NOVA
POWER SOLUTIONS, INC.

Fuel Savings through Enterprise Power Selection

A Technology White Paper – November 2015

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1.0 Military Standard Requirements

The Military Standard requirements (Mil-std's) that a shipboard UPS is typically required to meet include, but are not limited to, portions of the following:

- MIL-STD-1399, Section 300B, Electric Power, AC
- MIL-STD-901D, Shock
- MIL-STD-167-1A, Vibration
- MIL-STD-461E, Electromagnetic Interference
- MIL-STD-810F, Environmental
    - Section 501.4 – High Temperature
    - Section 502.4 – Low Temperature
    - Section 507.4 – Humidity
- MIL-STD-147D, Noise Limits

A reference in this white paper to Mil-std's refers to some combination of those listed above. Compliance to some or all of these Mil-STD requirements is specified in the system design requirements and varies among systems and programs.

2.0 Smart Power

2.1 The importance of power efficiency

When supplying a C5ISR cabinet with two 115VAC 60Hz single-phase 20A electrical circuits, which is the most common circuit size in shipboard C5ISR systems, there is a finite amount of power available for distribution and use within the cabinet. A lot of energy is wasted in rectifying and inverting electricity from AC to DC and back within the cabinet. This lost energy reduces the power capacity of the system, thereby reducing the capabilities of the cabinet and increasing the fuel costs to power these systems.

Using a ±48VDC output UPS, as opposed to an 115VAC output UPS, results in greater use of the limited power supplied to the system by reducing the numbers of rectification and conversion stages, where energy is lost through inefficiencies. This *lost* energy reduces the overall efficiency of our system by dissipating the power lost during these processes as heat energy into the cabinet[1]. By eliminating unnecessary power conversions in our system we can reclaim lost efficiencies and utilize this *found* energy to power more electronic components in the system with the same amount of input power.

[1] Most shipboard C5ISR systems are housed in cabinets and great engineering efforts and energy is required to dissipate the heat generated by servers, storage arrays and UPS's. Reducing the heat dissipation into a cabinet would reduce the size or

speed of the fans needed to dissipate that warm air, reducing the power consumption of air cooling technologies, and freeing electricity to meet system capabilities.

Most shipboard UPS's use *double conversion* technology, meaning that incoming AC electricity is first rectified to DC and then inverted back to AC. The AC/DC rectification stage is required to provide true uninterruptable, conditioned power. The internal UPS batteries are fed into the same DC bus used to supply the AC inverter. In the event AC power is lost, the UPS seamlessly provides AC output power from stored DC energy in the batteries. The UPS is considered *online* because there is zero millisecond interruption when switching from AC input power to DC battery power[2]. This has long been the best technology to properly condition incoming shipboard electricity and provide reliable output power.

Most modern computing equipment operates off DC power, which is accomplished by rectifying incoming AC power to DC voltage in a simple *brick* power supply[3]. This modern computing equipment is typically fed AC electricity from an online AC UPS. As a result, once shipboard AC power enters the cabinet, it incurs three stages of conversion before reaching the load equipment.

If electronic components are chosen which operate from -48VDC and a ±48VDC UPS is specified in our shipboard cabinet, then we reduce the number of power conversion stages from three to one, and power lost as inefficiencies during two unnecessary power conversion stages can be reclaimed. When coupled with load equipment that is smarter about its energy consumption, energy that was otherwise being released as heat into the cabinet can be used to power additional computing equipment. Further reducing the heat dissipated into the cabinet requires less heat management tools (fans) and increases the life and sustainability of the electronic components contained within.

The initial AC/DC rectification stage in an online UPS is crucial to properly conditioning incoming power, but providing reliable output power can be achieved with AC or DC power. Since our electronic load equipment uses DC power internally, it would make sense to eliminate two unnecessary conversion stages, which cost us electricity; both through their inefficiencies and in dissipating the heat they generate.

3.0 System Design Considerations

3.1 Summary

The current trend by the U.S. Navy is to consolidate several cabinets' worth of processors and servers into a fewer number of cabinets where possible. A natural conclusion would be that the amount of electricity required to power an enterprise solution would be extremely high. That however, is not the case as the power draw of some Blade Servers and Storage Arrays do not require a modification to the power already being provided to a typical electronics cabinet.

