How green is green?

The environmental benefits of using Diesel Rotary UPS systems to support your data center power infrastructure

1. Executive summary

Diesel Rotary UPS (DRUPS) systems – using flywheels for kinetic energy storage - are 'best in class' regarding energy efficiency. Best practices in the data center industry worldwide support this concept, including the best practices document issued by the European Code of Conduct for Data Centers.

There are, however, many static UPS vendors in today's market – using batteries for energy storage - that challenge this statement. However these static UPS vendors only focus on their own hardware delivery, the power electronics -- not the batteries, climate control, diesel generator sets and all other ancillary equipment needed to provide the data center with clean, uninterruptible and continuous power. Data center designers and operators should therefore always compare the overall efficiency of the total UPS system they are considering, including all necessary equipment to effectively support the IT load.

A DRUPS system is by definition "greener" than any static UPS system simply because it does not utilize standby batteries for energy storage. As a consequence, a DRUPS system does not require the use of components that incorporate significant quantities of environmentally damaging chemicals such as Lead Acid, Nickel or Cadmium. There are many other environmental benefits to a DRUPS system when compared to static UPS systems:

- DRUPS systems have an end-to-end system efficiency of up to 97%. In comparison, the efficiency of a static UPS system (including all ancillary equipment) will be around 92% to 94% at best. This increased efficiency of DRUPS systems has drastic positive impact on the Operational Expenses and the measured Power Usage Effectiveness (PUE) of a data center facility.

- Static UPS systems promote their efficiency operation modes (eco-mode, VFD mode). The tradeoff however, is less reliability. To protect the IT load against utility disturbances, such as harmonics, surges, and brownouts, the static UPS needs to transfer from eco-mode to the traditional, low efficiency dual conversion mode (VFI mode). This means switching in the power path using static switches, something data centers are moving away from due to the unreliability of static switches.

- DRUPS systems also offer efficiency modes where load and energy storage are matched to increase the system efficiency especially at partial loads, typical for the data center operation. High-efficiency modes using DRUPS technology do not impact the reliability of the system.

- DRUPS systems are also scalable to accommodate future power needs. This results in the best energy performance when considering both the anticipated start and end load capacities.

- DRUPS systems have a typical economical life cycle of 20 to 25 years. All components that need replacement during this period can be overhauled and re-used. At the end of the operational lifecycle, components can easily be recycled.

- A static UPS system has a lifetime of around 15 years and during its operational lifetime produces a lot of waste, such as batteries that are toxic, capacitors and other electronics. Use of static UPS contributes negatively to the Electronics Disposal Efficiency (EDE) of the data center.

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· DRUPS systems use less material, require smaller installation space, with reduced carbon footprint of hardware and installation equipment compared to the static UPS. The savings in installation space allow for revenue-generating IT equipment.

· The diesel fuel consumed by a DRUPS system during emergency operations is similar to static UPS systems in combination with a standby diesel generator set. The emission levels of a diesel DRUPS are minimal due to diesel start delay function and fuel optimized engines.

· DRUPS systems provide continuous support to critical cooling and mechanical systems, removing the need for expensive and highly complex 'thermal buffer' based cooling equipment. This solves the problem of 'thermal runaway' at source.

· DRUPS systems offer dramatic energy savings, as they can work at ambient temperatures of up to 40 degrees Celsius, while requiring no air conditioning. In comparison, a static UPS and its standby batteries must operate in an air-conditioned climate.

Based on these facts, DRUPS systems remain as the most environmental friendly UPS systems available in the market today with the lowest possible Total Cost of Ownership (TCO).

2. Introduction

"Green" operation is a hot topic in today's data center industry. Governments are concerned about high-energy consumption levels in data centers and companies have commitment to contribute to a better and cleaner environment. As a consequence, there have been a number of joint initiatives including the creation of the Energy Star Program, the Green Grid and the European Code of Conduct for data centers.

When looking at the energy consumption of a data center most losses are caused by the IT and cooling loads.

