Power and Cooling Considerations for Power-over-Ethernet (PoE)

By Neil Whiting

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Executive Summary

Power-over-Ethernet (PoE) can cut costs by enabling, for the first time, the deployment of a single Ethernet cable for simultaneous access to both power and data. However, lack of a power and cooling plan to support the PoE implementation can result in unanticipated downtime. This paper illustrates which power and cooling factors to consider when safeguarding a PoE investment.

Introduction

Power-over-Ethernet (PoE) eliminates a significant number of power cords in networking and data center environments. This translates into cost savings, greater freedom regarding the location of devices, and higher reliability (less infrastructure and therefore less opportunity for error). Benefits notwithstanding, anyone deploying PoE equipment should take into account the ramifications from a power protection and heat generation perspective.

Several equipment component categories make up a PoE network (see **Table 1)**. Each category should be analyzed to determine power consumption and heat production characteristics. Failure to do so will result in unanticipated downtime and premature deterioration of equipment. This paper illustrates power and cooling factors to consider when deploying a PoE network.

Table 1 – Definition of terms

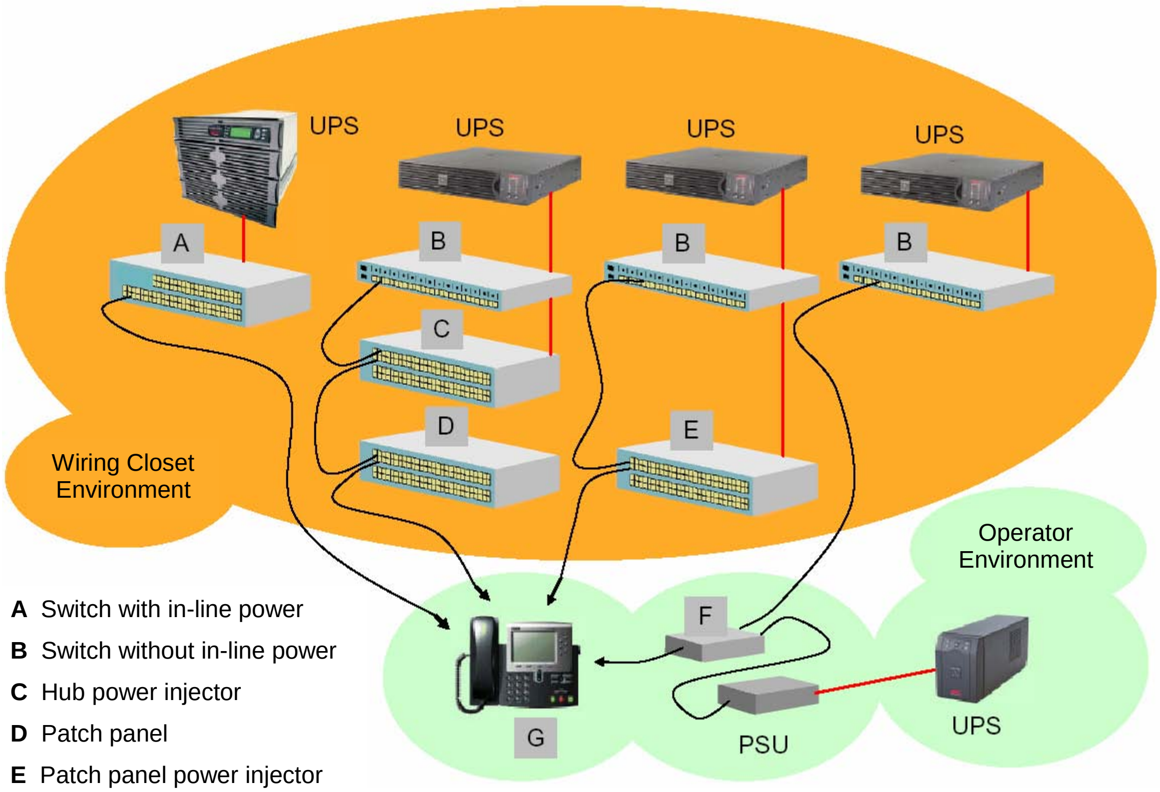
Term	Meaning	Definition
PSE	Power sourcing equipment	Any device that allows for power to be injected into a PoE network (i.e. endpoint PSE device, midspan PSE device).
PD	Powered device	Any device that consumes the power supplied by the PSE in order to operate (i.e. IP phone, wireless access point).
UPS	Uninterruptible power supply	Ensures availability of power to the PoE network in the event of a power supply disruption.

