Power factor and the uninterruptible power supply
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When specifying a new UPS, its power rating must be well matched to the job in hand or else it could fail just when it is needed. However, picking the correct power rating is not as straightforward as it may seem as, for most applications, the aspect of power factor and load profile will have to be taken into consideration.

Power factor

When power flows into a simple resistive load the power usage is easy to calculate – it is merely the product of the voltage applied and the current flowing into the load. However, when reactive components – such as inductive or capacitive elements – are present in the load, things become a bit more complicated.

Inductive and capacitive elements in a load will store energy for a short time – in magnetic fields (inductive) of in electric fields (capacitive). This energy is then released later in the 50 or 60 Hz cycle. Thus, the energy supplied to the load is used to power the load itself (the "real" or "active" power, expressed in Watts), but also feed these reactive elements (the "reactive" power, expressed in var). In this way, a power larger than that actually consumed by the load to do work may flow out of the UPS and into the load. This power that the load is apparently using is called the apparent power (expressed in VA).

The ratio of the active power and the apparent power is called the power factor. For loads with a lot of reactive elements, this ratio is a small number over a larger one. For loads with low reactive power, the ratio is closer to one (unity), typically 0.95 – 1.0.

However, when specifying a UPS, several different aspects of power factor have to be taken into account.

UPS input power factor – not a problem in a modern UPS

The UPS rectifier has reactive and capacitive components, so will also have a power factor and this will have to be accounted for when making the upstream electrical connection. The UPS input power factor is a characteristic of the design and is usually declared by the manufacturer in the technical specification. With modern IGBT (insulated-gate bipolar transistor) front-end rectifier technology, the input power factor is typically close to unity, 0.99, at 100% nominal load. The actual metered input power factor may, however, be slightly different as, for example, highly nonlinear loads can cause the input power factor to decrease slightly. Typically, though, a UPS input power factor will still be in the range of 0.97 – 0.99 and not of great concern. With older technology, using six- or 12-pulse rectifiers, the THDI (total harmonic distortion of current) and power factor require more attention.
### UPS rated output power factor is a UPS design factor

The rated output power factor describes the maximum active and apparent loading the UPS can tolerate by design. For example, a 100 kVA UPS with a rated output power factor of 1.0 can handle loads up to 100 kW active power and 100 kVA apparent power. If the power factor is 0.8, these loads become 80 kW and 100 kVA, respectively. To correctly select and size the UPS, the total active and apparent power of the load must be known. A UPS with rated power factor of as example 0.8 can handle loads of higher power factor as well – and vice versa.

A UPS will be called upon to support different types of load equipment and these may have nonlinear input stages. The compatibility of the UPS output stage (ie, the inverter) with different types of nonlinear load equipment is usually stated in the product documentation. If not, it must be checked with the manufacturer directly. Note that:

- In cases with high inrush currents or peak currents - eg, motor loads - even the stated range of UPS output power factor does not provide enough detail to determine if the UPS can support the load.
- With static loads, the UPS specification can be used to determine compliance.

The rated output power factor of UPS is not an indication of the quality of a UPS or say anything of its performance capability – it is merely used to state the ratio of the maximum active power versus maximum apparent power. Understanding the critical load profile and load input power factor is the key to making a decision how to specify the UPS power.

### UPS metered output power factor is dominated by load characteristics

Once the UPS has been installed and commissioned, the UPS real output apparent and active power can be checked by measuring them. The real output power factor can then be determined (it may differ from the calculated value, so it is best to check). This metered output power factor of the UPS is a characteristic of the load (not the UPS) and is determined by the design of the load input stages.

The difference between the metered output load and UPS rated load described in the specification tells us how much additional load can be connected before full capacity is utilized. For example, a UPS rated at 100 kVA with a power factor of 0.8 can handle 80 kW of active power. If the UPS output metered load shows 50 kVA apparent power and 45 kW active power then the total metered load power factor is 0.9 (=45/50). A further 50 kVA apparent power/35 kW active power can be connected to the UPS output before full capacity is reached. It is important to note that neither the UPS rated active power nor rated apparent power should be exceeded.
Choosing a rating

A UPS with a rated power factor of 1.0 means that you get equal amounts of kVA and kW out of the unit. With much modern equipment this is a good match as usually the load consumption kVA and kW are similar. However, if the load power factor differs from unity, the dominating limit is the kVA rating, not the kW rating. For example, for a load with a rated power of 80 kW / 100 kVA (power factor of 80/100 = 0.8):

- If the UPS rated output power factor is 1.0, then the UPS rated power needs to be a minimum of 100 kW / 100 kVA (100 = 80 / 0.8).
- If the UPS rated output power factor is 0.8, then the UPS rated power needs to be a minimum of 80 kW / 100 kVA (100 = 80 / 0.8)

Power factor is a major consideration when selecting a UPS. It is very important to understand that if the UPS cannot handle the real power and the reactive power consumed by the load an overload situation will quickly develop that could lead to UPS damage or outage and the critical load becoming unprotected.