Power and Cooling for VoIP and IP Telephony Applications

White Paper 69
Revision 1

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> Executive summary

Voice over IP (VoIP) deployments can cause unexpected or unplanned power and cooling requirements in wiring closets and wiring rooms. Most wiring closets do not have uninterruptible power available, and they do not provide the ventilation or cooling required to prevent equipment overheating. Understanding the unique cooling and powering needs of VoIP equipment allows planning for a successful and cost effective VoIP deployment. This paper explains how to plan for VoIP power and cooling needs, and describes simple, fast, reliable, and cost effective strategies for upgrading old facilities and building new facilities.

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Schneider Electric

Introduction

To replace legacy telecommunications and the PBX phone systems, VoIP and IP telephony will have to deliver similar or higher availability. One of the major reasons why the legacy PBX system has high availability is the fact that it has built-in battery back-up with a long runtime, providing power to the phone over the network. IP telephony will have to exploit the field proven, time tested concept of providing power with signal to deliver the expected availability. Hence the legacy wiring closet, which used to house passive devices like patch panels and hubs will now need to accommodate high power switches, routers and uninter-ruptible power supplies (UPS) with a long runtime. Cooling and airflow in these wiring closets now become important to ensure their continuous operation.

A typical IP telephony network is built in layers and each layer is made of components that reside in one of the four physical locations (**Figure 1**). Power and cooling requirements for these four locations vary as described in the following sections.
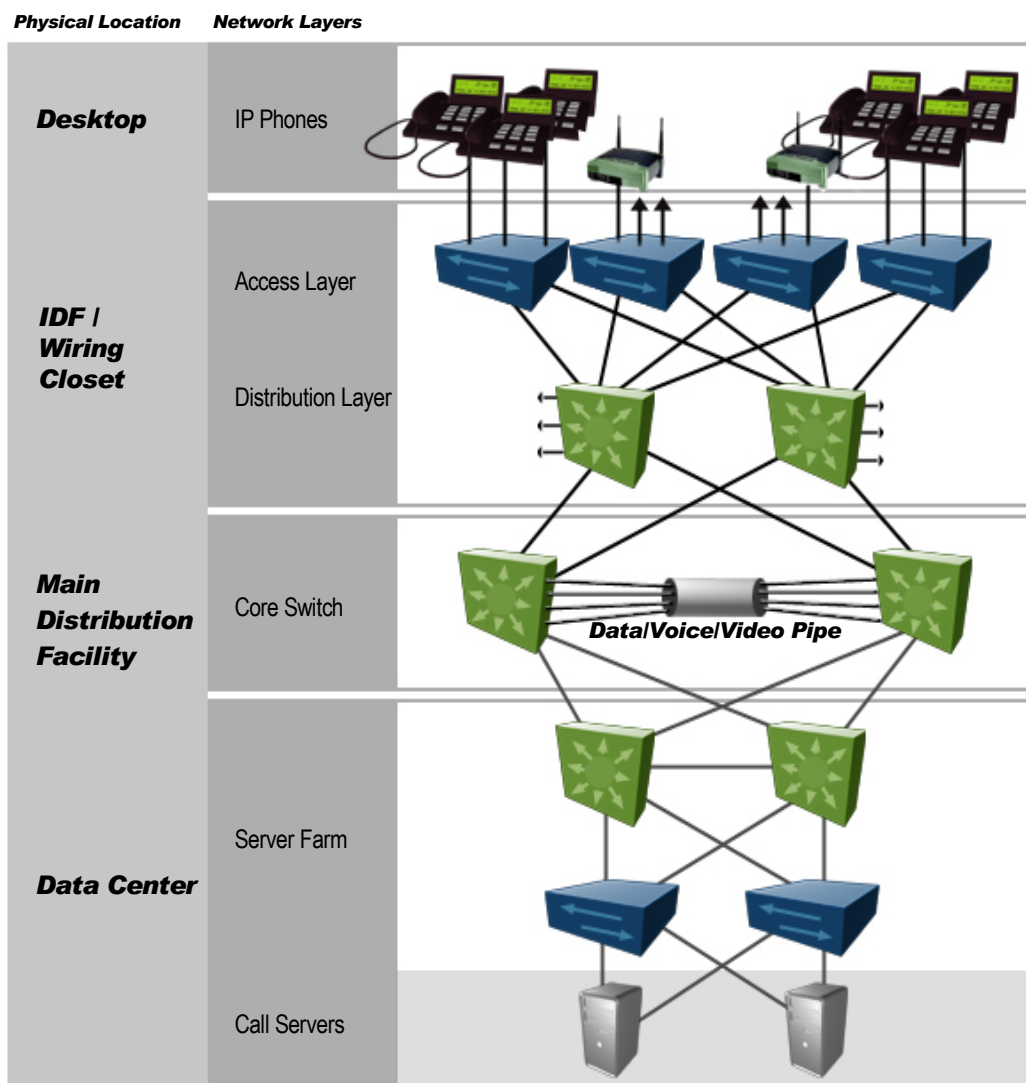
Figure 1

Typical IP telephony network layers and locations

Communications devices

Typical communications devices/endpoints are, IP phones (**Figure 2a**), wireless hubs (**Figure 2b**), as well as laptops running soft phones providing standard telephony functions. These IP phones typically draw 6-7 Watts but some devices may draw more power. A new draft regulation, IEEE 802.3af limits the average current drawn by such devices from CAT5 cables to 350mA and specifies the pins through which power can be transmitted. The network complying with this new standard will deliver approximately 15W of power up to a distance of 100 m (328 ft). For higher power consumption the communications devices will have to rely on other external power sources, like plug-in adaptors.

Figure 2a (left)

IP phone

2b (right)

Wireless hub

Environment

These communications devices are located on desktops, sometimes wall mounted and used in office environment. For newly deployed or upgraded networks they will be most likely powered from the data lines. However in some cases they must be powered from the wall outlets.

Problems

IP phones typically need to be as available as the legacy PBX phones they replace. The biggest problem to be solved here is to ensure their continuous operation even during an extended power outage.

