Efficiency and Other Benefits of 208 Volt Over 120 Volt Input for IT Equipment

By Neil Rasmussen

White Paper #27

Legendary Reliability®

Revision 2

Executive Summary

Decisions made regarding the distribution of 208V or 120V power to IT equipment can significantly impact overall efficiency of the data center. This paper explores the voltage connection options of 208 volt (V) and 120V for servers in North America and considers the efficiency implications of these choices. This same discussion applies to the use of 200V vs. 100V in Japan.

Introduction

This white paper explains why and when 208V is used instead of 120V for servers in North America. This same discussion applies to the use of 200V vs. 100V in Japan. Of particular interest is how server voltages relate to energy efficiency.

Background

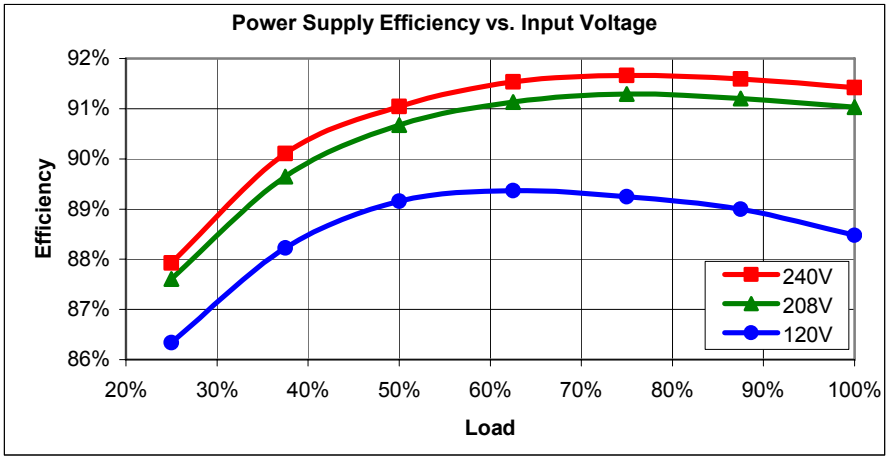
Most entry level and mid-range servers are configured and shipped with 120V plugs. However, the servers themselves are designed to accept any voltage worldwide, including 120V and 208V. Larger pedestal servers and rack-mount servers tend to be configured with 208V plugs.

One voltage is sometimes preferred over another for some very specific reasons. The reasons are explained in the following sections.

Energy Efficiency

Power supply energy efficiency is a measure of how much power is lost between the input and output of a server's power supply. Other metrics that measure the overall efficiency of a server, take into account the processing capability of a server per unit of power input. Although related to server power supplies, these efficiency metrics are not discussed in this paper. Server power supplies, when considered as a group, have a significant impact on energy efficiency of a data center. This has prompted some data center managers to specify high efficiency power supplies. The easiest way to improve the efficiency of existing server power supplies is simply to increase their input voltage. **Figure 1** illustrates a 1-3 percentage point improvement in power supply efficiency with increased voltage. This represents a savings of $4 to $31 per year per server in electrical cost by doing nothing more than moving equipment to a higher voltage source.

Figure 1 *– Power supply efficiency (source: HP)*



The reason for the increase in power supply efficiency stems from a basic electrical principle. For a given amount of power, as voltage increases, less current is required. Conversely, as voltage decreases, more current is required to maintain the same amount of power. For example, 120 volts x 10 amps = 1,200 volt-amps. If the voltage is doubled, only half the current is required (240 volts x 5 amps = 1000 volt-amps). The more current that wires, transformers, and other power supply components carry, the hotter those components get. This heat must be carried by the air conditioning system which further increases the amount of electricity required to support a given server.

Why 120V?

Convenience is the overwhelming reason why 120V is utilized in the data center and why virtually all small and departmental servers are installed with 120V plugs. U.S. electrical codes require that habitable space be wired with 120V receptacles with a receptacle for every 10 feet of exposed wall. Therefore, 120V is almost always available at any office site. However, typical 120V building wiring has a serious and fundamental limitation: the majority of wall receptacles are rated at 15 amps (15A) and a growing number are rated at 20 amps (20A).

The 15A rating of 120V office power is very important and a significant limitation. Underwriters Laboratory (UL) specifies that a single piece of electronic equipment is not permitted to continuously draw more than 80% of a receptacle's rating, or 12 amps for a 15A circuit. This places a limit of about 1,440 volt-amps (volts x amps) on a standard 15A receptacle.

Most new servers have power factor corrected supplies with nearly a 1 to 1 correlation between volt amps and watts. Thus the maximum corresponding watts available through a receptacle is 1,440 watts - which is the maximum power that a server can draw from a single 15A plug. Due to the losses of the server power supply, this corresponds to about 1,250 watts of power supply output rating in the server. Note that high efficiency power supplies would provide more than 1,250 watts output due to lower losses.

Therefore, the maximum power supply configuration typically seen for a server operating from 120V with a single 15A power plug is a server with a 1,250 W power supply system. However, services with a rating of 20A 120V are becoming more popular in commercial environments. For 20A 120V service, 16A or 1,920 volt-amps or watts is the maximum of power supply output rating in the server due to losses.

Server power supplies can offer redundancy. When a server has two power cords, each power cord and power supply must be sized to support the entire server.

