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The Benefits of Using Lithium-Ion Batteries as a Backup Power Source for UPS Systems in Distributed IT or 5G Networks

How 5G Micro Sites, Edge Data Centers, Server Rooms, Data Closets, and Other Remote Deployments Can Take Advantage of Lithium-Ion Batteries

Introduction

Today, you don't have to look very far to find a device that is powered by a lithium-ion battery. Chances are, you've got one in your pocket, or sitting somewhere on your desk! Lithium-ion batteries are the hidden power source behind billions of consumer products, everything from smartphones, tablets, and laptops to cordless power tools and digital cameras. Also, lithium-ion batteries are being developed and used as power sources for hybrid and self-driving vehicles, and as energy storage solutions for electrical grids, wind turbines, and solar panels.

Lithium-ion batteries have been with us for decades. In the 1970s, American scientists M. Stanley Whittingham and John B. Goodenough developed the initial lithium chemistries for battery use. In 1991, Sony introduced the first commercial rechargeable lithium battery, created by Japanese chemist Akira Yoshino, for powering hand-held camcorders. In 2019, in recognition for the impact that lithium batteries have had on our world, these three inventors were awarded the Nobel Prize in Chemistry.

Another area where lithium-ion batteries are coming into widespread use is as a backup power source for Uninterruptible Power Supplies (UPS), the devices that ensure uptime for mission-critical IT and/or network infrastructure in traditional or edge data centers. In this white paper, we'll take a closer look at the advantages of using lithium-ion batteries in conjunction with single-phase UPS systems, specifically for deployments in distributed IT or 5G networks.

Executive Summary

Lithium-ion batteries are coming into widespread use as a reliable backup power source for single-phase UPS systems in distributed network deployments, including 5G micro sites, edge data centers, server rooms, and data closets. With a higher power and energy density, faster recharge, and a longer lifespan and cycle life, lithium-ion batteries are a more robust alternative to traditional lead acid batteries. The smaller size and lower weight of lithium-ion batteries makes them ideal for space-constrained deployments and easier to ship to remote areas, while greater tolerance to extreme temperature changes makes them a better choice for outdoor use. A Battery Management System (BMS) ensures safe operation, and helps to make lithium-ion batteries a maintenance-free solution. Over the 15-year life of a UPS system, lithium-ion batteries provide a considerable savings in Total Cost of Ownership (TCO) by reducing maintenance and operations costs, and eliminating the replacement costs of lead acid batteries.

The Emergence of Distributed Networks

Over the next decade, many companies, industries, and organizations will have a need to deploy distributed networks over a wide geographic area. These IT and/or 5G networks will be made up of thousands of localized micro sites that will take one or more of the following forms:

5G (5th Generation) Micro Nodes – To achieve the higher operating frequency, reduced latency, and faster transmission rates promised by 5G mobile networks, providers will need to grow beyond their current 3G and 4G cell tower systems. They will need to deploy thousands of Radio Access Network (RAN) micro nodes or clusters throughout various cities, in buildings and at street level, as well as in industrial and agricultural facilities, and remote rural areas.

Edge Data Centers – An edge data center is any data center that houses IT servers located on the edge of a distributed network, with connections back to a centralized cloud core. The servers in edge data centers host localized applications that operate a variety of technologies, including autonomous vehicles, Internet of Things (IoT) devices (i.e. smart traffic lights), and Industrial Internet of Things (IIoT) devices in manufacturing and agricultural facilities.

Server Rooms and Data Closets – A server room or data closet is any room in a remote office or branch location that houses the mission-critical IT and network routing equipment for that site. Often, the servers and routers are on a distributed network that links back to a centralized location. Server rooms and data closets are found in office buildings, university campus buildings, hospitals and medical facilities that are part of a multi-site healthcare organization, and retail establishments such as chain stores and restaurants.

The classifications for these localized sites often overlap. For example, a 5G cell tower may have a modular edge data center installed as its base, which hosts the servers that operate the tower. An office data closet may host indoor 5G cells and IT servers on a distributed network, which qualifies it as both an edge data center and a 5G micro node. But whatever you choose to call it, the common goal of most of these sites is to deliver micro-edge computing with near-zero latency.