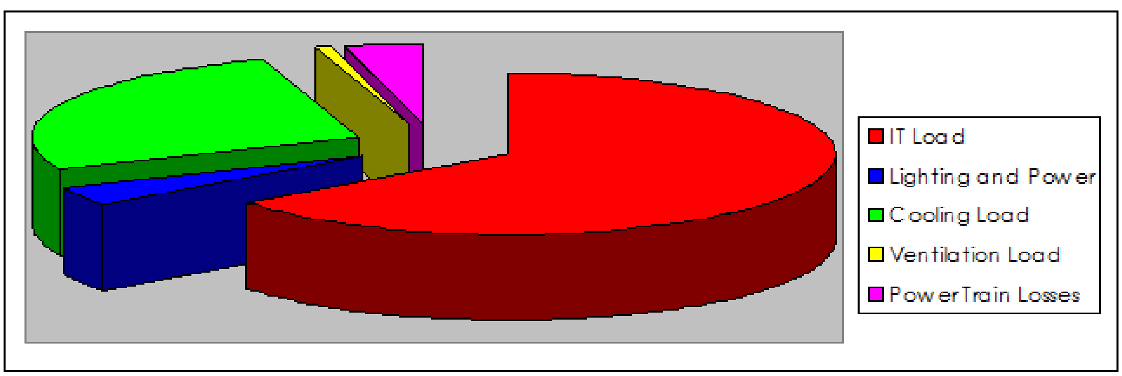

Figure 1 Example typical load distribution in +1 MW data center

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The most commonly used metrics by today's data center operators to measure and improve energy efficiency performance are:

- Power Usage Effectiveness (PUE)
- Data Center Infrastructure Efficiency (DCiE)

Because of the "big wins", these metrics focus largely upon cooling and IT equipment and the allowed maximum temperature in the data center facilities. However, using highly efficient UPS systems also has a positive impact on this metric.

Consequently, every UPS vendor is now stating how its UPS system is the most efficient and thus the greenest. But what is green in respect to UPS power? And how green is green?

The first major decision to be made is whether to select a static UPS technology – using power electronics, batteries, room conditioning and standby diesel generator sets - or a rotary UPS technology which utilizes simple and compact kinetic energy storage.

Decisions are most commonly made based on the energy efficiency information that are provided by vendors in marketing their products. But what is the value of this information when choosing the most energy efficient system? While it's easy to present the "green" aspects of an UPS system for marketing purposes and in advertisements, but when considering high-operating efficiency, data center operators must determine the circumstances under which the efficiency is measured.

Best practices for selecting the most energy efficient UPS system should be based on and include all of the auxiliary equipment required to supply clean, uninterruptible and continuous power to the IT load. When selecting a UPS system, data center operators should determine the "green" ratio of the equipment and the components used without focusing on energy efficiency alone. The decision should include the environmental impact of the UPS system and the components it uses during its operational life cycle.

This whitepaper addresses two main issues that impact the green-ratio of a UPS system:

- *The green-ratio on efficiency*: comparing energy efficiency of the total system, and a view on energy efficiency modes.

- *The green-ratio on components used*: what materials are used, can they be recycled and the installation space required for use of the system.

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1. The green ratio on efficiency

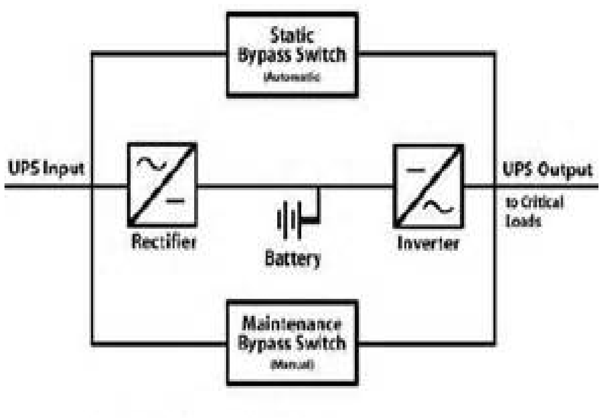

Figure 3 Dual conversion Static UPS concept

There is a considerable difference between the energy efficiency of static UPS systems and DRUPS systems. Static UPS systems comprise a high number of components that produce energy losses. The static UPS vendors always leave out the energy needed to recharge batteries, for the cooling of the standby batteries, and the power electronics. The static UPS concept is based on power conversion in the power path, meaning losses converting AC to DC and DC back to AC. There are some rotary UPS concepts that use power conversion (static rotary) and power electronics (hybrid).