PoE dramatically increases the potential power demand in the wiring closet. Therefore, it is essential that the proper power and cooling physical infrastructure be put in place to accommodate the initial deployment and future growth of the PoE network.

Although additional heat will be produced in the wiring closet by the PSE, additional heat produced by the remote PDs will be dissipated outside of the wiring closet due to the fact that the equipment resides in remote locations. Remote IP phones, wireless access points, RFID readers, network cameras, and network cables are examples of components where the heat is dissipated outside of the wiring closet. **Figure 1** illustrates typical PoE components both within and outside of the wiring closet.

The PSE is often located in a wiring closet, and supported by an uninterruptible power supply (UPS) to ensure availability during power supply disruption.

Figure 1 – Typical PoE Component Layout



A Switch with in-line power
B Switch without in-line power
C Hub power injector
D Patch panel
E Patch panel power injector
F Desk top power injector
G PoE enabled device

PSU Power Supply Unit (AC/DC) **UPS** Uninterruptible Power Supply

Applications for PoE

Applications which benefit from PoE include VoIP (voice over internet protocol), RFID (radio frequency identification), WLANS (wireless local area networks), and security cameras and access control.

As power is delivered to a PD over the data cable, devices such as WAP (wireless access points) and cameras can be installed in remote areas without requiring that an electrician install an AC outlet.

Currently the application benefiting most from PoE enabled networks is VoIP, but many other applications are evolving and growing. The development of these new applications will increase demands on the overall PoE system from a power and cooling perspective.

PoE Impact on Physical Infrastructure

Table 2 demonstrates the typical power demand that individual powered devices (PDs) put on the power sourcing equipment (PSE). Some of the devices listed in the table are designated "PoE+" devices and are outside of the support of the current PoE standard. The current standard allows for a maximum draw of 12.95 W per device. The proposed PoE+ (IEEE 802.3at) standard will likely double the PSE power available to a two pair connection (30 Watts per port) and quadruple the power available to a four pair connection (60 watts per port). This will further impact the demand for power and cooling within the wiring closet.

Table 2 – Individual Powered Device (PD) Power Demands

Application	Powered Device	Typical Power / PD
VOIP	IP phone	3 – 5 W
VOIP	Video IP phone	10 – 12 W
RFID	RFID readers	10 – 12 W
RFID	RFID readers (PoE+)	15 – 25 W
Wireless Networks	Wireless access point, 802.11a/b/g	8 – 12 W
Wireless Networks	Wireless mesh access point (PoE+)	25 – 50 W
Security and Access control	Fixed camera	10 – 12 W
Security and Access control	Door entry control, card reader	8 – 12 W
Security and Access control	Pan, tilt & zoom (PTZ) camera (PoE+)	15 – 20 W

PoE Case Study Comparison

PSE equipment generally falls into two categories of equipment: midspan and endpoint. A midspan PSE is a unit which injects power upstream, after the network switch. An endpoint PSE injects the power at the switch along with the data traffic.

The examples below illustrate and compare PoE deployments in three different companies:

- **Company A -** The wiring closet supports 50 employees and has two 48 port stackable switches which are then upgraded using two midspan units to provide PoE.

- **Company B -** The wiring closet supports 100 employees and has one rack-mounted switch with three 48 port and one 24 port card inserted, which are used to support PoE from within the switch.

- **Company C -** The wiring closet supports 200 employees, has two rack-mounted switches, each with three 48 port cards and one 24 port card inserted, which are used to support PoE from within the switch.

In each scenario a minimum of 7.4 W has been allowed for each PoE port, however, as the majority of the PD requirements are less than 5 watts, the midspan and endpoint units manage the power to each individual port. This ensures that the PDs requiring higher power are supported as necessary up to the maximum power available.

Both company B and C could enhance their systems further with external power supplies to support higher PoE loads.

Although the PSE can provide 15.4 W (44 V at 350 mA) or more per port, the PD can only draw a maximum of 12.95 W (37 V at 350 mA). This is because the IEEE 802.3af specification allows for the potential voltage drop and associated dissipation in the network cable and connections over its length of up to 100 meters (328 feet).

The electrical and thermal loadings in the wiring closet, as highlighted in **Tables 3 & 4**, reflect the UPS units operating in three different modes of operation:

- **Mode 1:** The UPS supports the load when the internal battery is fully charged (i.e. battery is on a float charge). This will be the normal situation for the majority of the time.
- **Mode 2:** The UPS supports the load and charges its battery. This can typically last for 3 hours following an interruption of the AC supply, but will vary depending of the length of disruption and the state of the battery at that time. Higher levels of heat will be dissipated in the wiring closet for longer periods when the UPS is recharging or running on battery. It is essential that the associated cooling is adequate and maintained through these periods.
- **Mode 3:** The UPS supports the load directly from the battery as a result of disruption to the AC supply. This also produces higher levels of heat that must be accounted for.

