

# Power Protection for Digital Medical Imaging and Diagnostic Equipment

## White Paper 86

Revision 2

by Viswas Purani

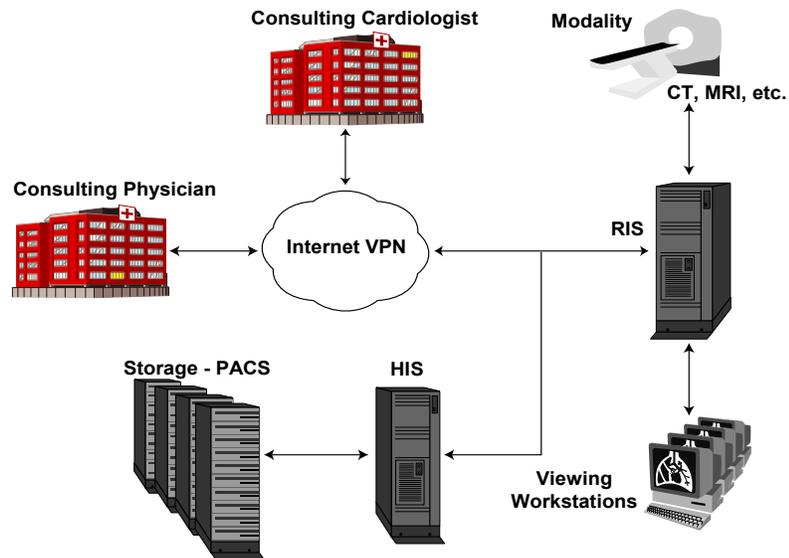
### Executive summary

Medical imaging and diagnostic equipment (MIDE) is increasingly being networked to Picture Archiving and Communications Systems (PACS), Radiology Information Systems (RIS), Hospital Information Systems (HIS), and getting connected to the hospital intranet as well as the Internet. Failing to implement the necessary physical infrastructure can result in unexpected downtime, and safety and compliance issues, which translates into lost revenue and exposure to expensive litigations, negatively affecting the bottom line. This paper explains how to plan for physical infrastructure when deploying medical imaging and diagnostic equipment, with emphasis on power and cooling.

## Introduction

The proliferation of information technology (IT) and other high technologies into medical imaging and diagnostic equipment over the years has resulted in the evolution of powerful new devices in the field of diagnostics and interventional radiology. The information generated and carried by these images is crucial to the treatment in cardiology, neurology, oncology, gynecology & obstetrics, orthopedics, surgery, and pulmonary medicine. These new developments have helped in the early detection and treatment of diseases and significantly improved patient care. A typical medical imaging and diagnostic equipment network is illustrated in **Figure 1**. This equipment can be broken down into five broad sub-categories:

1. Modalities that capture or generate the images
2. Picture Archiving and Communications Systems (PACS) that store the generated images and make them available to the physicians and nurses for diagnosis and treatment
3. Radiology Information Systems (RIS) and Hospital Information Systems (HIS) that monitor and manage the work flow of radiology departments and entire hospitals, all the way from the patient check-in, to scheduling and billing, to generating electronic medical records and management reporting
4. Computed Radiography (CR) that helps convert films to digital images on cassettes or Digital Radiography (DR) that provides cassette-less digital images
5. Laser printers that print films when required and other peripherals



**Figure 1**

*Typical MIDE network*

Modalities are high-tech medical imaging systems including Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), Ultrasound (US), and Electro-Cardiogram (ECG). They get connected to a PACS and to RIS/HIS through Local Area Networks (LANs), and/or Wireless Local Area Networks (WLANs), or Wide Area Networks (WANs). PACS may have their own Storage Area Networks (SANs) or Network Attached Storage (NAS) and the RIS and HIS may be made of several clusters of servers and a number of workstations distributed in different departments of the hospitals. Because of their numerous benefits combined with the enormous pressure on the hospitals to improve quality of care, reduce errors, comply with federal regulations like HIPAA, and simultaneously cut cost, adoption of all these technologies is inevitable, converting the traditional hospital into a “digital enterprise”.