A DRUPS system is the only rotary concept supplying conditioned AC power directly to the load without power conversion or use of power electronics. DRUPS systems combine a diesel engine, an alternator and a kinetic energy storage element (flywheel) to provide conditioned and continuous power to the IT load. No power conversion translates into a 2-3% better efficiency. Eliminating the recharging and cooling of batteries adds another 2-3%.

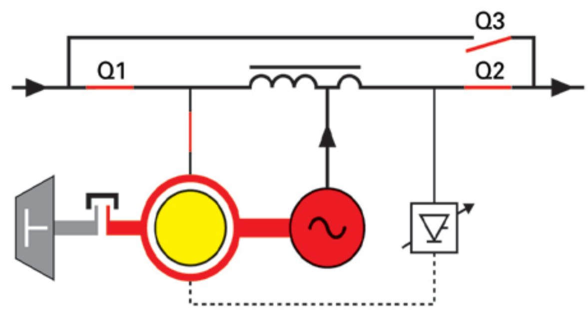

Figure 4 Example DRUPS concept

When compared to a static UPS system, the DRUPS system replaces all of the battery-backed static UPS equipment required to support the critical IT loads, and the standby diesel generating equipment required for continuous power supply. By combining these two functions within a single, simple, compact concept, a DRUPS system provides tangible and measurable environmental benefits. With loads more than 400 kW, the DRUPS technology will beat any other UPS technology on efficiency. DRUPS systems can achieve efficiency levels up to 97%, while the overall efficiency level of the best static UPS equipment, using advanced, expensive IGBT inverters, will reach around 94%, resulting in a system efficiency of 92% at best taking all the additional energy losses of other components into account.

Static UPS vendors will tell a different story, but it's imperative to make sure their statements include the energy use of all the necessary components within the efficiency numbers. For example, is the air conditioning required for both the inverters and battery room included? The ancillary equipment required for a static UPS system can reduce its overall efficiency by around 2-3%. It is clear that a 4-6% win in energy efficiency using DRUPS technology is good for the environment, but it also has a significant positive effect on the operating cost of the data center.

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Figure 5 shows two static UPS systems with different efficiency levels as they are compared to a DRUPS system with 97% efficiency. This example assumes a 10 MVA load and an operational lifetime of 15 years. Most static UPS systems cannot last more than 15 years -- DRUPS systems can (see section 4 below). Using a static UPS system means 167% extra energy losses over 15 years.

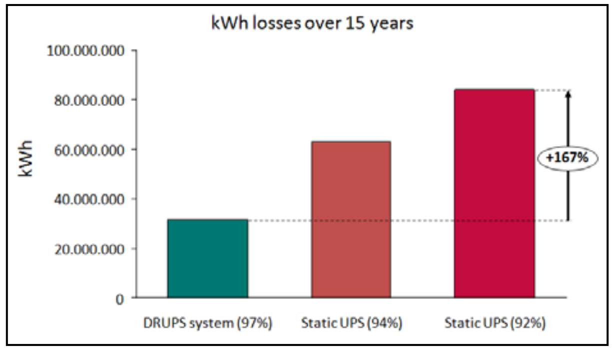

Figure 5 Energy losses per UPS concept

If we translate these annual losses to tons of carbon emissions and number of cars on the road, you will note a considerable difference between UPS concepts.

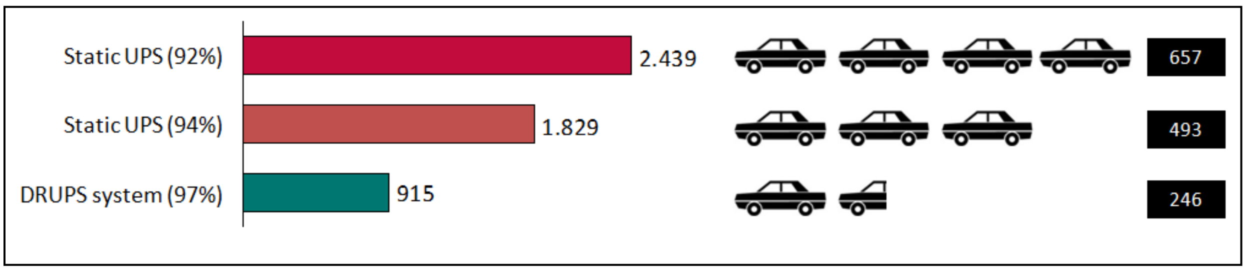

Figure 6 Tons of CO2 emission per year [6] *due to energy losses, equals to number of cars*

