POWER CONTINUITY IN HEALTHCARE: SIZING AND CONFIGURING POWER SYSTEMS FOR RELIABILITY AND COST-EFFECTIVENESS

Contents

Introduction

Technology, such as electronic medical records and digital imaging, have revolutionized healthcare by streamlining processes, increasing efficiency and, most importantly, improving patient outcomes. As these systems have become woven into the fabric of healthcare delivery, their continuous operation has become essential.

Simultaneously, the healthcare delivery network has expanded and become more interconnected with large hospitals often supporting smaller regional facilities, urgent care centers, outpatient surgery centers and other specialized facilities.

As a result, healthcare now represents one of the most varied applications for critical power systems. These systems must support growing data centers; critical operations, such as surgery rooms, emergency rooms and intensive care units; diagnostic systems and medical devices; and the technology that supports electronic medical records. There are so many applications and design considerations in today's hospital, that it is more important than ever to work closely with consultants, in-house facility and IT staff and infrastructure experts throughout the process to achieve the reliability, efficiency and flexibility today's healthcare facilities require.

Data centers and network closets remain the backbone of healthcare IT and these environments have each experienced significant changes in recent years as use of technology has expanded. Major hospital data centers are being upgraded to achieve higher levels of availability, efficiency and, particularly, scalability. This is being achieved through increased adoption of mission-critical power, thermal management, and monitoring and management technologies that can support the "always on" availability now required as well as provide the capacity to handle growing demands as they arise.

These same changes, on a smaller scale, have been applied to network closets to allow them to adapt to the increased capacity and criticality they have experienced as IT has expanded throughout the hospital and other healthcare facilities. Double conversion UPS systems, remote monitoring and, where required, advanced thermal management systems, are replacing less robust equipment in these critical applications. Increasingly, new network closets and micro or edge data centers are being supported with pre-engineered, integrated infrastructure systems that speed up deployment and optimize efficiency by combining power protection, power distribution and remote monitoring at the factory to create IT-ready infrastructure for server rooms and other remote local nodes.

Relying on a single supplier that can offer a broad range of power, thermal management, and monitoring and control technologies helps ensure infrastructure is precisely matched to application needs and can help simplify project management. It's also important to consider the service capabilities of your infrastructure provider.

Today, of course, the power system in healthcare facilities must support more than just standard IT systems. Critical operations throughout the hospital or clinic, such as operating rooms and intensive care units, also depend on clean, uninterruptible power to deliver life-saving services.

This paper will focus on the best practices and technologies to ensure uninterrupted power for critical operations within the healthcare field. It reviews two approaches to powering critical operations and provides recommendations for technologies and system configurations that have proven to be reliable and cost-effective in these applications. In addition, it explores the growing importance of energy efficiency in today's hospitals and the opportunity to use cutting-edge UPS technology to smoothly manage the power surges created by diagnostic equipment.

Centralized versus Distributed Design Approach

Before any design is initiated, a comprehensive assessment of current systems and requirements is necessary. In existing facilities, the assessment should identify all locations where UPS units are currently operating, the load they are supporting and whether the load is considered critical. It can also be helpful to consider the future plans for the facility and how the power consumption of critical and non-critical operations may change in the coming years.

For the purposes of this paper, we define critical those operations or environments that directly support patients in critical situations, such as emergency rooms, intensive care units and surgery rooms. Systems that support services such as diagnostic equipment, may be considered “critical” in a broader sense as extended downtime can have a significant impact on hospital finances, but are not immediately critical to the ability to support patients.

Consultants and electrical infrastructure specialists should be brought in at this phase to ensure all factors—including relevant national and local regulatory requirements and standards—are considered early in the process.

When designing a power system for critical operations in a hospital, there is a key strategic decision that should be made as early in the process as possible: whether to adopt a centralized or distributed approach to protect critical operations.

In older hospitals and clinics, some critical operations may have been added after the main facility was built and power protection systems, such as UPS, were included to support each critical operation. This creates a “distributed” power system within the hospital, with multiple de-centralized UPS systems supporting individual applications. This is not unlike the situation that occurred in the early evolution of the data center when each new equipment rack that was added included a dedicated UPS.