The backbone of this new digital hospital is a network made up of different modalities, PACS and RIS/HIS, CR/DR, printers, and peripherals. This highly complex network and its components has to comply with relevant standards like Digital Imaging and Communications in Medicine (DICOM), Health Language Seven (HL7), Underwriters Laboratory (UL), Federal Communications Commission (FCC), National Electrical Code (NEC), and other applicable local and national codes such as BS7671:2001 (U.K.), NFC15-100 (France), and VDE (Germany), as well as international such as CEI IEC 60364. This imposes a huge challenge to the IT and the facilities manager to provide the right physical infrastructure. This physical infrastructure has to be reliable, scalable, highly available, and manageable. It consists of:

1. Power systems such as uninterruptible power supplies (UPSs), power distribution units (PDUs), isolation transformers, and generators to provide uninterrupted, conditioned, clean power to the critical loads
2. Precision cooling systems that provide optimal environment by regulating temperature and humidity
3. Racks that house the critical network equipment like servers, switches, routers, and gateways
4. Physical security and fire protection systems
5. Cabling to interconnect equipment
6. Management systems to monitor and manage these systems, locally as well as remotely to ensure their satisfactory operation 7x24x365
7. Services to design, deliver, install, commission, operate and maintain these systems

Special attention should be given to the hospital wiring closets which allow networking of the modalities to PACS and RIS/HIS as well as other workstations and peripherals within the hospital premises. It is these backbone closets that support this complex hospital network carrying critical data, voice, and video, keeping the network up and running.

The hospital power system is a large complex electrical system consisting of high voltage transformers, automatic transfer switches (ATS), generators, isolation transformers, PDUs, etc. This power system feeds a variety of electrical loads including lighting, heating, ventilation air-conditioning (HVAC) systems, elevators, escalators, large pumps, fans, motors and more. The random nature of these loads (turning on and off randomly) creates an unstable power environment (i.e. sags and surges) that more sensitive imaging and diagnostic equipment and other IT networks that support them, must endure. Healthcare companies and hospitals faced with these challenges should engage partners like Schneider Electric with engineering expertise to perform complete physical infrastructure assessments that identify weaknesses and suggest corrective actions. This paper discusses and reviews the challenges imposed on physical infrastructure while deploying medical imaging and diagnostic equipment, with a focus on power and cooling.

## Modalities

Depending on the patient's ailment, a physician can use different modalities for diagnosis and treatment (i.e. X-Ray or CT for orthopedics, ECG or MRI for cardiology or Ultrasound for obstetrics). These modalities can be broadly classified into two categories: portable and stationary. Portables can be further classified into hand held (i.e. blood glucometer) and trolley or cart-mounted (i.e. ultrasound) while stationary devices can be further classified into desk-mounted (i.e. blood, urine analysis equipment) or floor-mounted (i.e. CT, MRI). **Figure 2** illustrates a cart-mounted ultrasound and **Figure 3** illustrates a floor-mounted MRI machine. The floor-mounted, desk-mounted, and cart-mounted devices need the most physical infrastructure planning.

**Figure 2 (left)***Cart mounted ultrasound***Figure 3 (right)***Floor mounted MRI*

## Environment

Modalities are generally used in an indoor office environment. The cart-mounted and desk-mounted modalities generally use 120 VAC, 208 VAC or 230 VAC single phase power less than 5 kVA<sup>1</sup>. The floor mounted devices typically require 208 VAC, 400 VAC or 480 VAC three-phase power, ranging from 20 kVA to 300 kVA or more. They require a lot of space and often times have their own separate room within the main hospital building or adjacent to it. They may be cooled with the building's comfort air-conditioning system or they may have a precision computer room air-conditioning (CRAC) system, which more tightly controls temperature and humidity in the environment. **Figure 4** illustrates a typical MRI facility with floor mounted equipment.

**Figure 4***Typical CT or MRI facility*

## Challenges

Modalities need to be protected from power anomalies that cause hardware failures such as blown power supplies or printed circuit boards (PCBs) as well as from system software crashes. Physical space is a major constraint for large modalities like CTs and MRIs, more so in big hospitals in urban areas, as they have no room to expand. These modalities consume a lot of power, so heat dissipation is a major challenge to the building cooling system. Often times, comfort cooling is not sufficient and precision cooling is required. One of the most critical requirements is to provide electrical isolation from the electrical utility input to protect the patient and the technicians from any shock hazards. Compliance to local, state, national, and international codes is of paramount importance (i.e. National Electrical Codes (NEC) in the United States).