Best practices

Sending power over the data line to the phone (so-called In-line power) is the best way to solve this problem. This way you eliminate the problem of ensuring power at the desktop location. The power is now being fed to the phone by the network switch located in the wiring closet supported by a UPS system with long runtime. For those communications devices powered from wall outlet (not using in-line power) a UPS system with a long battery back-up time (four, six, eight hours or more) can be provided.
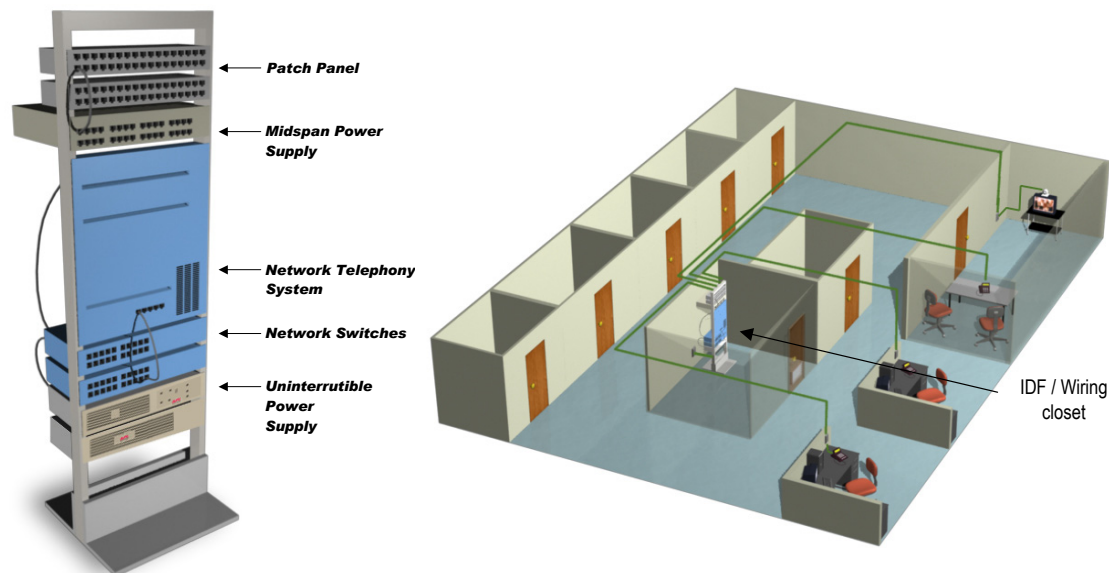
Intermediate distribution frame (IDF)

IDF or wiring closets comprises of layer 2, layer 3 access and distribution switches, hubs, routers, patch panels, UPS system with a battery back-up as well as any other miscellaneous telecommunications equipment mounted in a two post rack (**Figure 3a** and **3b**). Many new switches have built in capability to supply power over the data lines (so-called 'end-span' power supplies) to feed power to the communications devices. For switches without this capability, an appropriately sized external 'mid-span' power supply is used to inject in-line power.

Figure 3a (left)

IDF (wiring closet)

3b (right)

Typical layout of IDF

Environment

These IDFs or wiring closets are typically hidden in some remote location of the building with little or no ventilation and illumination. Unless the customer is moving into a new building, they most likely will want to reuse these wiring closets. Legacy telecommunication networks typically used wiring closets mainly for punchdown blocks, patch panels, and a few small stackable hubs or switches, but most of the new IP telephony equipment uses and dissipates considerably more power. These new IP telephony switches are generally 19" (482.6 mm) rack mount type and have varying air flow pattern depending on the manufacturers e.g. side to side, front to back etc. A typical IDF will house 1-3 racks worth of equipment, and draw 500 W to 4000 W of single phase AC power.

Problems

While deploying VoIP and IP Telephony these IDFs need the most attention in terms of power and cooling. They draw power in the range of 500W to as high as 4000 W single phase at either 120 or 208 VAC, depending on the network architecture and the type of switch used. Ensuring the right type of receptacle (e.g. L5-20, L5-30, L6-20, L6-30) and right amount of power with the right circuit breaker protection to all the network equipment, UPS and PDU in the wiring closet is a challenge. Cooling and airflow are often a bigger but often ignored problem to address in these wiring closets.

Best practices

All equipment in the IDF should be protected by a UPS system. The selection of the UPS system is based on:

- The total power required in Watts
- The run time required in minutes
- The level of redundancy or fault tolerance desired
- The voltages and receptacles required

The UPS system is sized to the sum of the Watt ratings of the loads. A common rack-mount UPS like the APC Smart-UPS (**Figure 4a**) will provide approximately four nines (99.99%) of power availability, while an N+1 redundant, UPS with built in bypass, like the APC Symmetra RM (**Figure 4b**), with one hour runtime will provide approximately five nines (99.999%), which may be sufficient for most applications. See **Appendix** for details on availability analysis.

Figure 4a (left)

APC Smart-UPS

4b (right)

APC Symmetra RM

UPS products are available with battery packs to provide different durations of run time. Products of the type shown in **Figures 4a** and **4b** have optional battery packs, which can be used to extend run time to up to 24 hours.

Higher levels of availability like six or seven nines may be needed for some critical applications like 911 services. Such requirements may be met by using dual network switches with dual power cords, dual UPS, and concurrently maintainable electrical architectures with generator back-up. Many companies like American Power Conversion Corporation by Schneider Electric have dedicated availability consulting services to evaluate and recommend high availability power infrastructures for such critical networks.

Finally, identify the plugs and receptacles required for all the equipment including the UPS in the wiring closet. Ideally all the equipment should be directly plugged into the back of the UPS or the transformer, and the use of additional outlet strips or rack PDUs should be avoided. However if there is a lot of equipment it may not be practical and a rack PDU strip should be used. In that case a high-grade rack PDU specifically designed for the purpose should be used. The PDU should have enough receptacles to plug all the current equipment with some spares for future needs. PDUs with a meter displaying the current power consumption are preferred as they reduce human errors like accidental overloading and resultant load drops.

