Power factor as it relates to UPS products

This white paper is designed to provide clarification about issues related to UPS power factor (pf).

The difference between input and output pf

First, we need to make a distinction between *input* and *output* pf. Input power factor is the load that the UPS presents to the upstream power system, which is something that a UPS designer can control. *Input pf* is a UPS *specification*.

Output power factor is determined by the nature of the loads downstream of the UPS, which is not something a UPS designer can control. Rather, the UPS needs to be designed to handle a range of load power factors. *Output pf* is a UPS *rating*.

UPSs are typically sized by kVA and pf. Multiplying the two gives you the maximum kW the UPS is rated to provide. Notice that if a UPS serves loads above its rated output pf, it will not be able to deliver its rated kVA. Instead, it will run into its maximum kW limit before it hits its maximum kVA limit. Because the kW rating is often the limiting factor (for loads above the UPS rated output pf), many engineers prefer to talk about UPS size in terms of kW, not kVA and pf.

Figure 1 shows kW and kVA limits for a 60 kVA, .9 pf UPS. Notice that below the .9 output pf rating the UPS is kVA limited (we run into the kVA limit before we reach maximum kW) and above the .9 pf rating the UPS is kW limited (we run into the kW limit before we reach maximum kVA).

A UPS comparison

Let us compare two UPSs with different kVA and output pf ratings. UPS #1 is 60 kVA with a .9 output pf rating. UPS #2 is 65 kVA with a .8 output pf. Figure 2 shows the possible kW and kvar (reactive power) limits of both UPSs, similar to a reactive capability curve for a generator. UPS #2 can deliver more kvar (and kVA) at low power factors. With loads above a .8 pf UPS #2 is limited to 52 kW while UPS #1 can serve loads up to 54 kW. Many modern critical loads are above a .9 lagging power factor so it is important to focus on the kW capabilities of your UPS rather than the kVA rating.

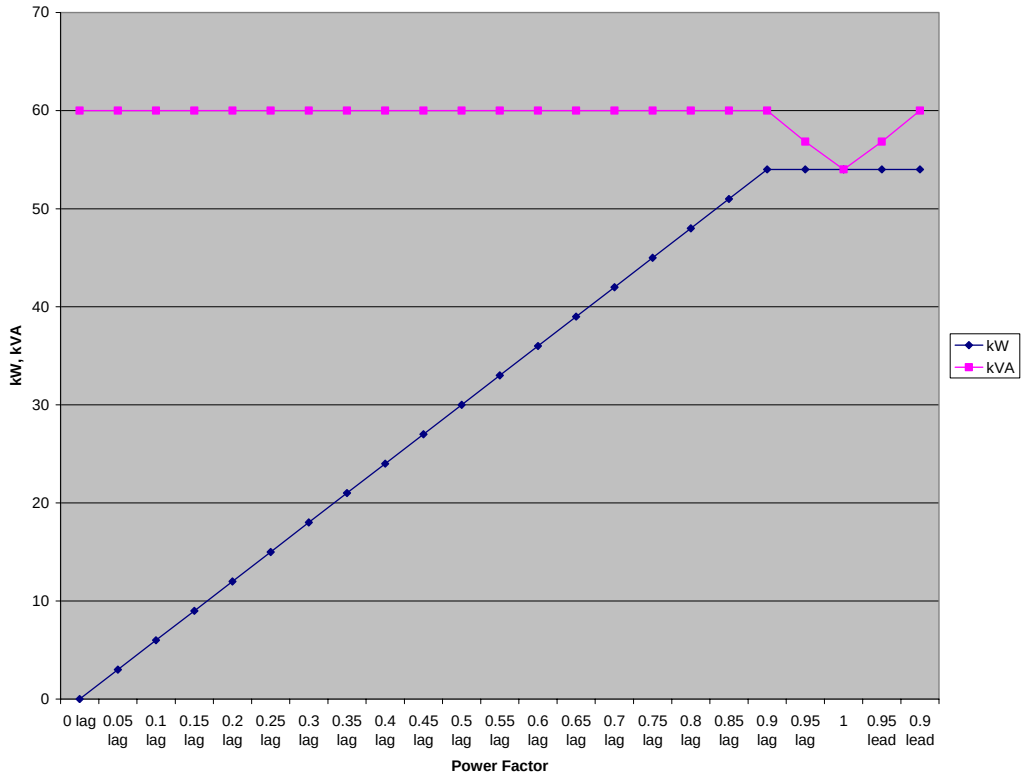

Figure 1. Comparison of kW and kVA limits for a 60 kVA, .9 pf UPS

Notice also that we have drawn these UPS capability curves up to a .9 leading power factor. Powerware® UPSs can deliver their rated kW up to .9 leading power factors without de-rating. This is not true of all UPSs. This topic is discussed further in another white paper from Eaton® entitled *Considering the effects of UPS operation with leading power factor loads*.