<sup>1</sup> See White Paper 15, [Watts and Volt-Amps: Powerful Confusion](#) for information on kilo volt amps

## Best practices

- Since the hospital power grid is electrically “noisy and dirty” with a lot of electrical surges and sags, it is a good practice to provide UPS protection to all sensitive, expensive electronics systems, LCD displays, workstations, printers, and peripherals. The UPS system protects the hardware, avoids unwarranted system crashes while tests are in progress, prevents loss of patient data files, and provides safe, reliable radiology examinations.
- UPS systems used in the hospital should meet the following stringent standards:
  - UL1778 – American Standard for UPS
  - CSA22.2 No. 107.1 – Canadian Standard of UPS
  - FCC Part 15 Class A – American Standard for Electromagnetic Radiation
  - ANSI C62.41- American Standard for surge withstand capability
  - IEC60950 – International Standard for UPS Systems
  - EN50091-1- European Standard for Electromagnetic compatibility

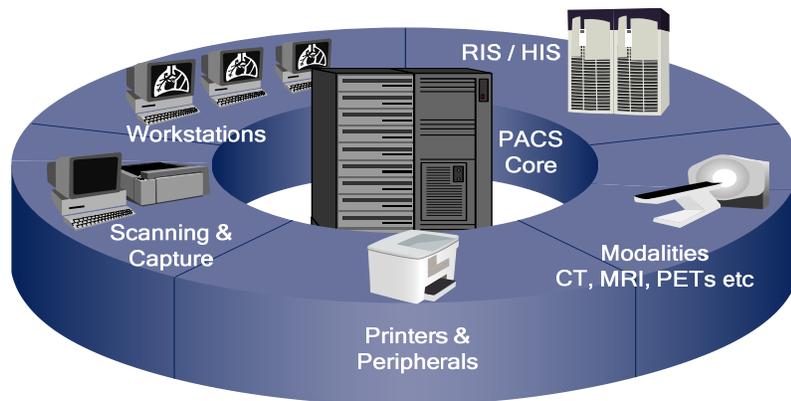
Depending on their usage, cart-mounted and desk-mounted devices may require the UPS to comply with the international standard IEC60601-1, “Standard for Medical Electrical Equipment, Part 1: General Requirements for Safety” for patient vicinity applications. The U.S. equivalent is UL 60601-1.

- For large floor-mounted modalities, a large UPS (50-300kVA typical) should be installed to protect the entire room. Isolation transformers and the appropriate circuit breakers should be used to limit the leakage currents and electrical shock hazards for such modalities. These isolation transformers are sometimes built into the UPS or may be optional outside of the UPS box. All equipment should be installed in compliance with relevant codes like NEC, NFPA 70, NFPA99 (for U.S), and all other applicable local and national codes such as BS7671:2001 (U.K.), NFC15-100 (France), and VDE (Germany), as well as international such as CEI IEC 60364. Understanding and interpreting the codes can, in some unique cases, become very controversial and the final say should be from the authorities having jurisdiction. In instances where budget constraints prohibit investment in a large facility level UPS, a smaller UPS (5-10kVA) dedicated to the sensitive electronics and computer system of the CT, MRI, and PET should be considered. In addition, UPS protection should be provided to all their viewing stations & workstations.
- Sizing of the UPS for many devices like CTs and MRIs can be challenging since they draw very high amounts of inrush current. Ample precautions should be taken while sizing their power systems (including UPS, generators, transformers, and switchgear). Their normal power consumption as well as the inrush current ratings are available from their manufacturers. Allow enough margins for miscellaneous loads and future growth. Many companies like Schneider Electric have dedicated systems engineers, power protection specialists, etc. who can help evaluate the right solution for every unique customer situation.
- Adequate cooling and air flow should be provided for all modalities that have sensitive electronics dissipating heat. For most of the cart and desk-mounted modalities, building HVAC should be sufficient. However for large floor mounted modalities like CTs, MRIs, or PETs supplemental cooling may be required. Precision cooling is preferred as it can provide temperature and humidity control in the CT/MRI room.
- All of the networked modalities and their physical infrastructure should be monitored and managed (i.e. environmental conditions of the radiology room, UPS battery life, runtime and capacity, and generator fuel) so that anomalies can be quickly detected and a corrective action be taken proactively to avoid any downtime.

## Picture archiving and communication systems (PACS)

PACS make it possible to electronically store, manage, distribute, and view images. Fundamentally, these systems are a network of all image acquisition devices, display workstations, and storage systems. They are made up of a broad range of technologies that enable digital radiology and digital hospitals to perform tele-radiology, tele-medicine, and tele-surgery. PACS have become more complex, encompassing systems that digitally acquire, convert, interpret, transmit, and store medical images. Diagnostic images will be available anytime, anywhere with little or no human intervention, making their distribution faster, easier, and more reliable. **Figure 5** illustrates the components of a typical PACS.