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[2] An *offline* UPS is typically only comprised of a DC-AC inverter that is turned on only when incoming AC power is lost, else AC input power is fed directly to AC output with little or no conditioning. The interruption is typically 8 minutes.
[3]This is out of our control – the printed circuit boards inside our computers require DC power.

A fully-loaded Blade Server, two storage arrays and various other components can be powered from two 115VAC 60Hz single-phase 20A circuits while meeting a 10 minute batter runtime requirement using components that are efficient with their power consumption. Doing so would allow retrofitting of legacy ships reducing integration costs by hundreds of thousands of dollars. However, careful consideration needs to be taken of both the voltage-type and amount of electricity needed to power the system components during system design.

3.2 Smart, Efficient Use of Available Power

The design of a C5ISR cabinet includes power or wattage draw and battery backup requirements. Electricity is a utility and there is only a finite amount of power available to each cabinet. The individual components that meet the entire system requirements then must be capable of not exceeding the finite amount of energy provided with the existing shipboard electrical system configuration. A battery pack has to be designed to support that system for a finite amount of time in the event of a temporary power loss.

While the power draw of modern servers has increased, their power management capabilities have improved with them, enabling faster processor performance at only slightly higher power consumption. The same can be said for the file storage arrays. Some devices are however, smarter about power management than others and will draw less power while providing the same capabilities and performance. When components of similar capability and performance are considered, the component requiring less power should be chosen, all things otherwise being equal[4].

By reducing the power draw of a system, the number of batteries required to meet the same runtime requirement is also reduced[5]. In addition to space considerations batteries can add a significant amount of weight to the cabinet that will have an impact on shock and vibration variables such as center of gravity (COG) and total weight.

[4] A more popular example would be the difference between a household appliance carrying the *Energy Star* logo and one without. The product with the logo is considered more attractive.

[5] Batteries will be discussed later in Section 7.

4.0 The Open Architecture Requirement

4.1 Advanced Telecommunications Computing Architecture (ATCA)

A benefit of the -48VDC Blade Server configuration is that it is an ATCA standard for use in the Telecommunications Industry. ATCA is an existing open architecture platform with over 400 contributing companies:

- *The series of specifications incorporates the latest trends in high speed interconnect technologies, next generation processors and improved reliability, manageability and serviceability.*
- *Companies participating in the AdvancedTCA effort have brought a wide range of knowledgeable of the industry. They include telecommunications equipment manufacturers, board and system level vendors, computer OEMs, software companies and chassis, connector and power supply vendors*[6.]
- *Many ATCA compliant products follow the Network Equipment Building System (NEBS) standard for safety, spatial and environmental design guidelines*[7.]

While the NEB's standards are by no means equivalent to the Mil-Std's the U.S. Navy follows, they are similar in their concern for shock, vibration, EMI and temperature/humidity.

The ATCA standard with NEBS-compliant product provides a large, competitive market from which the U.S. Navy could draw many networking and processing products from, not just power supplies.

For more information on ATCA, please visit www.advancedTCA.org.
For more information on NEBS, please visit www.nebs-faq.com.

[6] www.advancedtca.org

[7] www.nebs-faq.com/what_is_nebs.htm.

5.0 Blade Servers

5.1 Input Voltage Configurations

One should consider both the voltage-type and amount of electricity needed to power the system components during system design. Different components like Blade Servers and Storage Arrays operate from various input voltage configurations and some voltage-types and components offer more efficient use of power than others.

The preferred input power configuration of a Blade Server is not necessarily a standard 115VAC 60Hz single-phase input due to their large current draw. Common Blade Server input configurations include both 220VAC 60Hz input and -48VDC input, allowing for greater power management.

The -48VDC configuration is attractive because it conforms to an open architecture platform (ATCA) and is standards-based. A 220VAC configuration is commonly used in high-current draw applications (washers, dryers, refrigerator, and large air conditioners) because it doubles the voltage, thereby halving the current. However, in this configuration only -48VDC offers electrical redundancy without retro-fitting the shipboard electrical system.

5.2 220VAC 60Hz

An alternate method is to create 220VAC within the equipment cabinet using the current standard shipboard electrical configuration. This is accomplished by providing two separate 115VAC 60Hz inputs to two different UPS's capable of outputting 220VAC each. The 220VAC output from each UPS is then fed into the Blade Server. The combination of these two UPS outputs will adequately power a Blade Server configuration without major modifications, but does not provide electrical redundancy, an important factor in system design that should not be neglected.