If we translate annual losses to the economical effects (figure 8), we see a considerable difference in operating expenses in favor of DRUPS systems. The difference in Total Cost of Ownership (TCO) becomes even more critical when taking energy efficiency into account, as well as cost for battery replacement every 3-5 years, replacement of capacitors and additional maintenance costs. As 18% of all data center facilities see efficiency as the major decision criterion when purchasing an UPS system and 68% see it as one of the major decision criteria, the choice for DRUPS technology seems to be the most logical choice.

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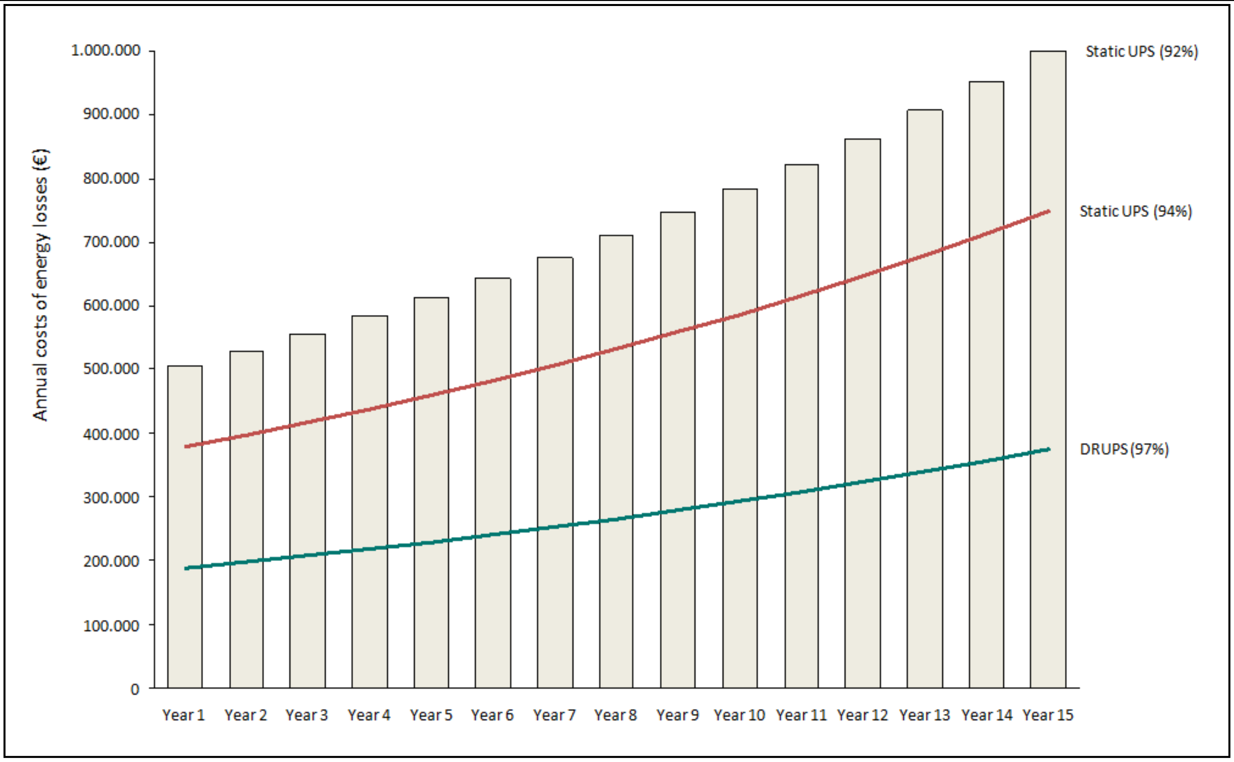

Figure 8 Annual costs of energy losses over 15 years

Static UPS vendors promote their eco-modes to present efficiency figures up to 98%. Maximum energy savings with static UPS systems are created in so called VFD mode or ECO mode. From start this VFD mode would put the IT load straight on utility power. No data center operator would ever consider doing this, as the primary goal of the UPS system is to maximize power control to optimize availability of the IT processes.