It is possible to wire special 120V receptacles for 30 amp service, but this is very unusual and requires larger wires and an electrician. Therefore, it is impractical and typically not used for large servers.

It should be noted that a server configured for the maximum power draw described above would use the entire capacity of the 120V circuit. **If additional devices like a monitor, PC, backup device, or RAID subsystem were required then the user would need to supply these from a second circuit which in some cases may require that an additional wire be installed from the AC power distribution panel.**

Although 120V is convenient, it presents a major disadvantage to energy constrained data centers. Many data center operators who are trying to reduce their electric bill fail to realize that 120V circuits are less efficient than higher voltage circuits.

Why 208V?

Power capacity is the primary reason for deploying 208V and is the reason why many enterprise servers are designed to accept 208V. In fact, almost all IT equipment can accept a wide voltage range from 100V up to 250V. The most common ratings for 208V receptacles are 20 amp and 30 amp, corresponding to about 3,600 and 5,400 watts, respectively, of power supply output rating in a server. Very few servers are manufactured that require greater power ratings (except for some large enterprise class severs). For these very large servers, the input power is either hard-wired or multiple 30A 208V cords are provided.

Based on the previous discussion regarding 120V, any server that draws more than the power supply output level of 1,920 watts (20A 120V service), will naturally need to use 208V. Therefore, users should expect this and understand that the use of the higher voltage is driven by fundamental electrical principles.

In addition to the fundamental need to use 208V at higher power, there are other practical reasons why 208V is advantageous.

Rack systems frequently combine a heterogeneous mix of equipment. It happens to be the case that typical rack configurations draw in the range of 1,600 to 5,000 watts. This is a poor match to the 120V limitation of 1,440W available, but an excellent match to 208V service at either 20 amps or 30 amps. Therefore a single power connection per rack is all that is required at 208V where as many as three connections might be required at 120V. This issue is discussed in depth in APC White Paper #29, "Rack Powering Options for High Density".

The trend towards more energy efficient data centers makes 208 even more advantages because a given server will draw less current at 208V than at 120V. The less current a server draws, the less heat is produced. Therefore its wiring devices, fusing, and switches will run cooler which will reduce their long-term risk of degradation or failure, as well as decrease the costs associated with cooling. In fact, there is great interest in the data center industry to move towards 230 volts distribution which will further reduce losses. This topic is covered in depth in APC White Paper #128, "Increasing Data Center Efficiency by Using Improved High Density Power Distribution".

An advantage of using 208V is that usually each 208V wall receptacle has its own circuit breaker. This means that the malfunction of a different load cannot trip the server's breaker. In 120V installations, it is very common for a single breaker to feed a number of receptacles. This means that in a 120V installation a number of unexpected points may exist where an overload can trip the server's breaker. Most MIS professionals have heard of a case where cleaning personnel have tripped the breaker feeding critical computer loads.

Another advantage of 208V is that the common power receptacles are locking using the twist-lock type plug, which reduces the chance of dislodging them. Furthermore, the quality of the contacts in 208V receptacles is generally higher than 120V receptacles, which greatly reduces the chance of intermittent connections.

What is 240V?

In residential installations in North America and in some limited business installations, 240V is available instead of 208V. Virtually all equipment that operates from single-phase 208V will also operate from 240V. All of the same advantages relative to 120V apply.

What about 3-phase?

Very few servers today require 3-phase power. There are many sites, which simply do not have 3-phase power available. Also, the 3-phase voltage in the rest of the world is much different than that in the USA, making it more difficult to design global products. However, both 120V and 208V single phase can be easily derived from North American 3-phase voltage by simple wire connections; 120V single phase is just the voltage from one of the three phases to neutral, while 208V single phase is the voltage between two of the three phases.

UPS systems for 208V

Users must take the server operating voltage into account when selecting a UPS. No "universal" UPS exists that operates with all combinations of voltage. Four output voltage options are shown below in **Table 1**.

Table 1 *– Voltage options*

Facility Voltage (UPS Input)	Equipment Voltage (UPS Output)	Example UPS	UPS Power Range
120V	120V	Smart-UPS	750VA - 3000VA
208V	208V (with 400VA of 120V for aux equipment)	Smart-UPS "T" Series	3000VA - 5000VA
208V	208V, 120V	Symmetra LX	4000VA - 16 kVA
208V 3-phase **480V 3-phase** **600V 3-phase**	208V 3-phase, 208V, 120V	Symmetra PX / MW, Galaxy	10 kVA – 1,600 kVA

For servers requiring 208V, the appropriate UPS is selected based on the level of power required. Where multiple product lines provide the power level required, the choice can be based on product features.

Conclusion

When weighing data center power distribution options, 208 volts offers a number of technical advantages. Only when 208V is deployed can higher power servers plug into standard NEMA outlets. Technically, 208V is a superior choice for powering computing equipment when compared with 120V due to lower current draw and higher power efficiency. However the ubiquitous nature of 120V wiring in North America and 100V in Japan make these lower voltages preferred by users. This has given rise to the situation where lower powered small business or departmental servers are powered by 120V, while larger and enterprise class servers are powered by 208V.

About the Author:

Neil Rasmussen is the Chief Technical Officer of APC-MGE. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks. Neil is currently leading the effort at APC to develop high-efficiency, modular, scalable data center infrastructure solutions and is the principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his Bachelors and Masters degrees from MIT in electrical engineering where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981, he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.