For the correct selection of the appropriate UPS model meeting the required power level, redundancy, voltage, and run time the process is simplified by using a UPS selector such as the UPS selector. This system has power data for all popular switches, servers and storage devices, which avoids the need to collect this data. In systems like this, the choice of configuring a UPS will provide various receptacle options

To ensure continuous operations of the equipment in the wiring closet 7 x 24 x 365, cooling and airflow issues must be identified and addressed. Power dissipation in the wiring closet should be calculated to decide on a cost effective way to solve the problem (see **Table 1**). The most important thing to note here is that many network switches draw a lot of power; however that does not mean they dissipate all the power consumed in the wiring closet. For example a layer 2 switch may draw 1800 W of power but it may be dissipating only 200 - 500 W in the closet. The rest of power is supplied over the network to the various IP phones scattered and dissipated all over the office area.

Table 1

VoIP wiring closet heat output calculation worksheet

Item	Data required	Heat output calculation	Heat output subtotal
Switches without in-line power, other IT equipment (except mid-span power units)	Sum of input rated power in Watts	Same as total IT load power in watts	_____ Watts
Switch with in-line power capability	Input rated power in Watts	0.6 x Input power rating	_____ Watts
Mid-span power units	Input rated power in Watts	0.4 x Input power rating	_____ Watts
Lighting	Power rating of any lighting devices permanently on in Watts	Power rating	_____ Watts
UPS system	Power rating of the UPS system (not the load) in Watts	0.09 x UPS power rating	_____ Watts
Total	Subtotals from above	Sum the above heat output subtotals	_____ Watts

Once power dissipated in the wiring closet is calculated follow the broad guidelines outlined in **Table 2**.

Table 2

VoIP wiring closet cooling solutions worksheet

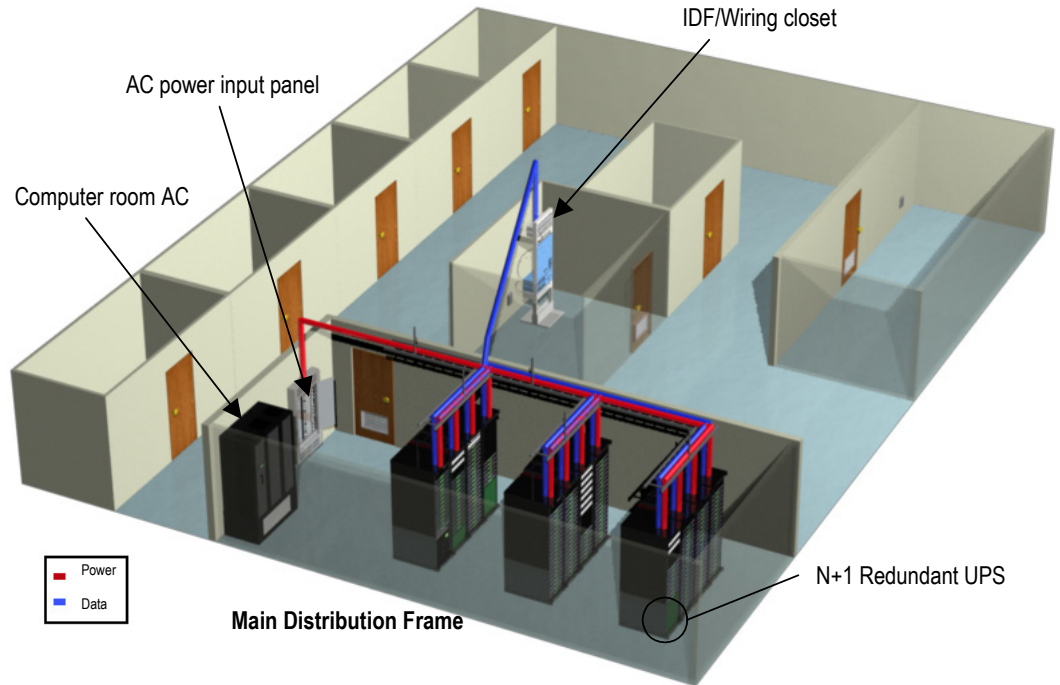| Total heat load in closet	Condition	Analysis	Action
< 100 W	Balance of building is conditioned space	Wall conduction and infiltration will be sufficient	None
< 100 W	Balance of building is hostile space, no HVAC system	Any fresh air from outside the room cannot be considered safe to use due to temperature or contaminants	Install a self-contained computer air conditioner in the closet adjacent to the equipment
100 – 500 W	Dropped ceiling (overhead) HVAC system exists, Balance of building is conditioned space	Fresh air from outside closet will be sufficient if drawn through, but door may block air. Bring air in through door and exhaust to HVAC return	Place a return grille in overhead ventilation system in top of closet, and place a vent in bottom half of closet door.
100 – 500 W	No access from closet to any HVAC system. Balance of building is conditioned space	Fresh air from outside closet will be sufficient if drawn through, but door may block air. Bring air in bottom of door and exhaust out top of door	Place an exhaust grille in top of closet door, and place an intake vent in bottom half of closet door.
500 – 1000 W	Dropped ceiling (overhead) HVAC system exists, Balance of building is conditioned space	Fresh air from outside closet will be sufficient if drawn through continuously, but door may block air and continuous fan operation is required and not assured	Place a return grille with ventilation fan assist in top of closet, and place a vent in bottom half of closet door.
500 – 1000 W	No access from closet to any HVAC system. Balance of building is conditioned space	Fresh air from outside closet will be sufficient if drawn through continuously, but no way to get the air.	Place an exhaust grille with ventilation fan assist in top of door, and place a vent grille in the bottom half of closet door.
> 1000 W	Dropped ceiling (overhead) HVAC system exists and is accessible, Balance of building is conditioned space	Fresh air from outside closet will be sufficient if drawn directly through the equipment and no hot exhaust air from the equipment recirculates to the equipment intake	Put equipment in an enclosed rack with a hot exhaust air scavenging system and place a vent grille in bottom half of closet door.
> 1000 W	HVAC system is not accessible, Balance of building is conditioned space	Moving air through the door is insufficient, local cooling of the equipment exhaust air is required	Install a self-contained computer air conditioner in the closet adjacent to the equipment

Finally, environmental monitoring (e.g. temperature and humidity) for these wiring closets is highly recommended as it will help flag any abnormal conditions, allow for enough time to take pro-active measures and avoid downtime.