Modern ECO modes in static UPS systems try to combine reliability and energy savings. But to protect the IT load against frequently occurring utility disturbances, such as harmonics, surges and brownouts, the static UPS needs to transfer to normal mode. Then the power is once again passed through both input and output stages, making it a traditional, low efficiency dual conversion system. And to change from ECO to normal mode means switching the power path using a static switch. Most data centers are moving away from static switches due to their questionable reliability, so putting a static switch in the mission-critical UPS system seems illogical.

DRUPS vendors also promote their energy efficiency modes. Their function is to match the power stored in the flywheel, with the load demand of the data center. This saves up to 2% in efficiency losses at lower load levels. Typically a data center will operate at partial load, because of the required redundancy. With the DRUPS energy efficiency mode energy is saved with no trade off in respect to reliability, which is the primary function of the UPS.

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4. The green ratio on components used

Batteries
Unlike static UPS systems, DRUPS systems use stored kinetic energy - not batteries - to secure the critical load during utility outages. Kinetic energy storage is achieved through using an electro mechanical flywheel containing a balanced steel flywheel (rotor) and copper windings for energy application and extraction. The use of such materials has a negligible impact on the environment and as such it achieves sustainability.

Sustainability is quite a different matter for static UPS systems. The batteries used in static UPS systems are normally Lead Acid or Nickel Cadmium. Both of these battery types contain extremely harmful, hazardous and carcinogenic materials such as Lead Compounds, Cadmium, Mercury and Sulfuric Acid and are toxic to manufacture and to dispose of. In a large or middle-sized data center the number of batteries required can amount to several thousands. Batteries have an expected life span of 3 to 8 years depending on the quality of the batteries. Replacing them generates considerable amounts of environmentally perilous chemical waste. This fact has not gone unnoticed by authorities worldwide and as a result both Lead Acid and Nickel Cadmium batteries are classified as hazardous wastes. For example the European Union uses its Battery Directive to ensure the safe and proper disposal of such batteries. As a DRUPS system does not contain these environmentally hazardous materials, its environmental impact is negligible when compared to a static UPS system.

Scalable modules
Of course you do not install the full load at day one if you have planned a staged approach to capacity development. With such an approach a full-scale installation at day one is both a waste of energy and money. But many static UPS suppliers trying to be green argue that this is modularity and that you should optimize the UPS design at the starting capacity and install more of the same as future power needs grow. The question remains if this approach actually leads to an optimized design for the targeted end capacity. If you look at the LEED document for data centers, it advises to map out power needs in time to reach the most energy efficient solution. The correct word therefore is not modularity but scalability -- and scalability is definitely not limited to static UPS technology. All DRUPS concepts can easily be configured to allow for the installation of additional modules over time and as the power demands increase. For instance, with loads from critical to essential and vice versa without the need for additional standby generating capacity and/or static UPS modules. Therefore, the use of a scalable DRUPS system allows for a high level of flexibility when it comes to load management.

Low use of space
DRUPS systems require approximately 40% to 60% less space than an equivalently sized static UPS system plus standby diesel generator sets. The DRUPS system can also reduce and simplify the distribution switchgear. Overall, DRUPS technology requires less material and space. In existing buildings, the critical space saved can be used as additional data center floor space for generating additional revenue. In the example below you see how using DRUPS can expand available space for data hall in the same building facility.