The Purpose of UPS Batteries

Each individual micro site on a distributed network requires a robust UPS system to guarantee uptime and protect mission-critical connectivity and response time. If the power fails, the UPS will automatically start up and provide power to the IT and network equipment housed at that site, until one or more things happens:

1. Local utility power is restored
2. IT administrators are able to move operations or virtual environments to other sites
3. Network administrators are able to reroute traffic to other network nodes
4. Operations people are able to shut down the IT servers and/or network node safely, without data corruption or loss

Often, a distributed 5G or edge network micro site will employ a single-phase UPS, as opposed to the three-phase UPS systems that you find in larger data centers and centralized network hubs, where power quality is a priority.

In many cases, the UPS is the sole auxiliary power source for that site. Unlike larger data centers, distributed network sites don't usually have additional power resources, such as generators. If utility power goes down, the UPS may be required to provide power to that site for 30 minutes or more. Therefore, a distributed site must have a reliable backup power source, one that will not fail when the UPS kicks in to ensure uptime of mission-critical IT and network equipment.

In addition to high power requirements, distributed micro sites often have a very small footprint and limited space, where most of the room is taken up by IT servers and network routers. Therefore, the backup power source for the UPS must be small and compact. In cases where a micro site is located in a rural or remote area, it may be harder to transport batteries out to that site, and harder for technicians to reach those places to perform maintenance if a battery or other equipment fails.

The Drawbacks of Lead Acid Batteries

A UPS is typically powered by strings of batteries. Until recently, Valve-Regulated Lead Acid (VRLA) batteries have been the battery of choice for UPS backups. But these types of batteries have significant drawbacks that make them ill-suited for use in distributed IT or 5G network deployments.

Unreliable Performance

In 2013, a Ponemon Research study discovered that 55% of data center outages and one-third of UPS system failures were due to lead acid battery failure. Unreliable battery performance was the leading cause of unplanned outages, beating out other causes such as human error, UPS capacity overload, IT or mission-critical infrastructure failure, weather events, and cyberattacks. (Although this study focused on outages in large data centers, the same causes could also be applied to 5G and edge sites.)

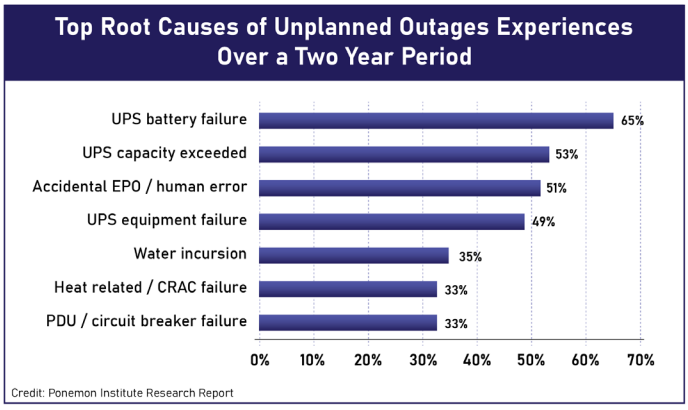

Figure 1: Top root causes of unplanned outages experienced over a two-year period.

Short Life

Even the best-quality lead acid batteries only have a lifespan of 5-7 years, which means they must be replaced 2-3 times over the 10-15-year lifespan of a UPS system. A battery's useful service life is determined by how often it is discharged and recharged. But factors like frequent discharge cycles, discharging below 50% State of Charge, overcharging, strained battery terminals, loose connections, and high or uneven ambient temperatures can shorten the battery's useful life.

Once the battery reaches 80% capacity, it is considered End Of Life (EOL). At this point, performance degradation accelerates, and the battery loses its ability to discharge at sufficient voltage. After 3-5 years of use, a VRLA battery's capacity is severely reduced, and it may be subject to "sudden death syndrome," where the battery fails at a crucial moment, resulting in UPS failure and downtime of IT or network equipment.