This may prove a necessary interim solution in some case, but as a long-term strategy it has some serious drawbacks. The most significant is management and maintenance. It’s simply more time-efficient and cost-effective to manage a single, centralized system than multiple, distributed ones. In addition, large UPS systems, such as those used in centralized designs, typically provide higher reliability (as measured by mean-time-between-failure MTBF rates) compared to smaller, distributed systems. They also provide a lower cost/kW and, because UPS systems operate more efficiently at higher utilization rates, will have lower energy costs than multiple small systems.

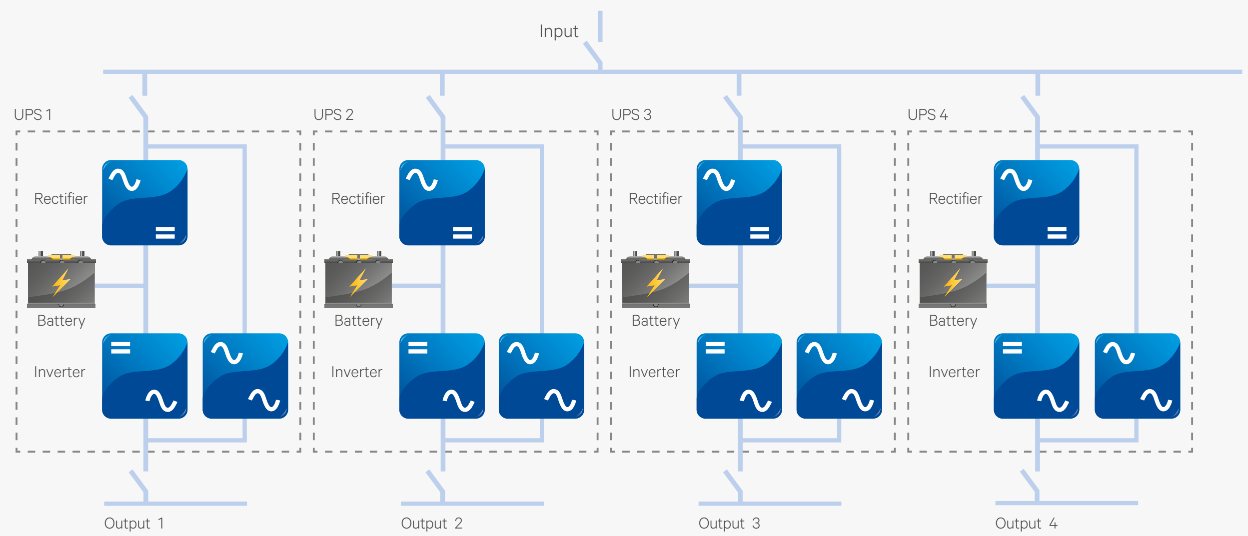

Figure 1: *An example of a distributed UPS configuration*

The benefits of a centralized approach to powering critical operations include:

- **Higher Availability**
  In addition to the higher reliability of large UPS systems, centralizing power protection expands the range of redundant configuration options that can be deployed. Depending on the chosen configuration, availability of critical operations can be precisely projected.
- **Flexible Distribution**
  A centralized power system enables more flexibility in how power is distributed to the load. Systems can be designed with redundant distribution paths or utilize a hybrid scheme in which the central UPS is supported by mid-size UPS systems in proximity to critical loads such as operating rooms.
- **Scalability**
  If properly sized, the centralized power system allows new technology to be deployed simply by plugging it into a protected socket. When significant additional power is needed, modern UPS systems can be configured to be expanded with minimal or no interruption to UPS power.
- **Simpler Management and Maintenance**
  With fewer, larger UPS systems, there is less to monitor and maintain. The centralized UPS is also often located in an electrical room instead of consuming valuable floor space. In addition, monthly generator tests can be conducted at full load to more accurately reflect real-world conditions.
- **Improved Efficiency**
  Large UPS systems typically have higher efficiencies and are more likely to be equipped with the energy saving control technologies discussed later in this paper. Centralizing the UPS can also increase UPS utilization. Instead of having multiple units across the facility operating at various loads, you have a single system that has been sized and configured to optimize utilization.
- **Lower Cost**
  The initial cost of deploying a large UPS is lower than deploying small, pluggable UPS units; and as small UPS deployments grow, the total cost of ownership will be significantly higher than a large UPS system. Higher costs are also incurred for monitoring, testing and replacing batteries for multiple small UPS units.