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Static UPS system	**Hitec DRUPS systems**
	
Equipment used: • 2 x (3 x 500 kVA static UPS) • 4 x 2.000 kVA HV diesel generator sets • HV paralleling switch panel + switch gear • Downstream LV switch gear • AC and room cooling	Equipment used: • 4 x 2.000 kVA HV DRUPS modules • HV switch gear
Total space required = 8,000 sf	**Total space required = 4,300 sf**

Figure 9 Static UPS concept space requirement compared to DRUPS concept

Optimal use of available diesel engine technology

Both DRUPS and static UPS systems should select diesel engines with the highest fuel economy, the lowest emission levels and the ability to run on zero sulfur diesel fuels. It is possible to use catalytic converters as filtration system for both DRUPS and static UPS systems. However, just like in a car, they reduce power output and data center operators want the maximum power available. Use of EPA compliant engines results in very low emission levels.

Another myth is the number of diesel engine starts when using DRUPS technology. Static UPS vendors confirm their technology can reduce the number of diesel starts, because batteries have a longer autonomy time than flywheels used in rotary UPS systems. To minimize the number of diesel engine starts, DRUPS systems integrate diesel start reduction and delay into their design. Diesel start reduction maintains the module output voltage within tolerance while allowing the main input voltage to fluctuate within prescribed limits. Diesel start delay function offers a 1-2 second delay in starting the diesel engine, as soon as a utility power quality problem is detected. Using both functions reduces the number of diesel starts to an equivalent level of that for a static UPS system with standby diesel generators. Taking into account that around 98% of all power quality problems last no longer than 2 seconds, the advantage of having several minutes of UPS power in batteries is negligible.

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Importantly, from an environmental perspective the diesel engine on a DRUPS system is the same as an engine in a standby diesel generator set. It only starts when the utility fails – just like a standby diesel generator. It uses the same fuel, emits the same gases, has the same acoustic and vibration profile, and requires the same air and water-cooling systems. The DRUPS concept just adds equipment to the standby diesel engine to ensure that it will always start. This is not true when using a standby diesel generator set for supplying continuous power to the IT load.

Integrated power conditioning and power factor compensation
The combination of a synchronous alternator and matched UPS choke within the DRUPS concept ensures that all load generated harmonics are prevented from reaching the incoming supply and vice versa. This combination of components also ensures that all utility derived harmonics are prevented from reaching the load. This combination enables DRUPS systems to provide all of the reactive power demanded by the load. This means that the incoming utility supply is presented with a near-unity power factor under all load conditions, without the need to provide additional, energy-consuming power factor correction equipment.

Re-use and recycle of components
DRUPS systems have an operational life cycle of 20 to 25 years. All components that need replacement during this time can be overhauled and re-used. When taking a DRUPS system out of operation, components can be re-used and such raw materials as copper and steel can be recycled. Its total carbon footprint is therefore very limited.

The trend in the data center industry is to examine the overall carbon footprint of the data center during its lifetime and the sustainable use of raw materials. When for example measuring the Electronics Disposal Efficiency (EDE) using a static UPS system has a negative impact. During its 15 years of maximum operational lifetime, a static UPS system produces a great deal of waste. Toxic batteries need to be exchanged every 3 to 8 years and most power electronics have a limited lifetime.

Support of cooling loads
Unlike a static UPS, a DRUPS system can provide continuous support to critical cooling loads and other mechanical systems. When utility supply fails a static UPS system will support the critical IT processes, but not the essential loads needed for the mechanical systems. This means they are left without power supply until the standby diesel generator sets have started up and synchronized which can take several minutes for a cooling plant to restart.

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A DRUPS system can provide continuous support to both critical and essential mechanical loads within the same concept. Typical characteristics of mechanical loads such as load steps and higher inrush currents can be managed by the robust DRUPS technology. With Active Redundancy Control, the DRUPS concept even allows the use of the redundant power available in a system for support of the essential loads. Having the cooling loads protected by the UPS removes the need for expensive and highly complex 'thermal buffer' based cooling equipment, solving the problem of 'thermal runaway' at source.

Allowance of higher temperatures on the data floor

To reduce energy losses many data centers also allow for a higher temperature in the data hall. This means when power fails the cooling loads are as critical as the IT load. Allowing for higher temperatures means there is less time left between the moment of power failure and the moment critical temperatures are reached that will harm the IT equipment. DRUPS systems allow the cooling loads to be on the critical power as well, protecting these loads despite of mechanical behavior and load steps involved. On the other hand, static UPS cannot handle these loads and will leave the cooling unprotected.

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