Size and Weight

Lead acid batteries are large and bulky, and take up valuable rack or floor space that could instead be used for IT or 5G equipment. This especially becomes a problem in sites where space is limited, such as modular or containerized data centers, micro 5G cabinets, or indoor data closets.

Also, lead acid batteries are heavy, and can literally "weigh down" a data center. In indoor sites, such as server rooms located on upper levels of a building, the floor may need to be reinforced to handle the extra weight of VRLA battery strings. In outdoor sites, the extra weight makes it harder for technicians to transport, install, and replace lead acid batteries, especially when servicing 5G towers or edge data centers in remote locations.

Temperature Sensitivity

A battery's operating temperature strongly affects its useful life, even if the battery is not being regularly charged or discharged. To keep their warranty and ensure a 5-7 year lifespan, VRLA batteries require a controlled room temperature of 25°C (77°F). Also, a lead acid battery's useful life is reduced by half each time the ambient temperature in that location is increased by 10°C.

In indoor environments where cooling is available, the cooling costs add to the TCO of lead acid batteries. In outdoor environments, the VRLA batteries may be subjected to extreme changes in temperature throughout the day and year, which causes them to degrade faster.

Maintenance and Replacement

Individual lead acid batteries require ongoing voltage checks and continuous performance monitoring to ensure that a single bad battery cell doesn't take down an entire string. Technicians must also periodically remove corrosion, fix loose connections, and replace defective or dying batteries.

Ongoing maintenance of lead acid batteries is costly and time-consuming, since technicians must often visit dozens of distributed sites to check the status of individual batteries. As mentioned, the size and weight of lead acid batteries makes it harder to transport replacements, especially when distributed sites are located in hard-to-reach remote areas.

The Advantages of Lithium-Ion Batteries

The advantages of lithium-ion batteries often make them a more practical option for UPS backup power, especially in small-scale and remote deployments.

Reliability and Availability

The failure of lithium-ion batteries in UPS applications is extremely rare. Today's battery providers utilize quality materials, superior design, and improved manufacturing methods to produce lithium-ion batteries that are built for reliability in all kinds of mission-critical environments.

Equivalent Energy & Faster Recharge

Lithium-ion batteries have a higher power density (watts per kilogram, or W/Kg) and energy density (watt hours per kilogram, or Wh/Kg) than lead acid batteries. They provide the same amount of energy in a lighter, more compact design.

Also, most lithium-ion batteries can be recharged to 90% capacity in under two hours, while VRLA batteries may take anywhere from four to 24 hours to fully recharge. If an edge data center or 5G cell station has multiple utility outages in a single day, the lithium-ion batteries can quickly be recharged to provide ride-through time for each outage.

Extended Lifespan & Cycle Life

Lithium-ion batteries have an estimated lifespan of 10-15 years, which is 2-3 times as long as the average 5-7 year lifespan of lead acid batteries. A lithium-ion battery may last the entire 15-year lifespan of your UPS. Also, lithium-ion batteries have a predictable degradation curve, which makes it easier to determine when they are approaching "end of life" and will need to be replaced; unlike lead acid batteries, aging lithium-ion batteries are not subject to "sudden death syndrome."

A typical lead acid battery has a cycle life of 200, meaning you can discharge the battery to 50% capacity and recharge it to 100% capacity, up to 200 times before the battery dies. But the lithium-ion chemistries used in batteries for UPS applications each have a longer cycle life – 1,000-2,000 cycles for the Nickel Manganese Cobalt (NMC) chemistry, and 2,000-4,000 cycles for the Lithium Iron Phosphate (LFP) chemistry. Additionally, you can discharge lithium-ion batteries from 100% to 0%, which is twice the available capacity of lead acid batteries. (See below for more on these chemistries.)

Smaller Size and Lower Weight

Lithium-ion batteries are up to 70% more compact than lead acid batteries. The smaller size of lithium-ion batteries makes it easier to install them in space-constrained deployments, such as modular or containerized data centers, 5G micro nodes, and data closets.

Also, lithium is a lightweight element, and lithium-ion batteries typically weigh about 1/3 less than most VRLA batteries. The lower weight makes lithium-ion batteries easier to carry, transport, and install, especially when delivering them to remote locations.

