

Calculating Total Power Requirements for Data Centers

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White Paper #3

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Executive Summary

Part of data center planning and design is to align the power and cooling requirements of the IT equipment with the capacity of infrastructure equipment to provide it. This paper presents methods for calculating power and cooling requirements and provides guidelines for determining the total electrical power capacity needed to support the data center, including IT equipment, cooling equipment, lighting, and power backup.

Introduction

With the adoption of scalable “pay as you grow” UPS architectures, its becoming easier to install these systems. It allows the data center manager to simply add modules as the needs of the data center grow. However, it is easy to lose sight of the future electrical needs of the data center or data room within a larger facility.

Sizing the electrical service for a data center or data room requires an understanding of the amount of electricity required by the cooling system, the UPS system, and the critical IT loads. The power requirements of these elements may vary substantially from each other, but can be accurately estimated using simple rules once the power requirements of the planned IT load are determined. In addition to estimating the size of the electrical service, these elements can be used to estimate the power output capacity of a standby generator system, if one is required for the data center loads.

Needs Assessment

Any initiative to improve the capabilities of a data center environment, no matter the size or scale, must begin with a needs assessment. The needs assessment essentially establishes the availability needs of the business applications being processed by the IT equipment. A business process that is not time sensitive, or is batch process driven may dictate power and air conditioning for the load in an “N” configuration, with no internal redundancies to increase availability. More time sensitive sites may require a degree of redundancy in key component systems and have configurations of an “N+1” topology. Every key system element would have a redundant piece of equipment so that if one of the units fails, the system could still maintain its function for the IT critical load. The most critical data center applications requiring total availability (7x24) would have a 2N topology where critical systems would be completely redundant. One critical system could fail, but another would maintain operational loads. This also provides for a degree of concurrent maintainability whereby maintenance could be performed on one system while another supplies the load. For more information on the different types of system configurations see APC White Paper #75, “Comparing UPS System Design Configurations”.

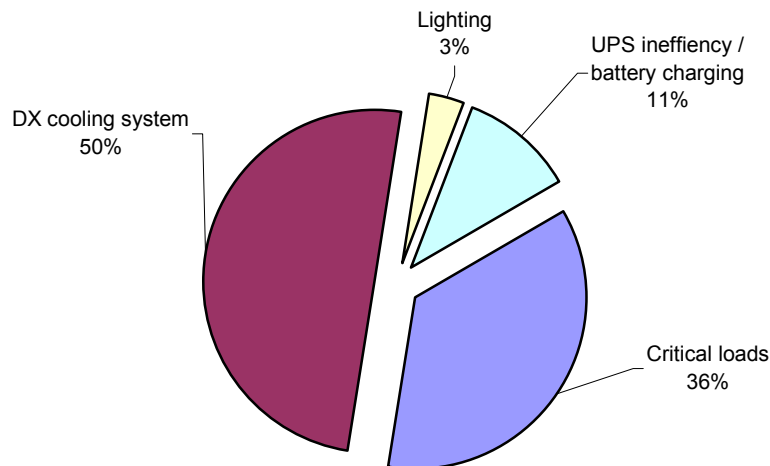
No matter what the actual UPS system design configuration is (N, N+1, 2N), the core issue of providing sufficient power to the critical load and keeping it cool is the same, and must be carefully addressed. Underestimating the required capacity may result in future power disruptions when forced to increase capacity, and over estimating leads to excessive initial installation costs and higher ongoing maintenance expenses.

Determining the Electrical Power Capacity Needed to Support a Data Center

Most data centers are part of a larger building. The steps in determining the electrical capacity described below will assist in estimating the capacity required for that portion of the building dedicated to the data center or data room. The difference between the steady state power and the peak power is important when calculating power capacity requirements and is noted throughout this paper. For more information on why power variations exist read APC White Paper #43, "Dynamic Power Variations in Data Centers and Network Rooms". For installations where critical components like air conditioning, chillers, or standby generators are shared and used to supply other loads beyond the data center, the sizing of the system requires a more complete and complex analysis by a consulting engineer.

Figure 1 illustrates a typical breakdown of how the electrical capacity is divided among the various loads in a data center. This breakdown assumes 5,000 ft², (465 m²) data center with an initial steady state critical load of 50kW, plus a future steady state load of 50kW. The cooling system is assumed to be direct expansion (DX) and the utility voltage is 480 volts AC.