**Figure 5**  
Typical PACS



### Environment

The core of the PACS is made up of high availability RAID storage and server clusters running Windows, Unix, Linux, or a propriety operating system. These RAID storage and server clusters are housed in racks in a computer / data room or data center environment. Typically they draw less than 10 kVA, single-phase AC power at 120 V, 208V, or 230 VAC. Very large systems may draw three-phase power.

### Challenges

PACS need to be available on demand to the nurse, physician, clinician, or specialist surgeon, providing latest imaging data of the patient under treatment. It needs to be highly available, 7x24x365 and there is little tolerance to downtime. Since the RAID drives and server clusters are confined to rack enclosures, handling their heat dissipation within the racks often becomes a bigger challenge.

### Best practices

- PACS should be protected with an N+1 redundant UPS system. This N+1 UPS system not only protects the hardware but also protects the software from malfunctioning and gracefully shuts down and reboots the operating system if needed, thereby preventing a hard crash. The N+1 redundancy of the UPS system mirrors the redundancy of the RAID storage drives and server clusters which are at the core of the PACS, providing high availability. For smaller, simpler systems, a basic UPS can be provided.
- Often times, additional receptacles are needed for plugging in all required devices. Rack based PDUs should be used to provide additional outlets. PDUs that can measure and display current, which can help prevent accidental overloading and shut down of the PACS are recommended. PDUs that allow remote outlet control via the web are desirable as they can help reboot a hung server or a storage drive efficiently.

- At a minimum, surge suppression should be provided for LCD/CRT based passive view-stations. For PC based active workstations running software applications, UPS protection with graceful shut down and reboot capabilities is highly recommended.
- The PACS storage and servers should be housed in secured, lockable, rack enclosures. These racks should be in a temperature controlled environment. The racks housing PACS storage and servers are generally very dense physically and in terms of power consumption. The rack doors should be perforated, allowing for maximum air-flow. When power draw in the rack exceeds 4 kW, the rack should be placed in a hot or cold aisle containment system. If this isn't possible, ducted racks should be used to capture hot return air and direct it back to the air conditioner. Alternatively, a row-based cooling unit can be used to provide supplemental cooling capacity (see **Figure 6**). For more information on containment systems for existing data centers see White Paper 153, [Implementing Hot Aisle and Cold Aisle Containment in Existing Data Centers](#).

## Figure 6

Example of ducted rack air containment (left)

(Schneider Electric Vertical Exhaust Duct shown)

Example of row-based cooling unit (right)

(Schneider Electric InRow RC shown)



- A good management strategy involves the management of PACS servers, storage, and their entire physical infrastructure including UPS, PDUs, batteries, and their critical environment (temperature and humidity). This will give early warning of any anomaly or impending disaster so that corrective actions can be taken and prevent all avoidable shutdowns.

## Radiology information systems (RIS) and hospital information systems (HIS)

RIS and HIS are server based systems running special software that make it possible to store, monitor, manage, and distribute patient medical information. They help patients in scheduling appointments, registration, and billing, and help hospitals in generating, maintaining, and managing patient's electronic medical records as well as generate workflow, worklist, management reporting, and variety of other tasks. These RIS and HIS are really becoming one large HIS and are integrated / networked with PACS as well as various other modalities within the hospitals providing complete automation. By converting them into "digital hospitals", they can significantly improve patient-care, minimizing human errors, saving lives, and reducing costs. **Figure 7** shows a typical RIS / HIS and its subcomponents.