Table 3 – Network system without PoE

	Company A		Company B		Company C	
Number of employees supported	50		100		200	
Number of switch ports provided	96		168		336	
AC load on UPS (Switch)	90 watts		827 watts		1653 watts	
Selected UPS rating VA / watts	750VA / 500 watts		2000VA / 1400 watts		5000VA / 3500 watts	
Electrical/ thermal load inside the wiring closet with UPS supporting the load	Electrical watts	Heat BTU / hr	Electrical watts	Heat BTU / hr	Electrical watts	Heat BTU / hr
Fully charged UPS battery (AC supply ON)	97	330	961	3283	1778	6071
UPS battery being charged (AC supply ON)	115	394	1021	3485	1797	6137
System on UPS battery (AC supply OFF)	N/A	404	N/A	3361	N/A	6137

Table 4 – Network system with PoE

	Company A		Company B		Company C	
Number of employees supported	50		100		200	
Number of Ethernet ports available with PoE	96		168		336	
PoE Devices	PoE Device Quantity		PoE Device Quantity		PoE Device Quantity	
IP Phone	50		100		200	
IP Video Phone	1		0		4	
RFID Portal	0		5		5	
Wireless Access Point	3		5		8	
Fixed camera	4		4		8	
Door entry control	4		2		5	
Number of Ethernet ports using PoE	62		116		230	
AC load on UPS (switch + PoE)	546 watts		1626 watts		3222 watts	
Selected UPS rating VA / watts	1500VA / 1425 watts		5000VA / 3500 watts		8000VA / 5600 watts	
Electrical/thermal load inside the wiring closet with UPS supporting the load	Electrical watts	Heat BTU / hr	Electrical watts	Heat BTU / hr	Electrical watts	Heat BTU / hr
Fully charged UPS battery (AC supply ON)	569 **	834	1748 **	4027	3580 **	8412
UPS battery being charged (AC supply ON)	692 **	1252	1767 **	4092	4354 **	11055
System on UPS battery (AC supply OFF)	N/A	919	N/A	4092	N/A	8980
	** Power required equates to the heat dissipated both inside & outside the wiring closet					
Heat dissipation outside wiring closet (PD)	1110 BTU / hr (32 5 W)		1943 BTU / hr (569 W)		3815 BTU / hr (1117 W)	

Table 5 illustrates the increase in demand for power and the associated increase in heat in the wiring closet when PoE is deployed. The heat increase is proportionately less than the power increase because the power is provided to devices both within and outside of the wiring closet (and therefore some of the heat is dissipated outside of the wiring closet). Note that the power and heat increases are more dramatic on the smaller system (Company A). This is because the PoE load dominates the overall power requirement.

Table 5 – Summary of the increased demand on the wiring closet from deploying PoE

UPS Mode		Company A	Company B	Company C
Fully charged UPS battery (AC supply ON)	AC Power	488%	82%	101%
	Heat	152%	23%	39%
UPS battery being charged (AC supply ON)	AC Power	499%	73%	142%
	Heat	218%	17%	80%
System on UPS battery (AC supply OFF)	Heat	127%	22%	46%

*Note - See **appendices 1a, 1b & 1c** for details of the data and calculations associated with Tables 3, 4, and 5.*

The following sections will examine both the power and cooling requirements for the wiring closet when deploying a PoE network. Company A, B, and C (from page 5) will be utilized as examples.

Addressing Power Demands in the Wiring Closet

When considering wiring closet power requirements, several key areas need to be considered.

AC feed requirements into the wiring closet

As can be seen from the Company A, B and C scenarios, the power required in the wiring closet dramatically increases when PoE is deployed and can easily escalate to 4000 W or more. Such an increase in demand will necessitate an upgrade of the electrical feed into the room if the existing feed has insufficient capacity. In North America, Japan, and other 100 V / 120 V areas, it is necessary to upgrade to a 208 V supply.

A change in AC feed capacity will also impact the associated outlet connectors. It will be essential to ensure that the correct plugs and receptacles are available. These changes will require the services of a qualified electrician. Planning for this situation will help to avoid unnecessary disruption and / or potential increases in downtime when executing the deployment of PoE and / or planning for PoE+.