Figure 1 – Breakdown of data center electrical requirements



Critical loads

A proper planning exercise in developing a data center, from a single rack sized environment to a full scale data center begins with determining the size of the critical load that must be served and protected. The critical load is all of the IT hardware components that make up the IT business architecture: servers, routers, computers, storage devices, telecommunications equipment, etc., as well as the security systems, fire and monitoring systems that protect them. This process begins with a list of all such devices, with their nameplate power rating, their voltage requirements, and whether they are single phase or three phase devices. The nameplate information must then be adjusted to reflect the true anticipated load. The nameplate power requirements are the worst-case power consumption numbers required by Underwriter's

Laboratory and in almost all cases, are well above the expected operating power level. Studies conducted by reputable consulting engineering firms and power supply manufacturers indicate that the nameplate rating of most IT devices is well in excess of the actual running load by a factor of at least 33%. The U.S. National Electrical Code (NEC) and similar worldwide regulatory bodies also recognize this fact and allow electrical system planners to add up nameplate data for anticipated loads and multiply by a diversity factor, anticipating that not all devices are running at full load 100% of the time. Alternatively, an advanced sizing calculator may be used such as the one found at the website below. Calculators such as this one gather power consumption data from a wide range of manufactures and further specify various equipment configurations.

www.apcc.com / template / size / apc / index.cfm

At this site an IT professional can configure a representative rack's worth of servers based on "brand-name" ingredients. This tool works behind the scenes to add up the known power requirements of each component within a given server's configuration. For example, when a user specifies a server, they will also be asked to record the quantity of CPU and other details within the box. Given the user's inputs, the UPS Selector will calculate the total power required for the rack. (The power will be stated in volt amps or VA) Also included in the tool are important facts about the manufacturers intended input voltage and power plug.

With the list of anticipated components comprising the critical load, the base load can be established by using a sizing calculator. For IT equipment unlisted in calculators as well as the power requirement for fire, security and monitoring systems, the following process should be used:

- A. Add up the nameplate power of the anticipated loads. If the wattage is not listed on the device, it can be determined by multiplying the current (amps) by the voltage of the device to get the VA, which approximates the amount of watts the device will consume.
- B. Multiply the anticipated VA number by 0.67 to estimate the actual power, in watts, that the critical load will represent.
- C. Divide the number by 1000 to establish the Kilowatt (kW) load level of the anticipated critical load.

Future loads

Data Center loads are not static. Once built or established, the IT equipment will be under an almost constant state of change during the lifetime of the data center. IT "refreshes" will, at a minimum, have a 3 year cycle where new, more powerful or efficient devices will be installed with, or replace the devices on the initial planning list. A realistic assessment of the scope and timing of future changes and upgrades should be developed by the IT organization to allow proper planning for the initial determination of power requirements. The "downstream" elements of the electrical power and distribution system can be scaled, or adjusted to known loads and future loading (See APC White Paper #37, "Avoiding Costs from Oversizing Data Center and Network Room Infrastructure"), but the electrical power service supplying the NCPI

components has to be sufficiently sized to carry the known load at start-up and future loads, or provision has to be made for installing additional capacity without incurring excessive downtime that would adversely affect the availability expected by the IT customer.

Once an estimate is made for the amount of future loading, it is added to the base loading information developed above to establish the electrical critical load number in kW.

UPS loads

Assuming that the availability determination in the needs assessment, explained above, requires the inclusion of UPS power (in almost all cases this is true), the total electrical load power must include a factor for the inefficiency of the UPS system as well as the additional power required for battery charging.

UPS efficiency varies between product models and varies dramatically depending on the loading of the UPS. UPS are rarely run at the operating points where their advertised efficiency is provided. A realistic and sufficiently accurate value for UPS efficiency in a typical installation is 88%.

Battery charging is a significant but intermittent power consumer. Under normal operation with a charged battery the battery charging load is negligible. However, when a battery has been partially or completely discharged the battery charging power can be on the order of 20% of the rated UPS load. Although this load only rarely occurs, the generator and service entrance must be sized for this load.