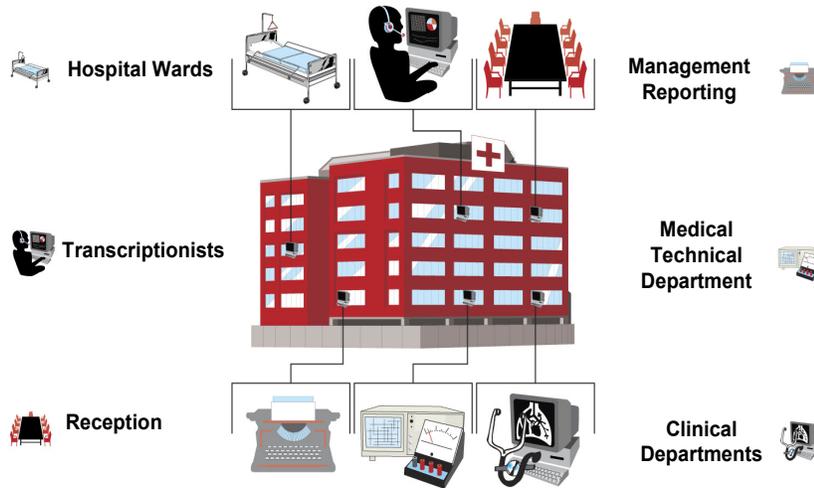
### Environment

These systems are generally housed in a data center environment drawing 10 kW single-phase 208 VAC or 230 VAC power on the lower side, to hundreds of kilowatts of three-phase 400 VAC or 480 VAC power on the higher side. The majority of data centers in hospitals have a UPS with battery back-up, precision air conditioning units, and a back-up generator.

### Challenges

RIS / HIS are the most important systems within the data center requiring longer runtime and higher redundancy and availability than most other equipment. Since these systems are

merging to form one big HIS on which the entire hospital depends for normal functioning, their availability requirements are generally 99.999% (five nines) or higher which translates to average unplanned downtime of 5 minutes per year or less. Additionally these systems may be located in high rise buildings and attention should be paid to the floor load (weight) handling capacity, elevator hauling capacity, door heights and widths to ensure that the physical infrastructure elements like UPS, batteries, and air-conditioning can be rolled in to their planned positions.

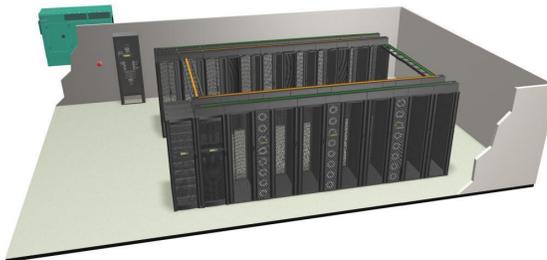


**Figure 7**

Typical RIS / HIS system

### Best practices

- The physical infrastructure supporting the RIS / HIS should provide highest levels of redundancy while minimizing the total cost of ownership. An N+1 redundant UPS with automatic and manual bypass is very common and often times it is extended to the generator as well as the precision air-conditioning systems to ensure the highest levels of availability. The entire infrastructure should be scalable to allow for future expansion, be manageable like the other IT equipment, and be serviceable to reduce mean time to recover. An example of such a system is the Schneider Electric InfraStruxure and is shown in **Figures 8**. All of these characteristics contribute to the overall availability of the system.



**Figure 8**

Schneider Electric  
InfraStruxure™

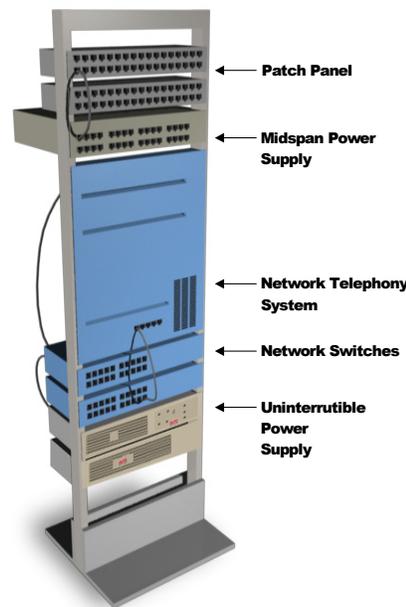
- Servers and systems requiring the highest levels of availability should be identified and grouped so that they can be provided with longer runtime and higher levels of redundancy in a separate area, and in separate racks within the data center. This concept of “targeted availability” helps increase availability of business critical systems 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 rack should be considered for highly-critical data centers and networks.
- PDUs should be able to measure and display current, which can help prevent accidental overloading and shutdown of the RIS / HIS. PDUs that allow remote outlet con-

Control via the web are desirable for rapidly rebooting a hung server or a storage drive. Isolation transformers should be used wherever required and mandated by local laws.

- Precision air conditioning equipment should have the capability to allow for expansion. Redundant air conditioning units should be considered for higher availability. For high power density racks (>4 kW / rack) additional air distribution and air containment should be used to avoid hot spots. For more information on cooling best practices refer to White Paper 49, [Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms](#).