Main distribution frame (MDF)

MDFs are also called MERs (main equipment rooms) or POP (point of ping or presence) rooms. They house the most critical VoIP and IP telephony equipment like layer 3 routers, switches and a variety of other networking, IT and telecommunications equipment (**Figure 5**). The typical T1 and T3 lines terminate into MDFs and provide connectivity to the Internet back bone.

Figure 5

Main distribution frame

Environment

MDFs are generally located in the basement or first floor, providing building services entrance. A typical MDF may have 4-12 racks worth of equipment and draw 4 kW to 40 kW single or three-phase 208 VAC power. There may be some equipment requiring –48 VDC power. The majority of the racks in MDFs are two post open racks used to mount a variety of IP telephony and IT equipment. This equipment may have different airflow patterns e.g. side to side, front to back etc. and can be 19" (482.6 mm) or 23" (588.8 mm) rack mount type. However the majority of the new IP telephony and IT equipment are 19" rack mount type.

Problems

Some MDF rooms do not have a UPS, many do not have adequate battery back-up time and often times may not have dedicated precision air-cooling system.

Best practices

Since these MDFs house a variety of critical network, IT and telephony equipment they should be treated like a small data center or a computer room. To get approximately five nines of power availability the MDF room should be protected by modular, redundant UPS with internal bypass and at least thirty minutes of back-up time. Higher runtimes with higher levels of availability, like six or seven nines, can be provided by using dual switches with dual cords, dual UPS, and concurrently maintainable electrical architectures with generator back up. Companies like Schneider Electric have dedicated availability consulting services to evaluate and recommend high availability architecture for such critical network infrastructure.

MDFs should have their own precision air conditioning units with environmental monitoring. Redundant air conditioning units should be considered for critical applications needing higher availability. For high power density racks (> 3 kW/Rack) additional air distribution and air

removal units should be used to avoid hot spots. Unlike servers and storage devices, many switches utilize side-to-side airflow. This creates special issues when installing in an environment which uses enclosed racks. These issues are discussed in detail in White Paper 50, *Cooling Solutions for Rack Equipment with Side-to-Side Airflow*.

Data center or server farm

The data center or server farm (**Figure 6**), houses all the IP telephony application servers with their software e.g. call managers, unified messaging etc. In addition, based on the network architecture and the size of the organization it may also house core switches (layer 3) and distribution switches (layer 2). Depending on their size (small, medium or large) a typical data center or server farm can house from tens to hundreds of racks, loaded with tens or hundreds of servers and a variety of IT, Networking and computing systems running business critical applications like ERP, CRM and other Web based services.
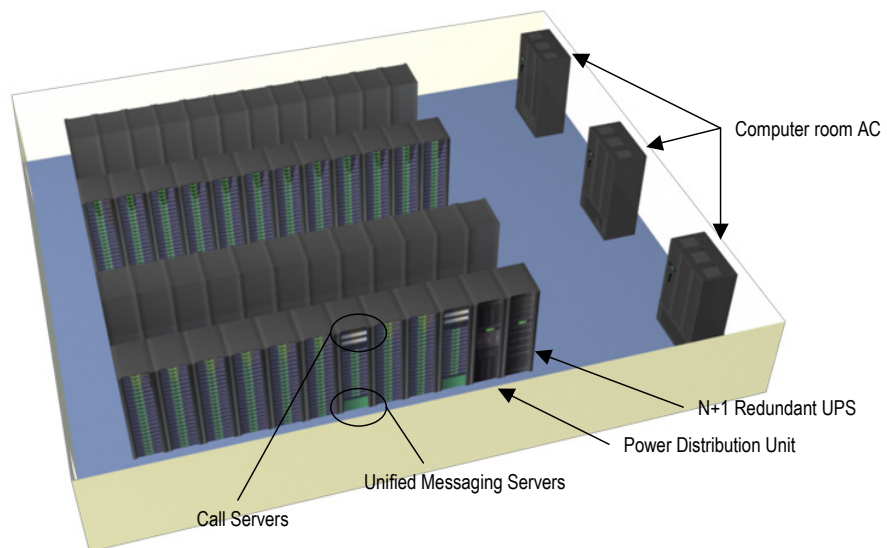
Figure 6

Typical data center or server farm

Computer room AC

N+1 Redundant UPS

Power Distribution Unit

Unified Messaging Servers

Call Servers

Environment

Data centers are generally located at corporate office drawing 10 kW single or three-phase 208 VAC power on the lower side, to hundreds of kilowatts of 3 phase 480 VAC power of the higher side. There can be some small –48 V DC power requirement for some telecommunications loads but predominantly it will be all AC power loads. The majority of data centers have a UPS with battery back-up, generator and precision air conditioning units.

Problems

IP telephony servers and switches are basically incidental incremental load to the data center which may require higher runtime, redundancy and availability then other IT and networking equipments.

Best practices

Even though the data center may have its own UPS and generator many times it might be appropriate to provide for a separate, redundant UPS with longer battery back-up time for the IP telephony equipment. Identify and group the IP telephony gear requiring longer runtime and higher availability in a separate area, in separate racks within the data center. Provide them with a dedicated UPS with longer runtime and N+1, N+2, availability as needed. This

concept of "targeted availability" helps increase availability of business critical IP telephony equipment without having to incur a large capital expense for the entire data center. Higher levels of redundancy like dual feeds with dual generators and dual N+1 UPS with dual power paths all the way to the server and other critical equipment in the rack may be considered for highly available data centers and networks.