System availability requirements

Deploying PoE increases the dependence on the physical infrastructure support systems (i.e. power and cooling), especially when supporting VoIP phones and WLAN access points. If VoIP is deployed and the associated phones are required to support emergency service calls (i.e. 911 services in North America and 112 services in Europe), then the level of availability should be equal to or better than the legacy telephone system it is replacing. Local or national requirements for emergency calls will need to be met.

Figure 2 below provides an availability level of approximately four nines (99.99%) assuming a runtime of at least one hour. The utility supply feeds a UPS, such as an APC Smart-UPS®, which then supports both the network switch and the associated POE midspan power injector in the event of AC line disruption.

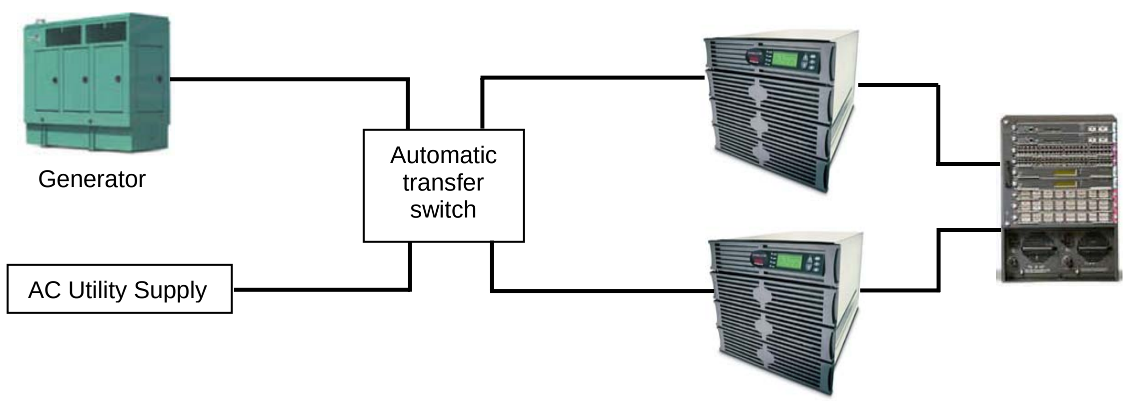
Figure 2 – Single path supply

Figure 3 provides an availability level of approximately five nines (99.999%) assuming a runtime of at least one hour. The utility supply feeds a UPS, such as an APC Symmetra RM® which in itself has a number of power modules configured to provide N+1 redundancy, which then supports the network switch with integrated PoE in the event of AC line disruption.

Figure 3 – Single path supply & single N+1 UPS

Figure 4 provides an availability level of approximately six nines (99.9999%) assuming a runtime of at least one hour, and is the best option for loads that have dual AC feeds (dual cord load). The utility supply and generator supply are connected into an ATS (automatic transfer switch). The ATS is capable of selecting the generator supply during a sustained failure of the utility supply. From the ATS, two separate supplies are fed to individual UPS units, such as the APC Symmetra RM units, configured to provide N+1 redundancy. The two UPS units then each feed separate line inputs into the network switch to power individual power supply units operating in a redundant mode.

Figure 4 – Dual path supply & dual N+1 UPS



For further details on appropriate architectures to achieve specific levels of availability and for applications embracing PoE such as VoIP, see APC White Paper #69 “Power and Cooling for VoIP and IP Telephony Applications”. In addition companies like APC have dedicated availability consulting services to evaluate and recommend high availability power infrastructures for critical networks.