## Wiring closets or intermediate distribution frame (IDF)

Medical imaging and diagnostic equipment are typically connected to a network. Modalities like CTs and MRIs get connected to PACS which are connected to RIS and HIS which in turn are connected to the hospital intranets and extranets. The wiring closets or IDFs, as shown in **Figure 9**, play a very vital role in ensuring the connectivity of this equipment and the availability of the network, 7x24x365. Wiring closets comprise of layer 2 and layer 3 access and distribution switches, hubs, routers, patch panels, UPS systems with a battery back-up as well as any other miscellaneous telecommunications equipment mounted generally in a two post rack. IDFs or wiring closets may also supply power over Ethernet (PoE) to networked devices like IP phones, web/security camera and any other devices drawing power up to 15 W. This imposes a lot more challenges on the power and cooling requirements in the closets.



**Figure 9**  
IDF (wiring closet)

### Environment

These IDFs or wiring closets are typically hidden in some remote location of the building with little or no ventilation and illumination. Legacy telecommunication networks typically used wiring closets mainly for punch-down blocks, patch panels, and a few small stackable hubs or switches. However, networking equipment that supplies power over Ethernet uses and dissipates considerably more power. These new switches support data, voice, and video, generally 19" rack mount type, and have varying air flow patterns depending on the manufacturers (i.e. side to side vs. front to back). A typical IDF will house 1-3 racks worth of equipment and draw 500 W to 4000 W of single phase AC power or more. Two post racks have largely been replaced with four post racks since newer equipment is getting heavier and deeper.

## Challenges

While deploying PACS, RIS, HIS, or new modalities that are being networked, these wiring closets or IDFs need the most attention in terms of power and cooling. It can be a challenge to ensure the right type of receptacles (i.e. L5-20, L5-30, L6-20, IEC 320 C19, and IEC 320 C13) and the right amount of power with the right circuit breaker protection to all the networking equipment. Cooling and airflow are often a bigger but 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 UPS should be 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 by taking the sum of the Watt ratings of the loads. A common rack-mount UPS (i.e. Smart-UPS™) will provide approximately four nines (99.99%) of power availability, while an N+1 redundant, UPS with built in bypass (i.e. Symmetra RM) with one hour runtime will provide approximately five nines (99.999%), which may be sufficient for most applications. See **Appendix** of White Paper 69, [Power and Cooling for VoIP and IP Telephony Applications](#) for details on this availability analysis. UPS products are available with battery packs to provide different durations of run time.

Identify the plugs and receptacles required for all the equipment including the UPS in the wiring closet. Ideally all of the equipment should be plugged directly 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 are many devices, it may not be practical and a rack PDU 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 error 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 APC by Schneider Electric [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, 7x24x365, cooling and airflow issues must be identified and addressed. The problem of heat dissipation and need for supplemental air-conditioning is most pronounced in the wiring closets which have no vents. Power dissipation in the wiring closet should be calculated to decide on a cost effective way to solve the problem (see **Table 1** & **Table 2** in White Paper 69, [Power and Cooling for VoIP and IP Telephony Applications](#) for details).

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

## Conclusion

To ensure high availability and reliability to medical imaging and diagnostic equipment, including PACS, RIS, HIS, modalities, and their network, special attention must be paid to their physical infrastructure. The biggest challenges are in terms of power, cooling, physical space, management, and services. Providing UPS protection to all such devices protects the hardware, prevents the software from unwarranted crashes, and increases their availability significantly. Cooling is a special problem for bigger floor mounted modalities, high density storage and servers for PACS as well as RIS / HIS and hospital wiring closets. In some cases, a building's HVAC system along with proper ducting, ventilation, and airflow may be sufficient. However in many situations, additional cooling in the form of precision air conditioning is required. Companies like Schneider Electric have dedicated team of systems engineers, power protection specialists, and availability consultants who can help in doing assessments and audits of data center physical infrastructure and provide detailed actionable reports on improving overall system reliability and availability while minimizing the total cost of ownership.



## Acknowledgements

Special thanks to **Viswas Purani** for authoring the original content of this white paper.



## Resources



### [The Different Types of UPS Systems](#)

White Paper 1



### [Avoiding costs from Oversizing Data Center and Network Room Infrastructure](#)

White Paper 37



### [Dynamic Power Variations in Data Centers and Network Rooms](#)

White Paper 43



### [Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms](#)

White Paper 49



### [Power and Cooling for VoIP and IP Telephony Applications](#)

White Paper 69



### [Implementing Hot Aisle and Cold Aisle Containment in Existing Data Centers](#)

White Paper 153



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## References

IEEE White book "IEEE Recommended Practice for Electric Systems in Health Care Facilities" IEEE std. 602-1996



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