Accommodate Higher Temperatures

In outdoor settings, lithium-ion batteries can tolerate higher ambient temperatures, and are less susceptible to sudden temperature changes that would shorten a lead acid battery's useful life. In indoor settings, lithium-ion batteries provide a savings in cooling costs, since server rooms and data closets can be kept at a higher ambient temperature without fear of damaging the batteries.

Less Maintenance

All lithium-ion batteries have a built-in Battery Management System (BMS) that monitors battery performance, reducing the risk of sudden battery failure. The BMS provides automatic status and fault monitoring, cell balancing, and power optimization for each individual battery.

A well-designed lithium-ion battery is virtually maintenance free, making it a "set it and forget it" solution. The BMS allows technicians to monitor battery health, in either a local or remote deployment. This allows you to maximize battery life, minimize downtime, and reduce labor and maintenance costs.

Cost Comparisons – Lithium-Ion vs. Lead Acid Batteries

Although the costs have decreased significantly over the last decade, lithium-ion batteries still require a higher initial investment than lead acid batteries. However, over a 15 year period, lithium-ion batteries offer long-term savings in Total Cost of Ownership (TCO) when used in 5G and IT network deployments.

Figure 2 shows the total combined costs of capital and operating expenses for both lead acid and lithium-ion batteries. Over a 15-year period, the combined costs for VRLA batteries are much higher.