One of the problems with a 220VAC configuration is that if either of the UPS's goes down, then the entire Blade Server goes down because both UPS's are necessary to operate the Blade Server. Whereas two UPS's are typically used to provide electrical redundancy, both UPS's are now required just to power the system, and the loss of either UPS results in a failure of the entire cabinet – either component becomes a single point of failure and is a major design flaw.

5.3 -48VDC

-48VDC power can be created using the current shipboard electrical configuration employing an UPS that takes as an input 115VA 60Hz single-phase 20A and outputs -48VDC power. A single ±VDC UPS will adequately power an enterprise solution without requiring a second UPS, so electrical redundancy can still be maintained by offering a second ±48VDC UPS and the cabinet still runs if either UPS is lost. This is how most existing C5ISR cabinets are already designed, except with online AC UPS's.

A ±48VDC UPS solution is also attractive in that it typically provides greater power efficiencies, in the range of 3-5% better than most Online AC UPS's. This equates to approximately 130 watts of energy not wasted as heat energy into a cabinet that uses a ±48VDC UPS. The cost is much higher than just inefficiencies, when you consider those 130 watts of heat energy, or 444 BTU's, require additional energy usage for dissipation. If you don't dissipate the heat energy created by inefficiencies, you reduce the lifetime of all the electronic components housed in the cabinet. This seems a small amount of energy to be concerned about, but when you multiply 130+ watts across one hundred UPS's on three hundred ships, wasted power due to inefficiencies costs the U.S. taxpayer hundreds of thousands, if not millions of dollars a year.

6.0 Batteries

6.1 Background

Batteries are considered a consumable, much like the brakes on your car or the fuel in your gas tank. Over time the batteries will lose their ability to take a full charge and therefore typically every 2-5 years, depending on the battery type and quality, the battery pack inside of an UPS should be replaced. For this reason, batteries are considered the single most important maintenance item in a shipboard UPS and by extension are the biggest concerns of logistics and supply chain management. All things considered, the battery chemistry used by all commercial, industrial, or military-grade UPS manufacturers. Sealed-Lead Acid (SLA) [8] is the most capable of meeting runtime and lifetime requirements.

The battery chemistry considered standard in the UPS industry is the rechargeable, non-hazardous Valve-Regulated Lead Acid (VRLA), or SLA. This is due to the chemistries ability to support high-discharge applications while offering a long-term storage life, both standard requirements of UPS applications. The compromise of using the SLA chemistry is that the battery is bulky and heavy due primarily to its low energy-density. While just about every other type of rechargeable battery offers a higher energy-density, none offer the long-term reliability or safety of the VRLA/SLA chemistry.

6.2 Other Battery Chemistry Alternatives

Nickel-Metal hydride (NiMh) and Nickel-Cadmium (NiCd) batteries have near identical characteristics to each other, where NiMh is only of slightly higher energy density than NiCd, providing more capacity in the same volume. When left on float-charge for periods longer than a couple of months, both batteries' chemistries will begin to lose capacitance through voltage evaporation. This is commonly referred to as *memory* because NiMh/NiCd batteries are meant to be used only in frequent charge/discharge applications where the full capacity of the battery is regularly exercised. This regular use maintains capacity by avoiding voltage evaporation.

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[8] Seal-lead Acid (SLA) is also referred to as Valve-Regulated Lead Acid (VRLA) and Absorbent Glass Mat (AGB)

The effect of a NiMh/NiCd battery sitting on a float charge for only a few months is an irreversible loss in capacity that is unnoticeable until the battery is needed most – a discharge cycle. While a regular discharge/charge cycle can be programmed into the UPS battery algorithm to avoid voltage evaporation, it inevitably requires you to discharge/charge the battery every 2-3 months, running the risk of having a discharged battery during an unplanned power outage which is obviously undesirable.

Lithium Ion (LiIon), on the other hand, supports long-term storage and provides high-depth discharge in a much smaller volume than any other chemistry. The high energy density that provides for the smaller volume is, however, inherently more unstable and special care needs to be taken with this chemistry since the failure of a LiIon battery can be violent or catastrophic. Lithium Ion has not necessarily been a cost-effective solution either. As a result of safety and cost concerns, LiIon batteries are used in a very limited number of shipboard applications, most of which are not UPS-related yet.