System runtime

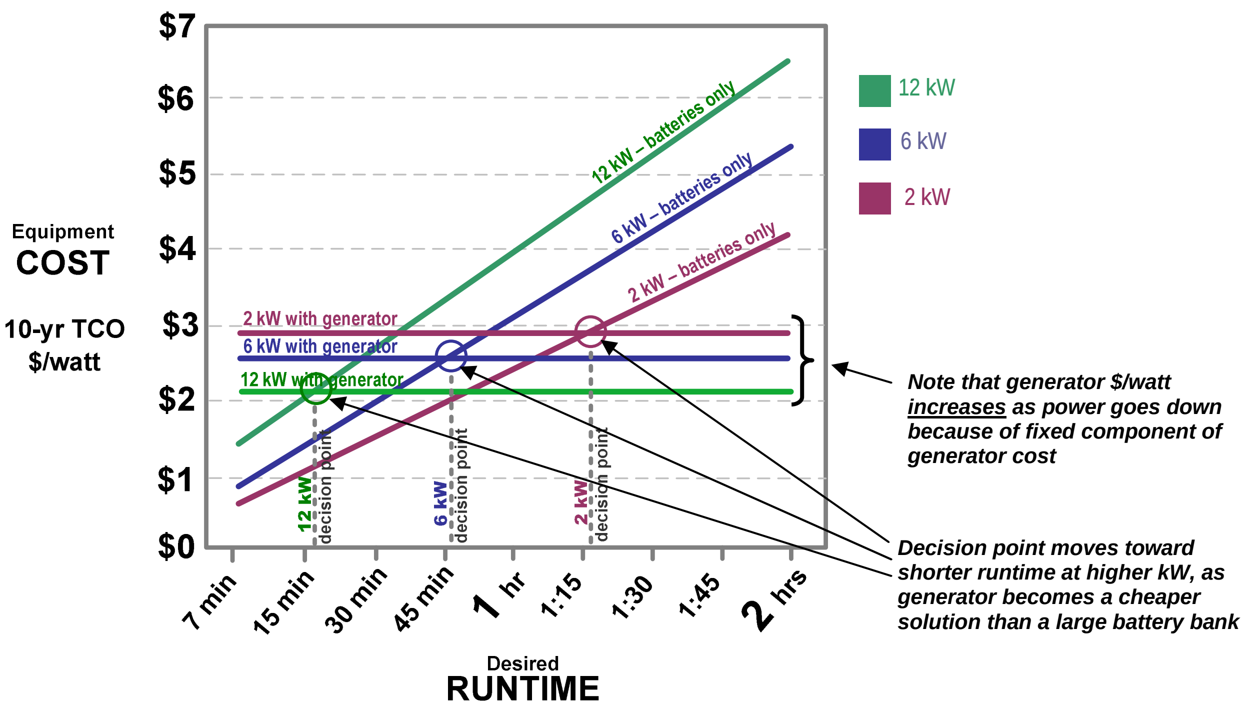
The typical runtime provided by a UPS in a wiring closet supporting a non-PoE network switch is twenty minutes. When PoE is deployed, however, not only does the total system load increase but the required runtime also increases. The required runtime for a PoE-enabled system will generally be a minimum of one hour but business or local and national regulations may dictate a longer runtime.

Extended runtimes can be achieved in the following ways:

1. Add batteries to the UPS to support the required runtime. When pursuing this scenario, the increased weight load and additional space requirements must be considered. To illustrate an example, consider "Company C" (see page 5). The battery required to support the PoE load for two hours, from an initial fifteen minutes, would weigh approximately 200 kg (440 lbs) and would require 19U of rack space. In addition, more power would be required to float charge and recharge the battery following a power failure. This will add to the heat generated in the wiring closet.

2. Use a generator to provide power specifically to the wiring closet or as part of the support for the entire facility. This will reduce the required runtime on the UPS back to approximately fifteen minutes. This becomes a more attractive solution as the load and runtime increases (see **Figure 5**).

Figure 5 – Representative TCO analysis for three different UPS loads



For more detail on determining when a standby generator is needed please see APC White Paper #52 "Four Steps to Determine When a Standby Generator is Needed for Small Data Centers and Network Rooms".

Power in the network cable

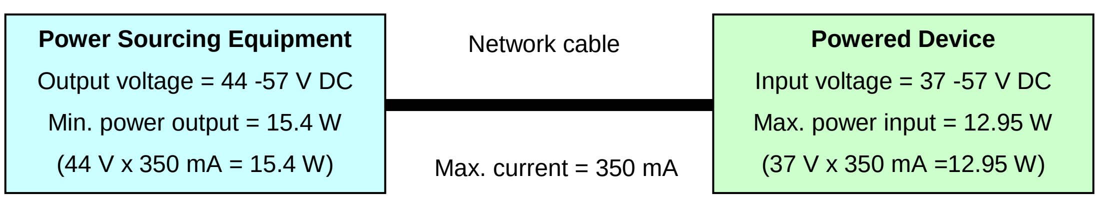
As current flows in the cable a voltage drop occurs along its length due to its resistance and results in energy being dissipated in the form of heat.

The IEEE 802.3af standard takes this voltage drop into account. As a result, PDs have a wider operating voltage range (36 V – 57 V DC) than the PSE supply range of (44 V – 57 V DC). In a worse case scenario, when the PSE is at its minimum voltage of 44 V, up to 7 V can be dropped along the length of the cable before the voltage seen by the PD is out of its operating range.

