it is possible to avoid the production of almost every kind of harmonics. However, the circuitry is much more complex than for passive PFC. Lütze power supplies are all equipped with active PFC.

10 Applications

10.1 Parallel connection of power supplies for increased capacity operation

An increase of the output power can be obtained by connecting power supplies in parallel. This can be necessary if the current required by the load is higher than a single power supply can deliver, for example after the expansion of an existing installation. The following preconditions must be met when connecting power supplies in parallel for the purpose of increased capacity:

- Parallel connection is only allowed for identical power supplies.
- The power supplies have to be switched on simultaneously.
- The following points must be observed when connecting the power supplies in order to prevent different voltage drops on the supply lines or at the terminals which would lead to unbalanced load at the common connection point:
 - Identical lengths of the supply lines
 - Identical conductor cross-sections of the supply lines
 - Terminal screws have to be fastened with the same torque to guarantee equal contact resistances.
 - The output voltages of the power supplies should not differ by more than 50 mV in the open circuit state. Otherwise safe operation cannot be guaranteed.

10.2 Redundancy

The term redundancy generally denotes the existence of several objects that are identical in functionality, content or nature.

In industrial automation, redundancy ensures that in the event of failure of a power supply another one takes over the supply, thereby maintaining operation of the system.

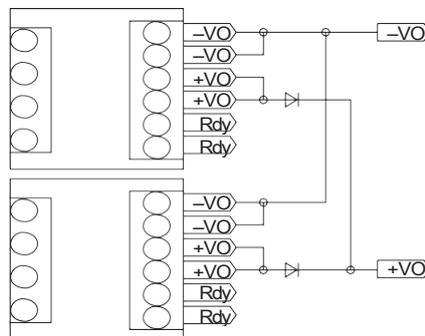
For this the individual power supplies must be isolated from each other, as one faulty power supply might impact on the other one. In the worst case the failed power supply effects a secondary-side short-circuit, which would result in failure of the second power supply. To isolate the power supplies from each other, isolating diodes (so-called O-ring diodes) must be looped into the secondary outputs of the power supplies. They then prevent reciprocal loading. This ensures an uninterrupted power supply. In the Lütze Delta series the isolating diodes are built-in to the output. In the Compact series the diodes must be installed externally as follows:

Lütze offers isolating diodes up to a nominal current of DC50A.

Correct sizing of power supply and fuse elements

Only a carefully designed power supply and fuse concept guarantees reliable protection.

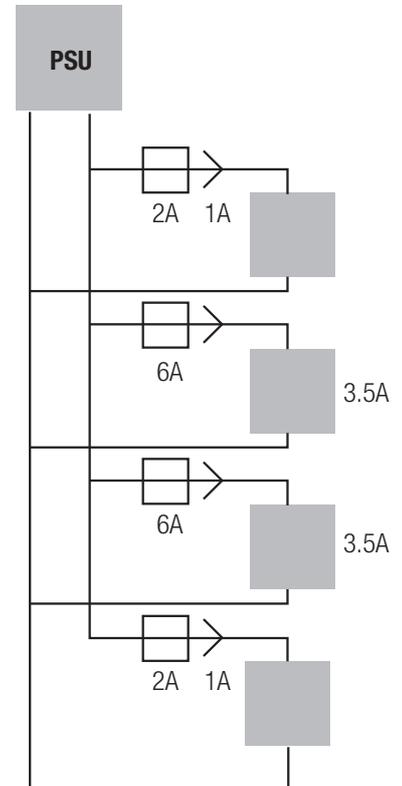
With individually protected branch circuits as shown on the left side of the figure above, the inclination is to underestimate the total power requirement and to choose a too small power supply.



Electronic fuses are usually specified precisely in the tripping current, but normally need 1.5 to 1.8 times the nominal current for a fast tripping. This is an intended behaviour to avoid nuisance tripping in case of short peak current demands (e.g. when a motor starts). The power supply must therefore be oversized for this “extra current” which is needed for a fast tripping in case of a fault in the system. Otherwise, the protective effect and selectivity will be questionable.

What does this mean in practice?

For example, if you have four branches, two requiring 1A nominal current and two others at 3.5A each. Two fuses with 2A and two with 6A would normally be chosen. In normal circumstances, 9A flows where a 10A power supply might be chosen.



If a 3.5A group then suffers a fault or a short-circuit, the 6A fuse requires 9A to trigger. This means that, together with the other three branches, the power supply must be able to supply 14.5A to shut-down the faulty branch.

The necessary current reserve is determined by the fuse with the greatest maximum ampere value and in this case is 5.5A. In practice, a 20A standard power supply would need to be used in this example, even though the nominal current is only 9A.

If a plant is modified, refurbished or extended during operation, there is a danger lurking here. At this time, it is very likely that nobody would think about the required “current reserve” any more, and the power supply is loaded up to the permitted nominal current. In the case of a branch failure, the power supply is then limiting the current before the fuse can cut-out the faulty branch.