6.3 Reducing Lifecycle and Training Costs

An attractive serviceability feature available in a growing number of UPS's is a hot-swappable battery pack. "Hot-swappable" refers to a battery pack that can be removed from the UPS and replaced with another battery pack while the UPS remains powered on and fully-functioning. There are a number of obvious benefits of not having to power down the cabinet or system to replace a bad battery pack.

Since batteries are considered consumables and the largest single-point of maintenance on an UPS, the benefit in hot-swapping an old battery for a replacement pack is significant. Entire C5ISR systems can be left running while this service is performed; thereby, completely eliminating any downtime associated with UPS maintenance.

The second largest maintenance items related to an UPS is filters. Typically, most manufacturers push or pull external air directly across the internal electronics contained within the UPS using only a foam filter to catch dust and debris. These filters need to be cleaned regularly to maintain adequate airflow across the electronics and maintain properly cooled components. Air filters that go unchecked and which become clogged will reduce airflow, increasing the temperature of internal components and therefore, reduce the shelf life of those components, increasing the chances of component failure.

An ideal UPS would be one that cools the electrical components without pushing air directly across the warm components. Products currently exist in the marketplace which dissipates heat through heat sinks cooled by forced air. Warm electrical components are mounted internal to a tubular heat sink which is cooled externally with forced air. The internal components are not exposed to the external environment but their heat is still dissipated with forced air. Products like this are life savers for filters and airborne contaminants.

7.0 The Requirement

7.1 Background

The typical electrical feed to a shipboard electronics cabinet is typically two separate 115VAC 60Hz single-phase, 20-amp circuits, usually from two different sections of the shipboard electrical system for redundancy. Historically, this power is conditioned through an UPS located at the bottom of a shock-mounted cabinet.

The UPS server's two primary functions: (1) to provide safe and consistent conditioned electrical power, and (2) to provide backup in the event of a temporary power loss. A Navy shipboard UPS differs materially from commercial UPS's as they have been designed and engineered to meet stringent environmental and Mil-std requirements as well as providing technical functionality that lower cost units cannot address.

A standard naval shipboard AC UPS should be an Online UPS, offering Double-Conversion technology. This technology first converts AC to DC power and then recreates the AC output sine-wave from a DC bus - meaning it works 100% of the time and is truly Uninterruptible. This is the only sure way to completely eliminate harmful electronic disturbances. Lower cost units do not perform the same double conversion and are considered Offline UPS's – meaning they pass input power through to the output and work, or go online, only in the event of a disturbance. Offline UPS's do not offer comparable power protection to Online UPS's and by the time an Offline UPS acts, it may already be too late to prevent an electronic disturbance from damaging your sensitive electronic system.

7.1 Variations from COTS Products

Technically, Navy shipboard UPS's accept underground, delta power as commonly supplied to the shipboard electronics cabinet, condition that power, and output 115/120VAC 60Hz, single phase electricity, grounded or ungrounded, depending on the design. Due to the unique environmental conditions found shipboard, these shipboard UPS's are typically designed to meet or exceed Mil-std's for shock, vibration, EMI, high temperature, low temperature, humidity, and shipboard noise.

Individual components inside a commercial product can be ruggedizes, but Electromagnetic Interference (EMI) and Shock and Vibration sustainability need to be considered during product design to ensure compliance to the strict Mil-std's.

The resulting product that best meets the requirements of these applications is a hybrid between Commercial-Off-The-Shelf (COTS) and Government-Off-The-Shelf (GOTS), both in terms of performance and value. Whereas 15 years ago the system requirements could be accommodated by COTS products, today the best solutions are arguably much closer to GOTS. Underpinning the shift is the fact that the number of Mil-std's found in the requirements continues to grow every year as the needs become more immediate.

7.3 Rugged or Ruggedized?

Traditionally, the Lead Systems Integrators have tried to use COTS components whenever possible to reduce cost and increase both availability and support. However, COTS products required ruggedization to pass Mil-std testing resulting in a hybrid ruggedized COTS/GOTS product that offers passable performance at or near the desired cost.

The untold lifecycle cost of training, supportability, and replacement however, cannot be underestimated when comparing what seems like a low initial investment because a commercially available Standby UPS product could be replaced dozens of times during the lifetime of a ruggedized UPS. Similarly, a ruggedized UPS could be replaced or repaired numerous times during the lifetime of a rugged UPS. What initially appears to be a low-cost investment can turn into an *exorbitantly* large total cost of ownership (TCO).