Heat from the cable can be more of an issue, especially when the cables are coming away from the network switch or midspan unit. They are tightly bundled together, thereby increasing the heating effect in that area. When powering a standard VoIP phone (which requires 3 – 5 W of power), the current flowing has minimal heat effect. However, if the network has a large number of higher power devices (12 – 15 W), then this effect should be taken into account and the cables broken down into smaller bundles.

Assuming a network cable is at its maximum length of 100 m (328 ft) and that it has a worse case resistance of 20 Ohms, then the voltage drop along the cable would be 7 V and the associated power loss in that single cable would be 2.45 W (see **Figure 6**).

Figure 6 – Illustration of voltage drop and power dissipation in a PoE network cable



Effect of power on data in the network cable

Delivering power over a network cable can introduce electromagnetic interference (EMI) as a result of noise generated by the PSE. This may cause crosstalk leading to data errors and ultimately to a reduction in data processing speed due to retransmission of data packets by upper layer protocols, such as Transmission Control Protocol. To minimize any effects ensure good quality network cables are used, Category 3 and above for 10BASE-T systems and Category 5 and above for 100BASE-TX and 1000BASE-T systems.

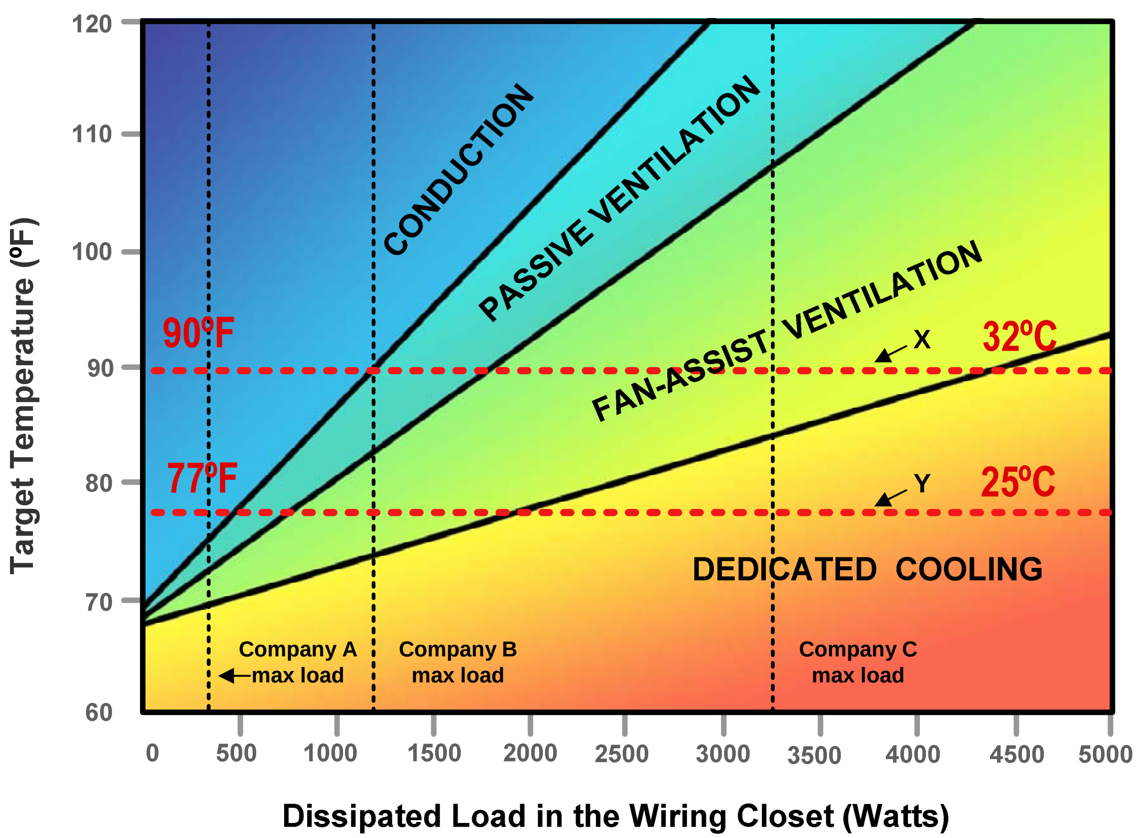
Meeting Cooling Needs in the Wiring Closet

Heat generated in the wiring closet increases when PoE is deployed. In order to achieve high availability it is essential to remove heat from the room and to maintain the equipment at a steady operating temperature. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends a maximum room temperature of 77°F (25°C) and an allowable maximum of 90°F (32.2°C). **Figure 7** plots the wiring closet temperatures and shows the heat dissipation associated with the solutions installed in Companies, A, B, and C. The lines labeled "X" and "Y" show the allowable ASHRAE limits.