Lighting loads

Lighting loads account for all the lighting in the data center portion of the building and are a function of the data center floor area. A good rule of thumb for this type of load is 2 watts per square foot or 21.5 watts per square meter.

Cooling loads

Refer to APC White Paper #25, "Calculating Total Cooling Requirements for Data Centers", for a detailed discussion of heat loads in data center environments. The paper provides tables to help calculate the cooling required for the heat generated by the IT equipment. It also allows the planner to establish the amount of cooling required to support a planned critical load. Cooling systems vary widely in efficiency but can be broken down into chilled water systems and direct expansion systems. Chilled water systems are generally more efficient and a rule of thumb for power consumption is 70% of the total peak load being supported. Direct expansion systems require about 100% of the total peak load being supported. Note that cooling loads have startup peak loads that exceed the steady state values which are accounted for in this calculation. Table 1 of this paper estimates the electrical power requirement of the cooling system using these rules. This will help establish the size of the electrical distribution system required to support the entire data center.

Sizing the electrical power system

Two important numbers have been determined that will assist in estimating the size of the electrical system that will power the data center environment: the Total Critical Load and the Total Cooling Load. In general, the electrical supply must be large enough to support the sum of these two numbers, plus the related data center lighting loads.

The steady-state power consumption of the loads within a data center establishes the power consumption for purposes of determining electrical costs. However, the Electrical Service and the Generator power sources that provide power to the data center cannot be sized to the steady state values. These sources must be sized to the peak power consumption of the loads, plus any derating or oversizing margins required by code or standard engineering practice. In practice, this causes the electrical service and generator sizing to be substantially larger than might be expected, as will be illustrated in the next section.

Final Electrical Capacity Computation

Once the total electrical capacity is estimated in Kilowatts from the process described above, two critical determinations can be made: the first is an estimate of the electrical service needed to supply the data center, and the second is the size of any standby power generator capacity that may be needed to achieve the desired availability.

Sizing of the Electrical Service

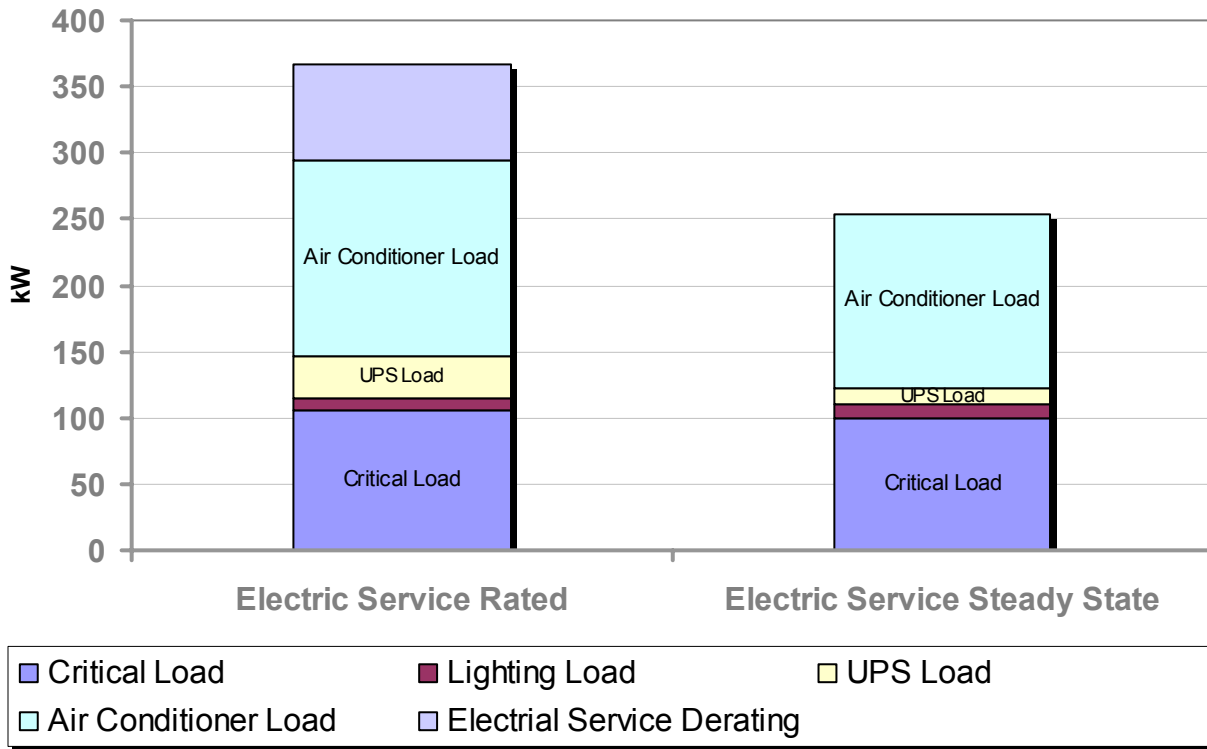
The electrical service can be calculated as follows:

1. Take the total electrical capacity required in Kilowatts and multiply by 125% to meet the requirements of the National Electrical Code and similar regulatory bodies.
2. Determine the three phase AC voltage of the service entrance to be supplied by the utility company. Typically this is 480 Volts AC in the United States and 230 Volts AC in most other parts of the world.
3. Use the following formula to determine the electrical service size to supply the data center, in Amps:

$$\text{Amps} = (\text{kW} \times 1000) / (\text{Volts} \times 1.73)$$

This provides an estimate of the electrical service capacity required to support the critical load, cooling, and the building functions for a data center. Using the assumptions of Figure 1, Figure 2 emphasizes the important distinction between rated (peak) power and steady state power by comparing the electrical service requirements for both. It must be noted that this is only an estimate, and that the final determination of the service size is highly dependent on accurate site specific information. It is strongly recommended that the services of a qualified professional consulting engineer be retained to verify the initial estimate and develop the final data center electrical supply design. Table 1, located at the end of the paper, can be used as a worksheet that assists in summarizing the discussion above.

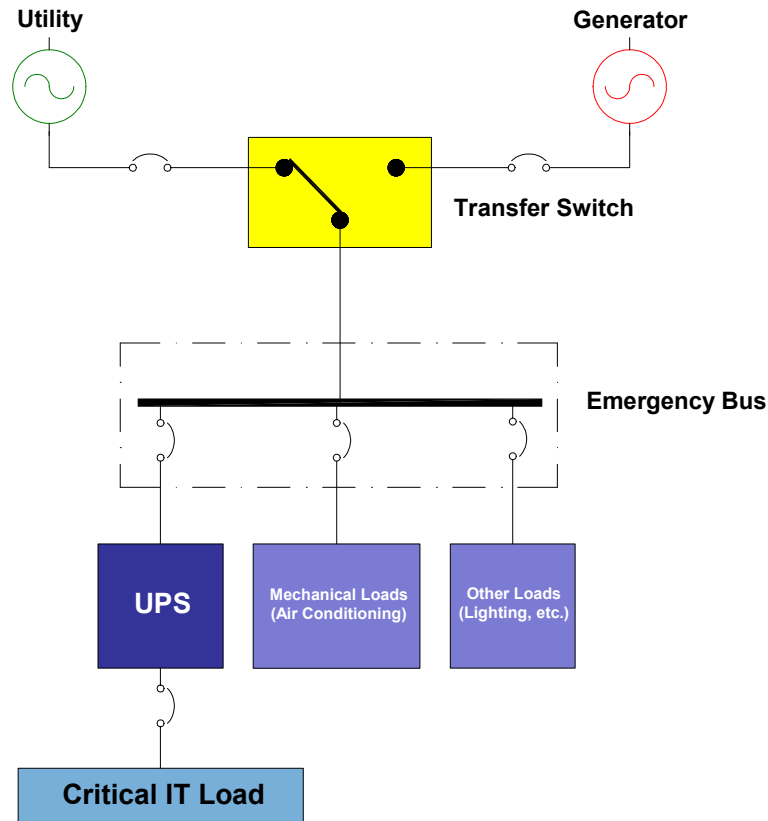
Figure 2 – Rated vs. steady-state electrical service power for a typical 100kW critical load.
 Electrical service rating is almost 4X the steady state critical load value



Sizing of Generator Standby Power Systems

Once the size of the electrical service has been determined, consideration can be given to sizing of an appropriate standby power generator, which will provide power in the event of a utility failure and increase the availability of the data center. A typical generator installation is illustrated in Figure 3 below:

Figure 3 – Typical generator system



The first thing to note on the diagram above is the assumption that the data center is the only load, and that it is to be fully protected by standby power. The “utility” supply may be only a part of a standard commercial electrical distribution system, so this diagram would be part of a subset of a much larger electrical system. This subset is the data center portion that supplies the critical IT loads.