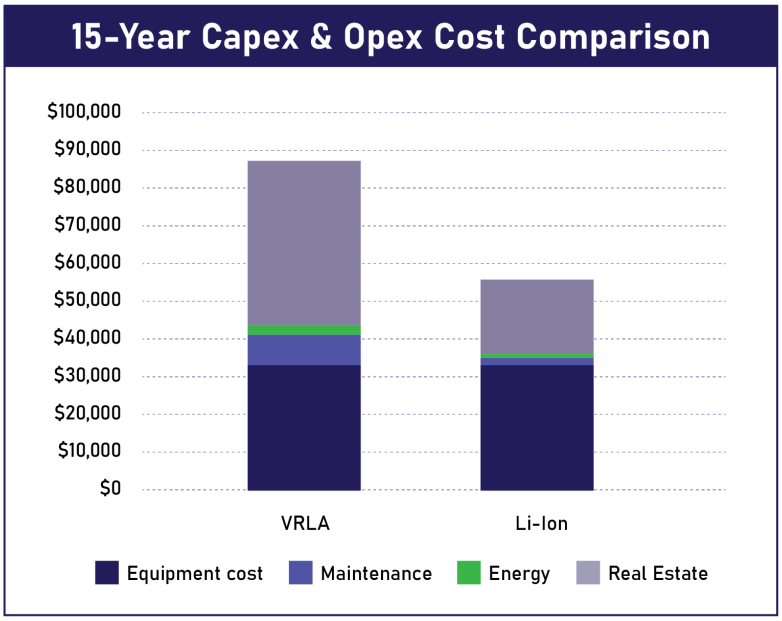

Figure 2: Combined CAPEX & OPEX cost comparison

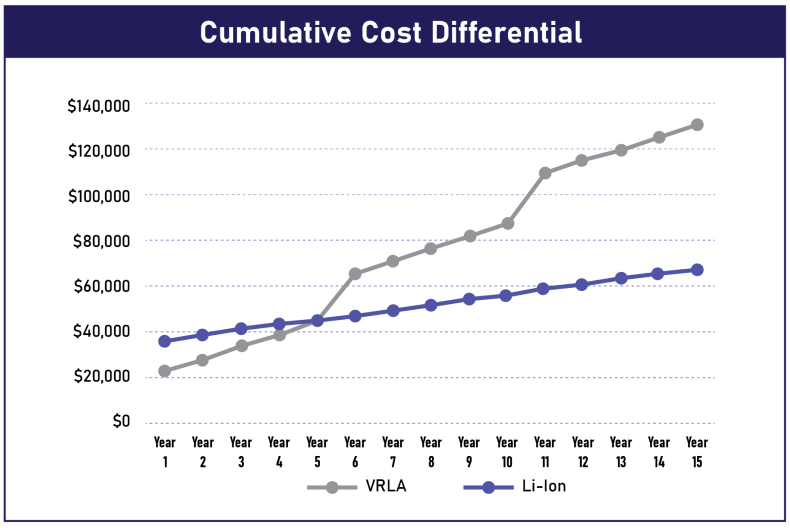

Figure 3 – 15-Year Cumulative Cost Differential

Figure 3 shows the cumulative cost differential over the 15-year lifespan that is typical of a UPS. While the initial costs of lead acid battery systems are lower, the total costs steadily increase over time, as the VRLA batteries must continuously be maintained and periodically replaced. Meanwhile, over this same period, the recurring costs of lithium-ion batteries are minimal, producing a Return On Investment (ROI) within five years of the initial battery deployment.

As mentioned, the longer lifespan and reliability of lithium-ion batteries means that they may last for the entire life of your UPS. This eliminates the cost of replacing batteries every few years, and also provides potential savings in labor, maintenance, shipping, and transportation that would otherwise be needed to service and replace the batteries in remote locations.

The Different Lithium Chemistries

Not all lithium-ion batteries are the same. There are different types of batteries with different lithium-based chemistries, and each type of battery has its own qualities and uses.

Table 1: Qualities of Lithium-Ion Battery Chemistries

Chemistry	Abbre-viation	Typical Voltage	Specific Energy (Density)	Cycle Life	Charge (C Rate)	Discharge (C Rate)	Typical Uses
Lithium Cobalt Oxide (LiCo02)	LCO	3.7V	150-200 Wh / Kg	500-1000	0.7 - 1.0C charges to 4.20 V	1C - 2.50 V cut off	Mobile consumer devices, such as laptops, smartphones, and digital cameras
Lithium Iron Phosphate (LiFePO4)	LFP	3.2V	90 - 170 Wh / Kg	2,000 - 4,000	C/2 to 4C, charges to 3.65 V	1C typical; 30C on some cells; 250V cut off	Stored energy for mission-critical environments. also used in electric vehicles
Lithium Nickel Cobalt Aluminum Oxide (LiNiCoAl02)	NCA	3.6V	155-260 Wh / Kg 500	500	0.7C, charges to 4.20V	1C typical; 3.00V cut off	Electric vehicles
Lithium Manganese Oxide (LiMn204)	LMO	3.7V	100-150 Wh / Kg	300-700	0.7-1.0C typical, 3C max.; charges to 4.20V	1C typical; 10C on some cells; 2.50V cut off	Medical devices, power tools, consumer devices, electric vehicles
Lithium Nickel Manganese Cobalt Oxide (LiNiMnCo02)	NMC	3.6V	150-200 Wh / Kg	1,000-2,000	0.7-1.0C, charges to 4.20V	1C typical; 2C on some cells; 2.50V cut off	Electric vehicle powertrains, cordless power tools, electrical grid storage

Choosing the Right Lithium-Ion Chemistry – LFP vs. NMC

The two types of lithium-ion chemistries commonly used in UPS batteries are Lithium Iron Phosphate (LFP) and Lithium Nickel Manganese Cobalt Oxide (NMC).

Which lithium-ion chemistry should you use? It depends on what types of distributed sites you will establish, and how you plan to use your UPS system. LFP batteries are more common and offer more advantages, but in some cases, NMC batteries may be a better option. The following table gives a quick comparison of the two chemistries.

Table 2: Lithium Iron Phosphate (LFP) vs. Nickel Manganese Cobalt (NMC)

Parameter	Lithium Iron Phosphate	Nickel Manganese Cobalt (NMC)	Comparison
Voltage	3.2 V	3.6 or 3.7 V	NMC batteries are smaller, lighter, and more compact, offering a higher energy density in both weight and volume. In UPS applications, NMC offers low-current power delivery over a longer time period.
Weight Energy Density	90 - 120 Wh/Kg	150 - 250 Wh/Kg	
Volume Energy Density	300 - 350 Wh/L (Watt hours per liter)	500 - 700 Wh/L	
Max. Discharge Rate	30 C	2 C	LFP batteries provide higher current delivery of power to a UPS over a shorter runtime, and can be recharged faster than NMC batteries.
Max. Charge Rate	10 C	0.5 C	
Typical Cycle Life (@80%)	2000 - 3000 cycles	500 - 1000 cycles	LFP batteries will deliver more cycles over a longer calendar life, and thus will continue to function longer than NMC batteries.
Calendar Life (@80%)	8+ years	3 - 4 years	