Figure 7 shows the effectiveness of various cooling scenarios in the wiring closet for reducing the overall room temperature. For all but the "Dedicated Air Conditioning System" scenario it is assumed that the temperature in the main building, in which the wiring closet is situated, is maintained at a lower temperature in order to absorb heat removed from the wiring closet.

The different closet cooling approaches are also illustrated in **Figure 7** and are explained in the following section.

Figure 7 – Wiring closet temperature versus dissipated load and associated cooling



Wiring Closet Cooling Methods

The following bullets describe the various wiring closet cooling methods:

- Conduction cooling is simply the heat leaving the room through the walls and ceilings and provides an acceptable approach with light loads.

- Passive ventilation is the use of ventilation grills, as shown in **Figure 8A**, allowing heat to leave the room naturally.

- Fan assisted ventilation is the use of a fan unit, as shown in **Figure 8B**, which draws warm air out of the room thus lowering the room temperature. The "Fan Assisted Ventilation Limit" lines show the effectiveness of a single fan unit, additional units will increase the air flow and reduce the room temperature.

- Dedicated air conditioning systems offer the most effective means of maintaining a constant temperature. However, the systems add considerable cost and AC load that needs to be supported during line interruptions.

Figure 8 – Examples of passive and fan-assisted ventilation systems

Figure 8A – Passive ventilation

Figure 8B – Fan-assisted ventilation

Given the data plotted in **Figure 7**, the three sample company scenarios (Company A, Company B and Company C, from page 5) can be described as follows:

- Company "A" - Under all running conditions, conduction cooling would be sufficient to keep the temperature level below curve "Y". The maximum heat of 367 watts (1253 BTU / hr) is generated in the wiring closet when the full load is being supported and the UPS battery is being charged.

- Company "B" - Under all running conditions, the use of fan assisted ventilation at 480 cfm (cubic feet per minute) would keep the temperature below curve "Y". The maximum heat of 1198 watts (4091 BTU /

hr) is generated in the wiring closet when the full load is being supported and the UPS battery is being charged.

- Company "C" - Under all running conditions, dedicated air conditioning would be required in order to keep the room temperature below curve "Y". The maximum heat of 3237 watts (11054 BTU/hr) is generated in the wiring closet when the full load is being supported and the UPS battery is being charged.

For further details on cooling for wiring closets, please see APC White Paper #68 " Cooling Strategies for IT Wiring Closets and Small Rooms".

Conclusion

PoE deployment has prompted the development of an array of business critical applications, such as VoIP, RFID and security. As a result, the level of availability required from the physical infrastructure (i.e. power, cooling) has to be high to meet business needs. The rising number of applications also dramatically increases network traffic demands. This, in turn, requires ever greater network capacity and the associated physical infrastructure to support it. With such increasing demands, it is essential that the physical infrastructure is audited and enhanced as necessary to avoid downtime and delays.

About the Author:

Neil Whiting is a Senior Application Engineer with APC based in the UK just north of London. He has worked in the power solution industry for over 30 years starting with AC / DC power supply design through to DC power systems for the Telecommunications industry and more recently AC power solutions for the converging IT and Telecommunications industry. He has a HND in Electrical, Electronic and Control Engineering and joined APC in April 2000, when APC acquired Advance Power Systems, during which time he has fulfilled both product management and application engineering roles.

Bibliography

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2. APC White Paper #5: “Cooling Imperatives for Data Centers and Network Rooms”
3. APC White Paper #50: “Cooling Solutions for Rack Equipment with Side-to-Side Airflow”
4. APC White Paper #52 “Four Steps to Determine When a Standby Generator is Needed for Small Data Centers and Network Rooms”
5. APC White Paper #62: “Powering Single-Corded Equipment in a Dual Path Environment”
6. APC White Paper # 69 “Power and Cooling for VoIP & IP Telephony Applications”
7. APC White Paper # 79: “Technical comparison of On-line vs. Line-interactive UPS designs”

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3. Cisco Systems http://www.cisco.com
4. PowerDsine http://www.powerdsine.com

Appendix

The following tables show the detail and assumption behind the information presented in Tables 3, 4 & 5.