To estimate the size of the generator required for the critical loads, use the calculation at the bottom of Table 1. However, there has to be consideration of the electrical characteristics of the loads to be attached to the generator through the transfer switch. Mechanical loads, for example, require high starting currents and impose harmonic currents that pose problems to a generator’s ability to supply the power needed. The UPS itself may contribute to this problem if it does not operate at a high input power factor, and may cause generator failure if it imposes a leading power factor on the generator.

The selection of a UPS system with operating characteristics favorable to reliable generator operation is an extensive discussion, not covered in this white paper. It is sufficient to note that the UPS must be chosen carefully to achieve end-to-end reliability. A UPS system that exhibits highly capacitive characteristics under low load conditions is to be avoided. Certain UPS topologies, such as the delta conversion, are ideal for generator supplied systems and will not produce the undesirable operating characteristics of traditional double conversion systems with input filter capacitors. This choice alone in the selection of the UPS can

influence the required generator size greatly, frequently by a factor of 3 (the generator would have to be 1.75 to 3 times larger for a typical double conversion UPS than a Delta Conversion UPS). As in the case of electrical service power, Figure 4 emphasizes the important distinction between rated (peak) power and steady state power by comparing the electrical generator requirements for both.

When selecting a generator, base the choice on the kW rating of the generator for purposes of simplicity, but be aware that generators are designed to operate loads at a lower power factor than 1.0, typically 0.8. This means that the current and voltage will be slightly out of phase and that the generator must withstand that difference. A 1000 kW generator, designed to operate loads having a power factor of 0.8 will be rated at 1200 kVA. Do not confuse the kVA rating with the true power capacity of the generator, which is always in kW. For more information on power factor see APC White Paper #15, "Watts and Volt-Amps: Powerful Confusion".

Figure 4 – Rated vs. Steady-State electrical generator power for a typical 100KW critical load.
Electrical service rating is over 4X the steady state critical load value