Ensure that the data center's precision air conditioning equipment has enough cooling capacity for the new additional IP telephony equipment. Redundant air conditioning units may be considered for higher availability. For high power density racks (> 3 kW/Rack) additional air distribution and air removal units should be used to avoid hot spots. Avoidable mistakes that are routinely made when installing cooling systems and racks in data centers or network rooms compromise availability and increase costs. For more information on this topic refer to White Paper 49, *Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms*.

Related resource
White Paper 49

Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms

Conclusion

There are no problems with the communications devices as they are used in office environments. Similarly there are no major problems in the data center or server farms as IP telephony equipment is just incidental incremental load. However, 'targeted availability' may be provided to critical IP telephony servers and switches. With MDFs there may be a limited problem with available run time, which can be solved by providing a generator or a larger battery back-up with UPS. The biggest problems in terms of power and cooling lie within the wiring closets. Small, dedicated UPS with extended runtime is a cost effective solution compared to one big centralized UPS powering all wiring closets. Cooling is a special problem for wiring closets, in many cases ventilation alone is sufficient. In some cases targeted spot air conditioning is required.

Resources
Click on icon to link to resource

The Different Types of UPS Systems
White Paper 1

Essential Cooling System Requirements for Next Generations of Data Centers
White Paper 5

Effects of UPS on System Availability
White Paper 24

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Cooling Solutions for Rack Equipment with Side-to-Side Airflow
White Paper 50

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Appendix

Availability analysis approach

Schneider Electric's Data Center Science Center uses an integrated availability analysis approach to calculate availability levels. This approach uses a combination of Reliability Block Diagram (RBD) and state space modeling to represent the environment to be modeled. RBDs are used to represent subsystems of the architecture, and state space diagrams, also referred to as Markov diagrams, are used to represent the various states the electrical architecture may enter. For example when the utility fails the UPS will transfer to battery. All data sources for the analysis are based on industry-accepted third parties such as IEEE and RAC (**Table A2**). These statistical availability levels are based on independently validated assumptions.

Joanne Bechta Dugan, Ph.D., Professor at University of Virginia-
"[I have] found the analysis credible and the methodology sound. The combination of Reliability Block Diagrams (RBD) and Markov reward models (MRM) is an excellent choice that allows the flexibility and accuracy of the MRM to be combined with the simplicity of the RBD."

An availability analysis is done in order to quantify the impact of various electrical architectures. The availabilities of 26 different architectures were calculated and compared against each other. Six architectures where then chosen to represent the GOOD, BETTER and BEST architecture for both a wiring closet and data center. The choices were based on cost / availability trade-offs. The six architectures chosen are shown below along with their availability results.
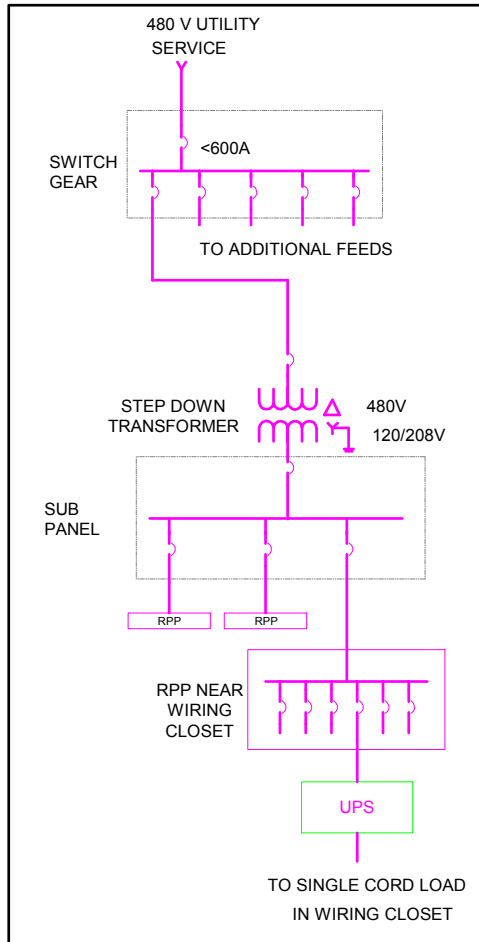
Architectures for wiring closet or IDF