Specifying a rugged UPS solution, built and designed *rugged*, or not *ruggedized*, will significantly reduce the amount of time, effort and financial investment to maintain over the products lifetime than comparable COTS or ruggedized UPS solutions.

7.4 Proprietary Features

Most of the shipboard UPS's available today offer similar features which enable system designers, integrators, and logistical support personnel interoperability between vendors and platforms with minimal headaches. Rugged or ruggedized UPS's with proprietary features of functionality can lead to integration, maintenance and lifecycle support issues and should be carefully assessed against the benefits of standards-based implementations. Features like input and output connectors are the most common variation among manufacturers; however, most manufacturers offer industry or military standard connectors and adaptor cables that are easily and inexpensive to produce.

Common communication methods like Simple Signal[9], RS232[10], and SNMP[11] follow industry standards, but it's not uncommon for a SNMP manufacturer to offer a proprietary Management Information Base Fuel Savings through Enterprise Power Selection.

For the same reasons cites above, proprietary features of this nature should be assessed carefully against the benefits of the standards-based SNMP network agents following the industry standard for UPS's – MIB RFC 1628.

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[9] This can be as simple as a voltage driven by a pull-down resistor indicating alarm-state.

[10] Refers to Electronics Industries Association (EIA) Recommended Standard 2232 (RS-232)

[11] Refers to Internet Engineering Task Force's (IETF) Simple Network Management Protocol (SNMP)

A Power Distribution Unit (PDU) or Assembly (PDA) is usually used to complement the shipboard UPS's visual indicators and audible enunciators, reproducing these features and providing load switching at the top of the cabinet (because the shipboard UPS is usually installed at the very bottom due to its weight.) There are various PDA's available from different vendors and a standard shipboard UPS will provide the communication signals necessary to provide interoperability. Any shipboard UPS attempting to incorporate these functions internally should be discouraged to allow true interoperability and reduce cost and redundancy.

8.0 Conclusion

To power an enterprise solution from the existing shipboard electrical system, care should be taken to choose individual system components that meet the capability requirements at the lowest power consumption by taking into account input voltage configurations and smart power use. This would reduce the amount of batteries needed to back-up that system for the required runtime and inherently reduce the volume and weight of the UPS in the cabinet.

The organization making the initial investment often has no relationship with the organization responsible for the maintenance of the system. This leads to solutions produced at the lowest initial cost but a higher lifecycle cost. The entire cost of the system can be reduced by procuring higher-quality products with a higher confidence in passing the military standards, at higher efficiencies. These *rugged* products will stand up to harsh environments longer and cost the taxpayer less during the lifetime of the system.

	Investment		Technical Features					Maintenance, Training and Supportability		
UPS Type	Initial Cost	Total Cost of Ownership	Mil-std compliancy	Power Factor Correction	True Online	Battery Backup	Efficiency	Hot-swappable Battery Pack	Flow-through Heat Sink design	Typical Availability
Commercial	Lowest	Highest	None	✓	✓	✓	85%	✓	✗	Off-the-Shelf
Ruggedized	Medium	Medium	Most	✓	✓	✓	85%	✓	✗	Build-to-order[12]
Rugged	Highest	Lowest	All	✓	✓	✓	85-90%	✓	✓	Build-to-order[3]

Table 8-1. Conclusion

Special Note: The market for shipboard-grade UPS's when compared to COTS-products is rather small and the shelf life of battery packs should be a stock concern, so both rugged and ruggedized UPS's are typically custom built when an order is placed. Care should be taken when evaluating individual vendors through because *Build-to-order* could mean 4 weeks or 3 months, depending on the vendor's ability to keep stock of partially-manufactured goods.

ABOUT NOVA POWER SOLUTIONS

NOVA Power Solutions, Inc. a wholly owned subsidiary of LTI DataComm, a certified small, veteran-founded business headquartered in Sterling, Virginia has been a leading supplier of high quality power protection products since 1989.

We are a premier provider of mission critical rugged uninterruptible power systems; providing shipboard, rack-mounted and bulk-mounted UPS power supplies and battery back-up modules for U.S. mission-critical C41 and Combat systems.

The mission at NOVA Power is not just to provide a Commercial-Off-The-Shelf (COTS) Uninterruptible Power Supply (UPS), but to offer a tailored power protection solution to meet the specific requirement of each and every customer. NOVA prides itself on providing the highest level of pre- and post-sale service, including customer support. Additional information can be found at www.novapower.com.