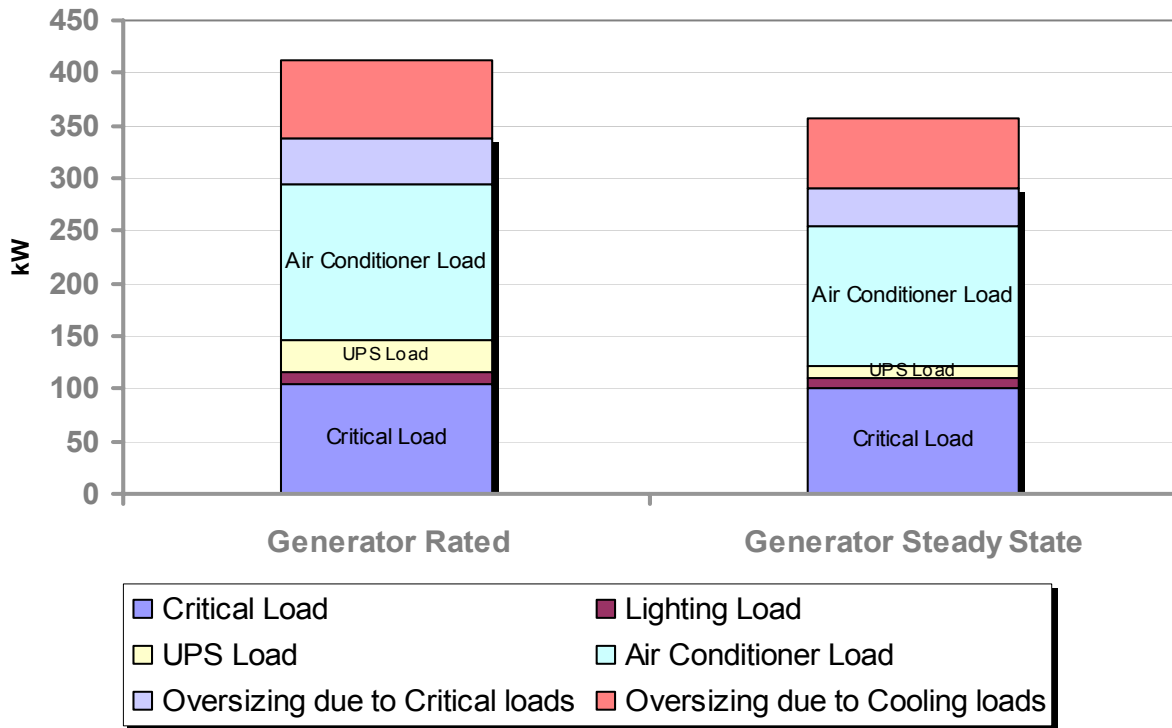


Table 1 – Data center power requirement estimate calculation worksheet

Item	Data Required	Calculation	Subtotal kW
Power Requirement – Electrical			
Critical load- sizing calculator value from APC website	Rating of each IT device	$(\text{ Calculator total in VA} \times 0.67) / 1000$	# 1 _____ kW
For equipment not listed in the sizing calculator, critical load – nameplate	Subtotal VA (include fire, security and monitoring systems)	$(\text{ Subtotal VA} \times 0.67) / 1000$	# 2 _____ kW
Future loads	VA of nameplate of each anticipated IT device	$[\text{ (Add VA rating of future devices)} \times 0.67] / 1000$	# 3 _____ kW
Peak power draw due to variation in critical loads	Total steady state critical load power draw	$(\# 1 + \# 2 + \# 3) \times 1.05$	# 4 _____ kW
UPS inefficiency and battery charging	Actual Load + Future Loads (In kW)	$(\# 1 + \# 2 + \# 3) \times 0.32$	# 5 _____ kW
Lighting	Total floor area associated with the data center	$0.002 \times \text{ floor area (sq ft), or } 0.0215 \times \text{ floor area (sq m)}$	# 6 _____ kW
Total power to support electrical demands	Total from # 4, # 5 and # 6 above	# 4 + # 5 + # 6	# 7 _____ kW
Power Requirement - Cooling			
Total power to support cooling demands	Total from # 7 above	For Chiller systems # 7 x 0.7 For DX systems # 7 x 1.0	# 8 _____ kW
Total Power Requirement			
Total power to support electrical and cooling demands	Total from # 7 and # 8 above	# 7 + # 8	# 9 _____ kW
Size of Electrical Service Estimate			
Requirements to meet NEC and other regulators	Total from # 9 above	$\# 9 \times 1.25$	# 10 _____ kW
Three phase AC voltage provided at service entrance	AC voltage		# 11 _____ VAC
Electrical service required from utility company in Amps	Total from # 10 and AC voltage in # 11	$(\# 10 \times 1000) / (\# 11 \times 1.73)$	_____ Amps
Size of Standby Generator Estimate (If applicable)			
Critical loads requiring generator back up	Total from # 7 above	$\# 7 \times 1.3^*$	# 12 _____ kW
Cooling loads requiring generator back up	Total from # 8 above	$\# 8 \times 1.5$	# 13 _____ kW
Size of generator needed	Total from # 12 and # 13 above	# 12 + # 13	_____ kW

*WARNING: The 1.3 variable applies to fully power factor corrected UPS. A 3.0 multiplier must be used when using traditional double conversion UPS with input harmonic filters.

Conclusions

Assessing the electrical power required to support and cool the critical loads within the data center is essential in planning for the development of a facility that will meet the end user's availability expectations. By employing the process described above, a reasonable estimate of the power requirements can be made. This will help specify the size of the Network-Critical Physical Infrastructure components that will achieve the availability determined by the needs assessment. Once the sizing determination is made, conceptual and detailed planning can go forward with the assistance of a competent NCPI systems supplier or, in the case of larger scale data centers, a consulting engineer. Cost estimation can then be made based on the size and reliability configuration determined from the power needs assessment process described above.

About the Author:

Richard L. Sawyer is a Sr. Systems Application Engineer for APC. He has 25 years of experience in large scale data center construction and operations for Fortune 100 companies. He is on the Board of Directors, AFCOM.