For new facilities, and those undergoing an expansion or facility upgrade, a centralized power system design to support critical operations will be easier to manage, provide greater reliability and efficiency, and be less expensive. It can also be configured to support a hybrid distributed and centralized approach where a centralized UPS is providing redundancy for multiple distributed systems. In this case, the centralized UPS feeds the input breaker line of the distributed UPS.

Ensuring Power Reliability for Critical Operations

Once you have determined whether to support critical operations through a centralized or distributed approach, consider the UPS technology and configuration that best supports your availability objectives. Availability is generally measured as the percent of time over a year in which the system is actively powering loads. For example, a power system that delivers 99.999 percent availability is down 5.26 minutes per year. A number of factors influence power system availability including equipment quality and design, the degree of redundancy within the power system and service and maintenance practices.

From a technology perspective, online double conversion UPS systems provide the highest degree of protection of any UPS topology. This topology uses a rectifier to convert incoming AC power to DC and then an inverter to create a clean AC waveform for delivery to the load, thus removing even the smallest power anomalies.

Double conversion UPS systems are available in a broad range of sizes and capacities, including three-phase UPS systems that provide greater flexibility in distributing power downstream and generally support higher capacities, deliver greater reliability and enable more advanced monitoring than single-phase systems.

The next major design decision should focus on redundancy. The centralized approach to power protection provides greater flexibility in designing redundancy into the system. Redundancy reduces single points of failure within the critical power system, enables future growth and increases operating flexibility.

While there are a number of proven redundancy configurations, two are used most commonly in centralized power systems for critical hospital operations: parallel redundant and N+1.

In the parallel redundant configuration, two or more UPS units are connected in parallel, so that in case of failure of one of them, the other will power the critical load. This is a fairly simple configuration that delivers high availability, but does have higher initial costs than an N+1 configuration.

In the N+1 configuration, the UPS system is sized and configured so that, at peak loads, there is always one unit that can remain in standby and is not required to power the load. If any of the other units fails, or is taken offline for service, the load from that UPS switches to the standby unit. For example, if the total projected load for a hospital's critical operations is 800 kW, the UPS system may be designed with five 250 kW modules. The four primary modules are capable of supporting the full load, with some buffer capacity, and the fifth unit provides redundancy for each of the four primary units.

This configuration simplifies scalability as an additional 250 kW module can be added to increase the load the primary systems can support without sacrificing redundancy. Also, the system can be designed with two redundant modules (N+2) to maintain redundancy when one of the primary units is taken off line for service and one redundant unit is required to support the load.

Remote management and diagnostics are extremely powerful tools to maximize uptime by reducing the mean time to repair. Using communication cards within the UPS and software-based management systems, these systems can continuously collect UPS operating data to provide immediate notification of operating problems and early warning of potential problems. In a hybrid environment, centralized monitoring can be used to improve control over all UPS units in a facility.

The final piece of the reliability puzzle is service. Plan for both preventive maintenance and emergency response service. Regular preventive maintenance services, with an optimum frequency of twice annually, have been shown to increase UPS MTBF. Emergency response services help ensure fast response to any issues that may occur.