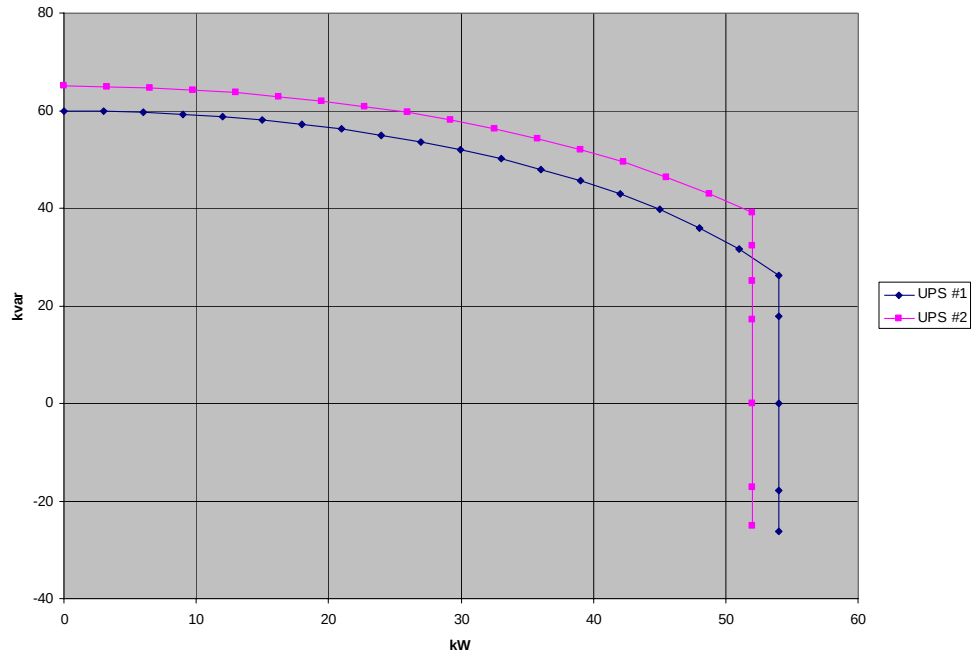

Figure 2. UPS capability curve comparison

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A specific UPS example

Let's look at a specific UPS, a Powerware 9390. The input pf is specified at 0.99 (minimum), which means basically unity pf (kW ≅ kVA). Combined with the low input current harmonics (THD < 4.5%), this UPS is a very low impact load, which is an important consideration especially when serving the UPS with backup generators.

The nominal output pf of the Powerware 9390 is 0.9 lagging. It can serve up to 0.9 pf leading loads without de-rating. With a unity pf load, a 100 kVA Powerware 9390 can only carry 90 kVA (90 kW). With a 0.8 lagging pf load, a 100 kVA Powerware 9390 can only carry the full 100 kVA, which is only 80 kW.

The difference between input and output pf also plays a role when sizing input, bypass, and output wiring and breakers for the UPS. Appendix A of the Powerware 9390 Installation and Operation manual gives nominal maximum input, output, and bypass currents and corresponding recommended breaker sizes.

One might expect the input current to be significantly larger than the bypass or output current, to account for the additional power sometimes required to charge the batteries. For the same reason, the input breaker would be expected to be larger than the bypass and output breakers. However, the actual input currents are only slightly larger than the output currents. Due to the higher input pf, the UPS needs less current to deliver the same amount of kW. Because the currents are fairly close and because on the bypass and UPS output a UPS designer may slightly oversize the breakers to handle downstream inrush, the recommended input, bypass, and output breakers are the same size.

Consider a 100 kVA, 480V Powerware 9390 UPS. Input current plus charging current is 130A. Full load current, applicable to both the bypass and UPS output paths, is 120A. 130A is only 8% higher than 120A, which at first glance does not appear to be enough margin to recharge the UPS in a reasonable time. But when you consider that the UPS only needs 110A of input current (calculated at .98 pf, to be conservative), this leaves 20A for re-charging, or 18%. For both the 130A of input current and 120A of bypass and output current, the recommended breaker sizes are 200A if 80% rated or 150A if continuously (100%) rated.

Conclusion

In this paper, we have presented a description of both the *input* power factor *specification* for a UPS, and the *output* power factor *rating* of a UPS. These similar-sounding terms can cause significant confusion, and it is important for specifiers and users to understand their significance to avoid accidentally undersizing their power protection system or unnecessarily oversizing their upstream wiring and protection. As always it is a hallmark of the Powerware brand to provide ease of installation while ensuring compatibility with modern data center loads.

Eaton—Setting the standard for three-phase UPS power protection

For more than 40 years—from the first commercial UPS to the new, high-efficiency Powerware 9395 UPS—Powerware UPSs from Eaton have set the standard for power protection and backup, and helped Eaton earn the designation of "Power Quality Company of the Year" from Frost & Sullivan for three years in a row. To find out more, visit us on the Web at **www.powerware.com** or call us at 800-356-5794.

About the author

Thomas M. Blooming, P.E. is an application engineer with Eaton Corporation, supporting Eaton's power quality products. He focuses on UPS application issues. Tom formerly was a senior product engineer in Eaton's power factor correction group. He handled application issues related to power factor correction capacitor banks, harmonic filters, static-switched capacitor banks, and active harmonic filters, as well as many power quality-related questions. Prior to that Tom worked in the Cutler-Hammer Engineering Services & Systems group and provided clients with electric power engineering expertise, focusing in the areas of power quality and reliability. Tom has performed numerous power systems measurements and studies. He has published technical papers and taught engineering workshops and training seminars on power quality issues. Tom received a B.S. in Electrical Engineering from Marquette University, an M.Eng. in Electric Power Engineering from Rensselaer Polytechnic Institute, and an M.B.A. from Keller Graduate School of Management.