Table A1 – Calculations and assumptions for the network systems without PoE - Reference Table 3

System without PoE	**Company "A" 50 People supported**			**Company "B" 100 People supported**			**Company "C" 200 People supported**		
Actual number of Ethernet ports	**96**			**168**			**336**		
Existing network system without PoE		Watts	BTU / hr		Watts	BTU / hr		Watts	BTU / hr
Switch load on PSU		68			620			1240	
Switch load on UPS with PSU efficiency = 75%		90			827			1653	
Total system load on the UPS		**90**			**827**			**1653**	
Selected UPS rating (VA / Watts)	750VA / 500 watts			2000VA / 1400 watts			5000VA / 3500 watts		
UPS supporting the load with a fully charged battery (AC Supply On)									
Typical UPS efficiency with a 50% loading	93%			86%			93%		
UPS dissipation due to inefficiency whilst supporting required load		7			135			124	
Total AC load the in wiring closet (Switch + UPS)		**97**			**961**			**1778**	
Total thermal load in the wiring closet (Switch + UPS)			**330**			**3283**			**6071**
UPS supporting the load and charging the battery (AC Supply On)									
Typical UPS efficiency with a 50% loading	78%			81%			92%		
UPS dissipation due to inefficiency whilst supporting required load		25			194			144	
Total AC load the in wiring closet (Switch + UPS)		**115**			**1021**			**1797**	
Total thermal load in the wiring closet (Switch + UPS)			**394**			**3485**			**6137**
UPS supporting the load whilst running on battery (AC supply failure)									
Typical UPS efficiency with a 50% loading	76%			84%			92%		
UPS dissipation due to inefficiency whilst supporting required load		28			157			144	
Total thermal load in the wiring closet (Switch + UPS)		118	**404**		984	**3361**		1797	**6137**

Table A2 – Calculations and assumptions for the Network System with PoE -- Reference Table 4

System with PoE		**Company "A"**		**Company "B"**		**Company "C"**	
		50 People supported		**100 People supported**		**200 People supported**	
Actual number of Ethernet ports available with PoE		**96**		**168**		**336**	
Actual number of PoE ports used		**62**		**116**		**230**	
PoE loads on Switch & midspan PSU. Efficiency = 89%	Device load (Watts)	Device Quantity	Total Device load (Watts)	Device Quantity	Total Device load (Watts)	Device Quantity	Total Device load (Watts)
IP Phone	4	50	225	100	449	200	899
Video IP Phone	11	1	12	0	0	4	49
RFID Portal	11	0	0	5	62	5	62
Wireless device	10	3	34	5	56	8	90
Fixed camera	11	4	49	4	49	8	99
Door entry control	10	4	45	2	22	5	56
PoE load on UPS with PSU efficiency = 80%			456		799		1569
Switch Load on UPS with PSU efficiency = 75%			90		827		1653
Total system load on the UPS			**546**		**1626**		**3222**

Table A3 – Calculations and assumptions for the Network System with PoE -- Reference Table 4

System with PoE	Company "A" 50 People supported			Company "B" 100 People supported			Company "C" 200 People supported		
Actual number of Ethernet ports available with PoE	**96**			**168**			**336**		
Actual number of PoE ports used	**62**			**116**			**230**		
Total system load on the UPS (watts)	**546**			**1626**			**3222**		
Selected UPS rating (VA / watts)	1500VA / 1425 watts			5000VA / 3500 watts			8000VA / 5600 watts		
UPS supporting the load with a fully charged battery (AC Supply On)	%	Watts	BTU / hr	%	Watts	BTU / hr	%	Watts	BTU / hr
Typical UPS efficiency with a 50% loading	96%			93%			90%		
UPS dissipation due to inefficiency whilst supporting required load		23			122			358	
Total AC load in the wiring closet (Switch + PoE + UPS)		**569**			**1748**			**3580**	
Total thermal load dissipated in the wiring closet (Switch + PoE + UPS)		244	**834**		1179	**4027**		2463	**8412**
UPS supporting the load and charging the battery (AC Supply On)									
Typical UPS efficiency with a 50% loading	79%			92%			74%		
UPS dissipation due to inefficiency whilst supporting required load		145			141			1132	
Total AC load in the wiring closet (Switch + PoE + UPS)		**692**			**1767**			**4354**	
Total thermal load dissipated in the wiring closet (Switch + PoE + UPS)		367	**1252**		1198	**4092**		3237	**11055**
UPS supporting the load whilst running on battery (AC supply failure)									
Typical UPS efficiency with a 50% loading	92%			92%			86%		
UPS dissipation due to inefficiency whilst supporting required load		48			141			525	
Total thermal load dissipated in the wiring closet (Switch + PoE + UPS)		269	**919**		1198	**4092**		2630	**8980**
Thermal loading outside the wiring closet									
Total thermal load dissipated outside the wiring closet (PoE devices)		325	**1110**		569	**1943**		1117	**3815**