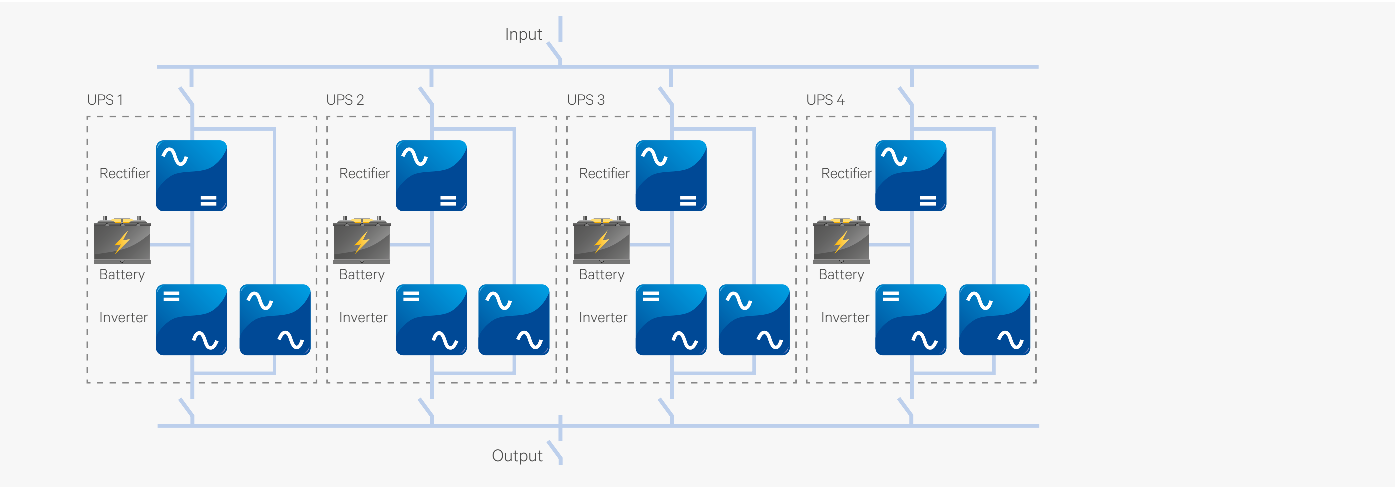

Figure 2: *An example of a parallel redundant configuration*

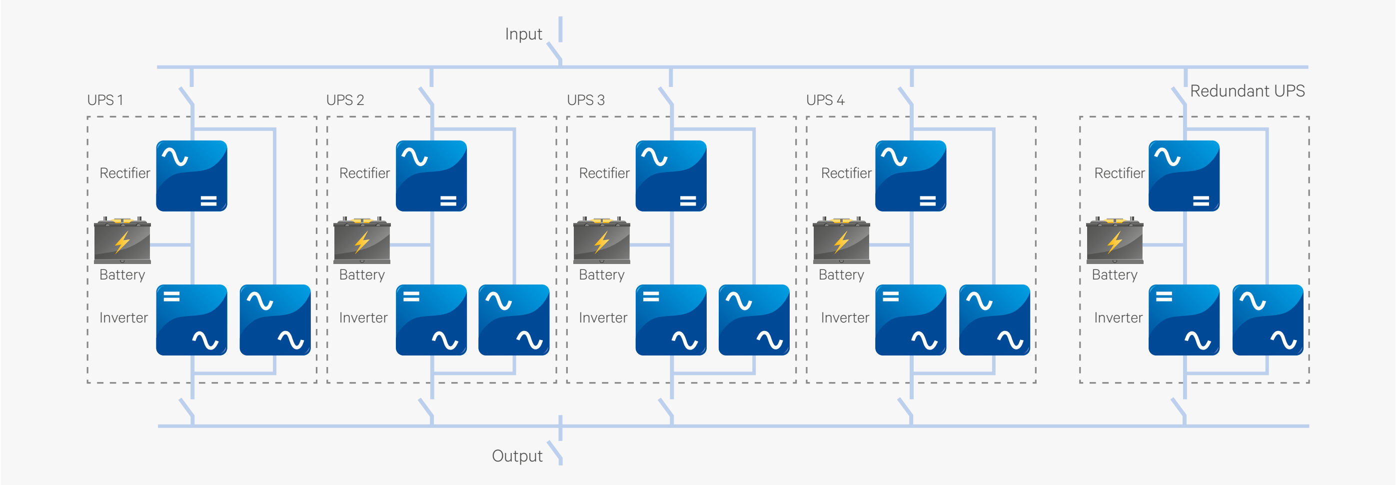

Figure 3: *An example of a N+1 configuration*

Taking a holistic approach to UPS service, in which all units across the facility are included in monitoring and service plans, is typically the most cost-effective approach. Infrastructure vendors, such as Vertiv, now offer comprehensive UPS service options that include remote monitoring and data analysis, preventive maintenance and battery replacement, and emergency response. These services ensure UPS systems are operating at peak performance while removing the burden of maintenance from in-house staff.

Optimizing Power System Efficiency

Power efficiency is the ratio between the output active power and the input active power of a system. The power used by the UPS is dissipated in the form of heat. Lower efficiency UPS systems not only waste electricity by themselves, but also generate heat that may require bigger, dedicated cooling systems, which in turn will consume even more power.