GOOD
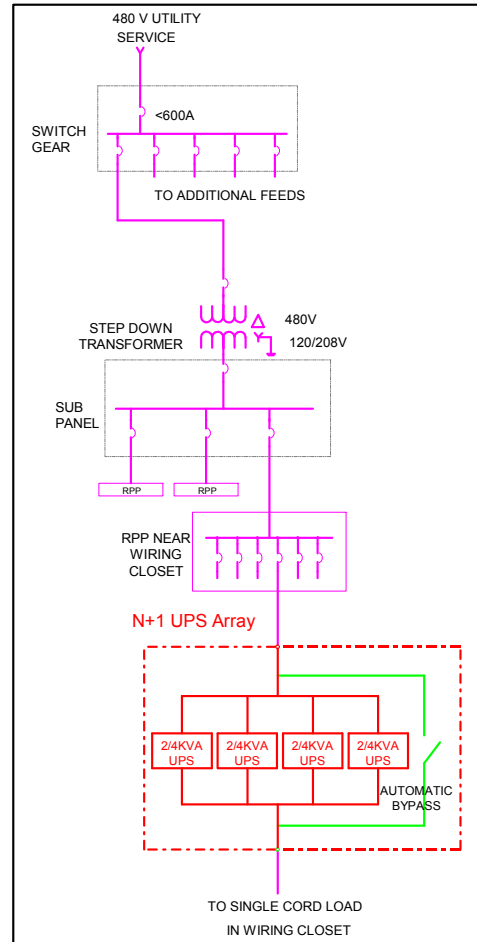
SINGLE CORD LOAD

Battery Runtime = 1 Hr

4-9s
99.9979872%

BETTER

SINGLE CORD LOAD

Battery Runtime = 1 Hr

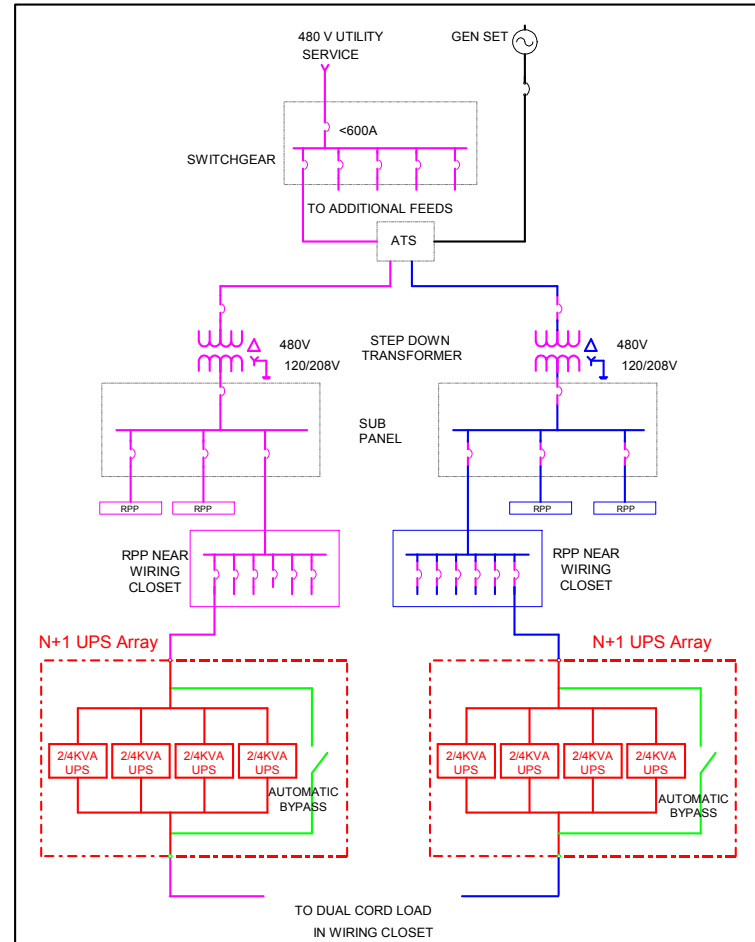5-9s
99.99938958%

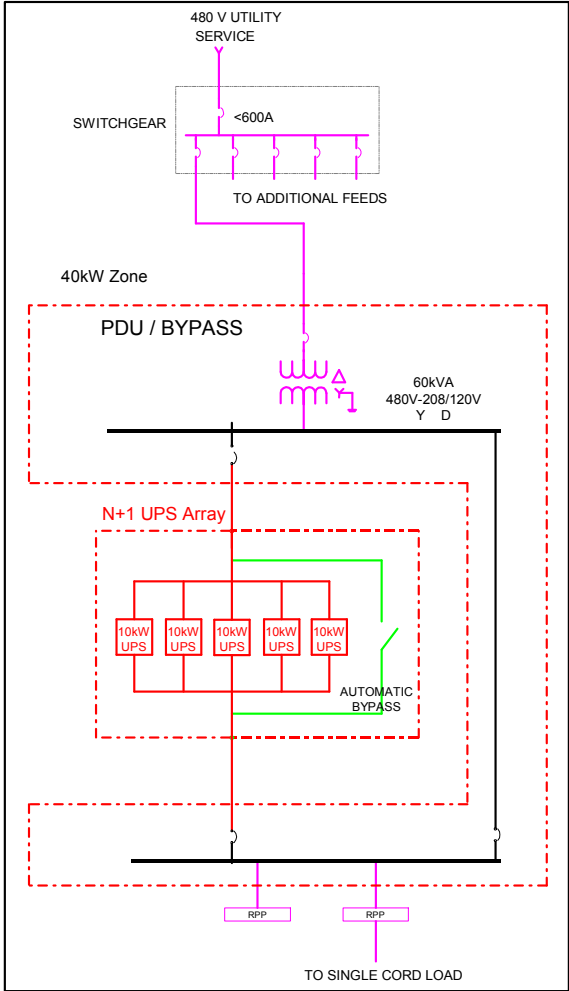**BEST**

DUAL CORD LOAD

Battery Runtime = 1 Hr

6-9s
99.99995489%

Architectures for data center or MDF
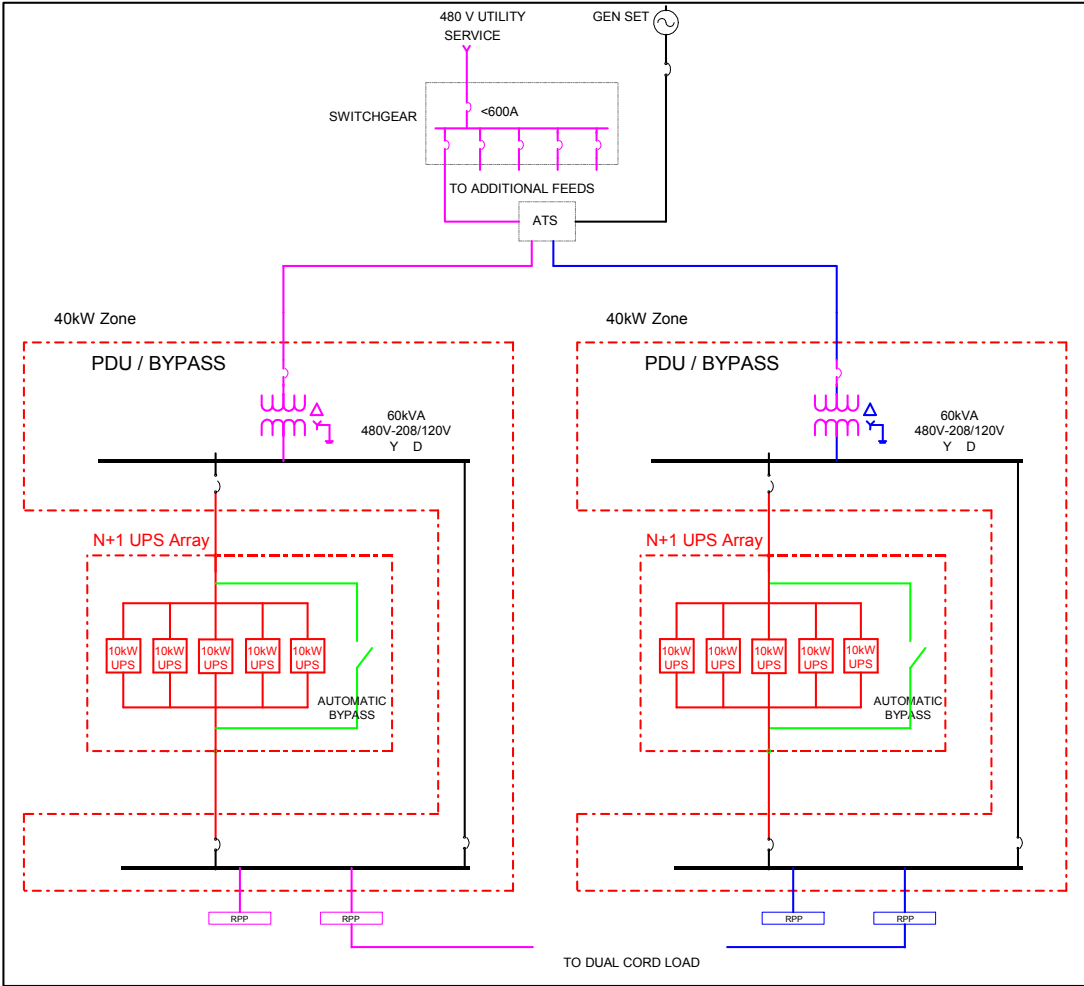

GOOD

SINGLE CORD LOAD

Battery Runtime = 1/2 Hr

4-9s
99.99860878%

BETTER

DUAL CORD LOAD

Battery Runtime = 1/2 Hr

6-9s
99.99994652%

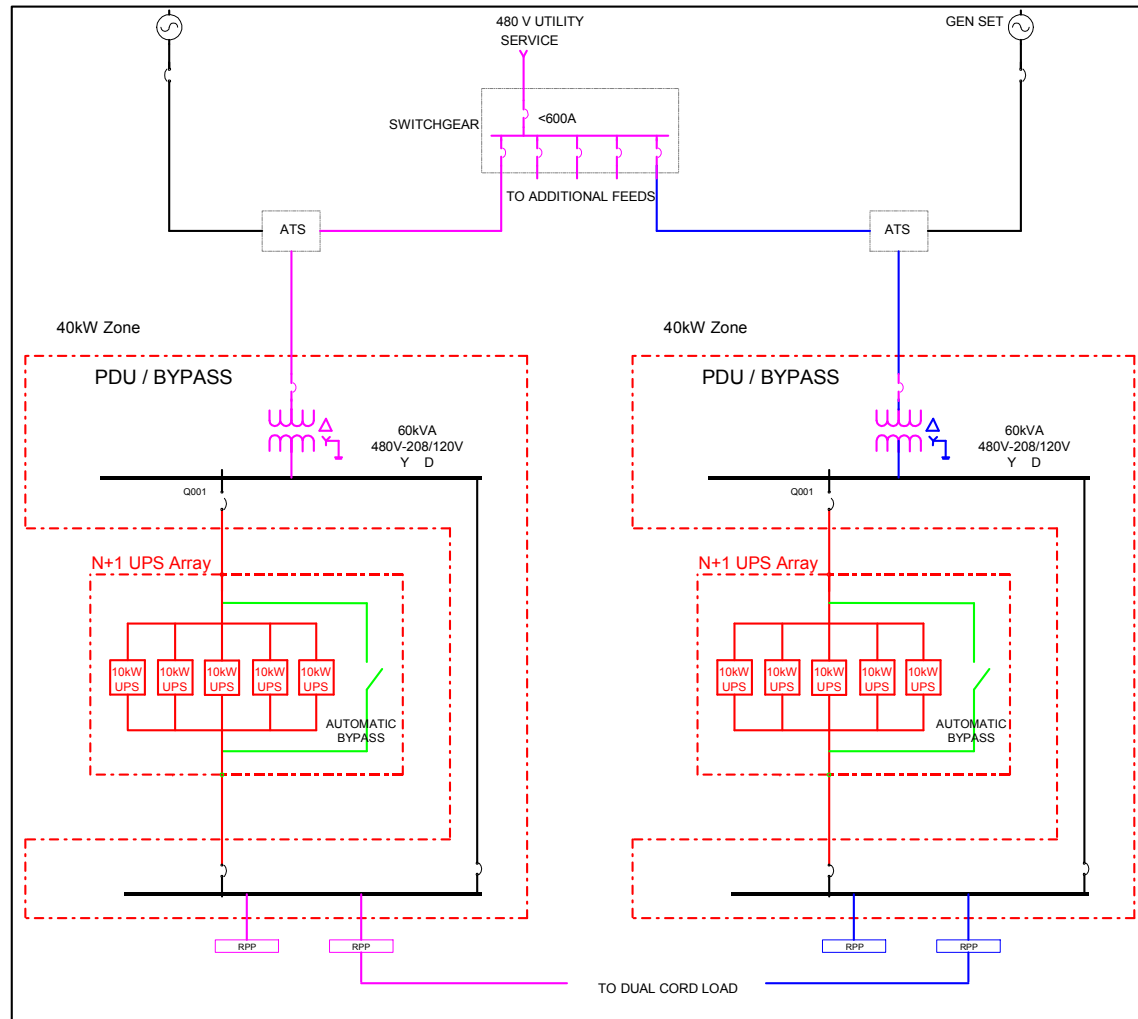## Architectures for data center or MDF

BEST

DUAL CORD LOAD

Battery Runtime = 1/2 Hr

7-9s
99.99999517%

Data used in analysis

Most of the data used to model the architectures is from third party sources. Data for the rack ATS is based on field data for Schneider Electric's rack ATS product, which has been on the market for approximately 5 years and has a significant installed base. In this analysis the following key components are included:

1. Terminations
2. Circuit breakers
3. UPS systems
4. PDU
5. Static transfer switch (STS)
6. Rack ATS
7. Generator
8. ATS

The PDU is broken down into three basic subcomponents: Circuit breakers, step-down transformer and terminations. The subpanel is evaluated based on one main breaker, one branch circuit breaker and terminations all in series. The **Table A2** includes the values and sources of failure rate $\left(\dfrac{1}{MTTF} \right)$ and recovery rate $\left(\dfrac{1}{MTTR} \right)$ data for each subcomponent, where MTTF is the mean time to failure and MTTR is mean time to recover.