A high efficiency UPS can generate significant cost savings over its life. For example, comparing two UPS systems with a load of 400 kW, if one is operating at 92 percent efficiency and one at 98 percent efficiency, the lower efficiency unit will generate additional losses of 322 MWh/year compared to the higher efficiency unit. Over an average lifespan of 10 years, that adds up to 3,220 MWh. At a cost of 0,10€ per kW, this translates into savings of 322,000€ over ten years.

Newer UPS systems also feature multiple operating modes that allow them to optimize energy usage based on current requirements. Essentially, the system incorporates three UPS topologies in one unit with intelligent controls providing the ability to switch between operating modes based on incoming power quality and changes in criticality. In maximum power control mode, the system functions as a double-conversion UPS to provide the highest level of power conditioning, protecting the load from all types of electrical disturbances but at the cost of the energy required to convert power within the UPS. Even in this mode, efficiency can exceed 95 percent. In maximum energy saving mode, the system detects when the need for power conditioning is non-existent and allows the energy flow to pass through the bypass line to achieve efficiencies as high as 99 percent. The third mode is high-efficiency with power conditioning. In this mode, the UPS uses the line interactive topology with the UPS inverter serving as an active filter, compensating only for major disturbances. This mode has typical efficiencies between 96 and 98 percent.

Another energy saving opportunity is to use circular redundancy in parallel to optimize the efficiency of a redundant system at low loads. If the total number of power modules is not necessary to power the output load, the UPS controls determine the number of power modules required, while maintaining redundancy, to support the actual load and take any unnecessary unit off line. As soon as an increase in the load is verified, the dormant power modules are started up.

For example, using the N+1 configuration example provided earlier, if the load on the four primary UPS modules dropped below 500 kW—as may be the case when surgery rooms aren't in use overnight—one module could be automatically put in stand-by until the load returns to normal levels.

These efficiency enhancements should be appreciated by the owner of the hospital due to both the energy reduced electricity consumption of the UPS system as well as the reduced demands on the cooling system to extract the heat dissipated by the UPS and the loads.

Improving Power Management

Diagnostic machines, such as MRI and CAT scan equipment, can create a large power draw while operating with peak demands as high as 400 kW. With increased use of diagnostic equipment in most facilities, this can force system engineers to oversize the power system to compensate for these machines, resulting in higher initial costs and reduced efficiencies. Similarly, the addition of new generation diagnostic scanners in a facility may increase the likelihood of a power overload condition, threatening the availability of the entire system or forcing an expensive upgrade.

Responding to this challenge Vertiv has worked with medical equipment manufacturers to pioneer the use of UPS systems in peak shaving applications. Micro UPS systems embedded in the diagnostic equipment can be set up to use batteries to provide the additional power needed from the central system during the peaks. These peaks typically last less than 20 seconds and can occur sporadically throughout the day, depending upon the nature of the machine.

Smart use of dedicated UPS systems upstream from diagnostic equipment allows the network to be sized to "normal peaks" rather than to the extremes created by power-hungry units, ultimately reducing initial costs and improving operating efficiency. In addition, the UPS battery system can be used to protect against outages, as well as peak shaving, depending on how the battery is sized.

OEM Application for Siemens Healthineers

About the company:
Siemens is one of the world's largest producers of energy-efficient, resource-saving technologies and a leading supplier of systems for power generation and transmission as well as medical diagnosis.

Situation:
Siemens Healthineers developed a next-generation CT scanner that used two 120 kW X-ray tubes for advanced imaging needs. When in use, these scanners can trigger high peak power demand for the facility, creating challenges for hospitals with a limited energy infrastructure.

Solution:
Vertiv worked with Siemens to pair these next-gen, dual-source CT scanners with a peak-shaving UPS solution from Vertiv. These UPS systems bridged those peaks during CT use – typically some 30-50 scans each day – by seamlessly transitioning to battery power.

Results:
The joint solution from Siemens and Vertiv enables advanced imaging services in hospitals that lack the existing critical infrastructure for dual-source CT scanners. By bridging the peaks created during CT operation, Vertiv UPS systems ensure uninterrupted power across the facility. Siemens determined about 10-15 percent of the dual-source CT scanners sold each year would be deployed to facilities in need of a peak shaving UPS solution from Vertiv.

Regulatory Compliance and the Power System

Before getting too far down the design path, it's important to understand some basic regulations and standards that relate to the power system in the healthcare field.

Across most of Europe, Africa and the Middle East – with the notable exception of Germany and Austria – standard UPS systems must meet IEC standards for electrical equipment in healthcare settings, including critical life support systems. UPS systems are not, however, considered medical devices, which means they are subject to regulations limiting their proximity to patients. A UPS system cannot be connected to a patient and cannot be located within 1.5 meters of a patient. More relevantly, a UPS system must be installed upstream from the safety transformer. That transformer acts as a boundary between normal building power distribution and distribution for medical equipment.

One important caveat: devices such as scanners and imaging machines are not considered medical grade devices, are not considered to have any electrical connection to the patient, and therefore may be connected to a UPS. These machines are not life-critical devices; if the power goes out, the hospital simply stops doing scans. They are, however, important to the hospital or clinics ability to deliver services to patients and outages have operational and financial consequences. Therefore, the hospital realizes a number of benefits by ensuring power to this equipment is protected by a UPS. The UPS, in this case, may require special certification for use in healthcare applications, such as UL/cUL in the U.S. markets or BIS in India for units below 5 kVA.

The same isn't true of a ventilator, for example. It's also important to note these types of scanners can require a great deal of power, but only in peaks when they're actually being used. UPS systems can help hospitals manage those peaks when the grid can't.

There are, of course, differences in the way various UPS systems handle electrical distribution and variations in electrical codes from country to country. Stemming on IEC 60364-710, most European codes and standards are consistent, however national regulations may apply on top of these – mostly related to installation codes, including sizing for cables and switches. It's important to understand those local codes and standards when installing a UPS in any setting, including hospitals and healthcare facilities.

Questions to Ask When Designing Your Power System

This paper has provided an overview of some of the key design considerations involved in protecting critical operations in hospitals. But every application has unique challenges and there are rarely "off-the-shelf" solutions available.

To ensure your system meets your long-term needs for reliability, efficiency and growth, make sure to collaborate with your consultants and engineers to address these questions.

- **How will the system scale if we need more power?**

  When implementing a UPS system it's important to understand future requirements and ensure a growth plan is in place to cost-effectively meet those requirements. Providing just the capacity required today – with no growth plan – can limit the ability to expand or add new equipment and increase the cost and disruption of future technology. As availability requirements rise, power system redundancy is often implemented to reduce single points of failure, enable future growth and increase operating flexibility.

- **What is the load profile?**

  What is the load profile for the various equipment the power system will be required to support in terms of average and peak power consumption, expected backup time, etc. These need to be consolidated to create the load profile for the power system that ensures all needs will be met.

- **What levels of availability can we expect? Are we achieving redundancy in the most cost effective way?**

  System availability is a key criterion on which your power system will be measured. Different approaches to redundancy can support different availability levels, but higher levels of availability often come at increased cost. Make sure you review the various options suitable for your application and understand the advantages and trade-offs of each. What are the single points of failure within your system and their MTBF? Are you comfortable operating without redundancy during UPS service? Are there single points of failure within the distribution system and what systems would be impacted by a failure?

- **Based on our projected operating conditions what efficiency can we expect?**

  UPS systems not only vary in the efficiency they can support in normal operating mode, but also in their ability to intelligently switch between multiple operating modes to minimize energy consumption. Will the quality of incoming utility power enable you to take advantage of high-efficiency operating modes? Do loads vary enough to allow you to take some units off line when loads are reduced?

- **Should we use peak shaving to improve energy management of diagnostic systems?**

  Peak shaving of the surges created by diagnostic machines can improve energy management and prevent oversizing of the power system. Are there opportunities within the facility to employ UPS to provide peak shaving?

- **How will power system components be serviced?**

  Service is too often an afterthought in power system design, but selecting a service partner early in the process can simplify startup, help determine whether remote monitoring is required and ensure proper service and emergency procedures are provided through the life of the system.

Conclusion

Instead of providing protection at the device level, healthcare facilities in general and hospitals in particular will find they can achieve much higher power availability and simpler, cost-effective management by moving power protection upstream.

For smaller facilities, this may mean providing a single, large UPS directly downstream of the transfer switch to the facility. Larger facilities may require multiple critical branches with a single large UPS on each branch with redundant distribution to critical loads.

In either case, with proper planning and design, a centralized UPS system upstream of power distribution can provide protection for all critical operations the facility, creating a power protection system that is more reliable, more scalable and more manageable than the distributed approach.

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