Assumptions used in the analysis

As with any availability analysis, assumptions must be made to create a valid model. These are listed in **Table A1**.

Table A1

Assumptions of analysis

Assumption	Description
Reliability data	Most of the data used to model the architectures is from third party sources. Where no data was available industry estimates were used. See Table A2 for reliability data summary.
Failure rates of components	All components in the analysis exhibit a constant failure rate. This is the best assumption, given that the equipment will be used only for its designed useful life period. If products were used beyond their useful life, then non-linearity would need to be built into the failure rate.
Repair teams	For "n" components in series it is assumed that "n" repairpersons are available.
System components remain operating	All components within the system are assumed to remain operating while failed components are repaired.
Independence of failures	These models assume construction of the described architectures in accordance with Industry Best Practices. These result in a very low likelihood of common cause failures and propagation because of physical and electrical isolation.
Failure rate of wiring	Wiring between the components within the architectures has not been included in the calculations because wiring has a failure rate too low to predict with certainty and statistical relevance. Also previous work has shown that such a low failure rate minimally affects the overall availability. Major terminations have still been accounted for.
Human error	Downtime due to human error has not been accounted for in this analysis. Although this is a significant cause of data center downtime, the focus of these models is to compare power infrastructure architectures, and to identify physical weaknesses within those architectures. In addition, there exists a lack of data relating to how human error affects the availability.
Power availability is the key measure	This analysis provides information related to power availability. The availability of the business process will typically be lower because the return of power does not immediately result in the return of business availability. The IT systems typically have a restart time which adds unavailability that is not counted in this analysis
No benefit of fault isolation	The failure of any critical load is considered a failure, and equivalent to the failure of all loads at once. For some businesses, the failure of a single load is of less business consequence than the failure of all critical loads. In this analysis only one load was analyzed.

Table A2

Components and values

Component	Failure rate	Recovery rate	Source of data	Comments
Raw utility	3.887E-003	30.487	EPRI - Data for utility power was collected and a weighted average of all distributed power events was calculated.	This data is highly dependent on geographic location.
Diesel engine generator	1.0274E-04	0.25641	IEEE Gold Book Std 493-1997, Page 406	Failure Rate is based on operating hours. 0.01350 failures per start attempt per Table 3-4 pg 44.
Automatic transfer switch	9.7949E-06	0.17422	Survey of Reliability / Availability - ASHRAE paper # 4489	
Termination, 0-600 V	1.4498E-08	0.26316	IEEE Gold Book Std 493-1997, Page 41	
6 terminations	8.6988E-08	0.26316	Computed from value by IEEE Gold Book Std 493-1997, Page 41	Upstream of the transformer, one termination exists per conductor. Since there are 2 sets of terminations between components a total of six terminations are used.
8 terminations	1.1598E-07	0.26316	Computed from value by IEEE Gold Book Std 493-1997, Page 41	Downstream of the transformer, one termination exists per conductor plus the neutral. Since there are 2 sets of terminations between components a total of eight terminations are used.
Circuit breaker	3.9954E-07	0.45455	IEEE Gold Book Std 493-1997, Page 40	Fixed (including Molded case), 0-600A
PDU transformer, stepdown	7.0776E-07	0.01667	MTBF is from IEEE Gold Book Std 493-1997, Page 40, MTTR is average given by Marcus Transformer Data and Square D.	<100kVA
Static transfer switch	4.1600E-06	0.16667	Gordon Associates, Raleigh, NC	Failure Rate includes Controls; Recovery Rate was not given by ASHRAE for this size STS, so the value used is from the 600-1000A STS
UPS backplane	7.0000E-07	0.25000	Estimate based on Symmetra field data	
UPS with bypass	4.00E-06	3.00000	Failure Rate is from Power Quality Magazine, Feb 2001 issue, Recovery Rate data is based on assumption of spare part kept on site.	This failure data assumes a modular UPS with Bypass.
UPS no bypass	3.64E-05	3.00000	Failure Rate is from Power Quality Magazine, Feb 2001 issue, Recovery Rate data is based on assumption of 4 hours for service person to arrive, and 4 hours to repair system	UPS without bypass. MTBF is 27,440 hrs without bypass per MGE "Power Systems Applications Guide"

State space models

Six state space models were used to represent the various states in which the six architectures can exist. In addition to the reliability data, other variables were defined for use within the six state space models (**Table A3**).

Table A3

State space model variables

Variable	Value	Source of data	Comments
PbypassFailSwitch	0.001	Industry average	Probability that the bypass will fail to switch successfully to utility in the case of a UPS fault.
Pbatfailed	0.001	Gordon Associates - Raleigh, NC	Probability that the UPS load drops when switching to battery. Includes controls
Pbatfailed (redundant UPS)	0.000001	The square of the value above	Assumes both UPS battery systems to be completely independent
Tbat	1 or ½ hour		Battery runtime dependent on scenario
Pgenfail_start	0.0135	IEEE Gold Book Std 493-1997, Page 44	Probability of generator failing to start. Failure Rate is based on operating hours. 0.01350 failures per start attempt per Table 3-4 pg 44. This probability accounts for ATS as well.
Pgenfail_start (redundant UPS)	0.00911	50 x the square of the value above	Pgenfailed was reduced by a factor of 50 to account for common cause failures between redundant generator sets
Tgen_start	0.05278	Industry average	Time delay for generator to start after a power outage. Equates to 190 seconds