In choosing whether to use an LFP or NMC battery with your UPS system, you should ask yourself the following questions:

- How much available space do you have?
- How long or short is the required battery runtime? In other words, will you need a battery that discharges a higher current in a quick burst that lasts only a few minutes? Or will you need a battery that discharges a lower current slowly over several hours?
- How quickly and frequently will the battery need to be recharged after every discharge?
- How long will the battery be in service?
- Is cooling available? If not, what kinds of temperature extremes will the battery be subjected to?

For example, you may have an edge data center located at the base of a 5G cell tower, in a remote desert area that sees day temperatures above 100°F, and night temperatures below 50°F. In this case, you should use an LFP battery, which is more tolerant of extreme temperature swings. The LFP battery also has a longer calendar and cycle life, which means it needs to be replaced less often.

On the other hand, you may have a UPS located in an extremely small space, such as an office data closet with only enough room for a 10U server rack, or a 5G micro site box attached to the top of a smart traffic light. In these cases, you might want to consider using NMC batteries, since they are more compact and easier to fit into small, space-constrained areas.

Safety Concerns

Many companies have safety concerns about using lithium-ion batteries as a backup power source. They are afraid that an unstable battery will explode or cause a fire that may damage their critical IT or network equipment.

All types of batteries are vulnerable to a condition known as thermal runaway. This occurs when the battery chemistry reaches such a high temperature that the battery can no longer safely disperse heat, which may result in an explosion or fire. Thermal runaway may be caused by overcharging, physical damage to the battery, an internal fault, or an excessively hot environment.

However, the lithium-ion batteries used in UPS applications have several features that help to ensure battery safety. First, the lithium-ion chemistries used have extremely high thermal runaway temperatures. An LFP battery must reach an internal temperature of 270°C (518°F) to achieve thermal runaway; an NMC battery must reach an internal temperature of 210°C (410°F). This means the battery must be severely heated or overcharged before it reaches a temperature where thermal runaway becomes possible.

Also, as mentioned, all lithium batteries come with a Battery Management System that monitors the battery's parameters. The BMS has a control temperature limit, meaning it will automatically disconnect the battery from its load or charger if it reaches an internal temperature (usually around 70°C/158°F) that may shorten the battery's useful life. In other words, the BMS will shut down the battery long before it achieves thermal runaway temperature.

Finally, today's lithium-ion batteries for UPS systems are manufactured with quality in mind, with a durable battery design and cell packaging. Most batteries include overcharge protection, safety fuses, and hardened materials layers, and are made to comply with UL and other applicable safety standards.

Environmental Concerns of Lithium-Ion Batteries

The technology for recycling lithium-ion batteries is still under development. Unlike the lead that is present in VRLA batteries, lithium isn't a toxic heavy metal, so until now, there has been less urgency to recycle these types of batteries. Also, the lifespan of lithium-ion batteries is so long (up to 15 years) that many batteries have yet to reach end-of-life stages, where recycling becomes necessary. But some providers are now establishing recycling programs for lithium-ion batteries, which include the following features:

Recovery – Many battery manufacturers now have a policy of accepting and collecting used lithium-ion batteries from their customers.

Reuse – In a well-designed battery, lithium cells can easily be removed and reused. In many cases, up to 30% of a recovered lithium-ion battery's original energy can be repurposed for lower energy applications, such as solar energy storage or as a power source for minor recreational vehicles (i.e. golf carts). Also, key battery components such as the steel battery tray, ballast, and compression plates can be refinished and reused as part of a new battery system.

Recycle – When lithium-ion cells eventually reach end of life, they can be returned to the industrial cell manufacturers who made them. The cell manufacturers can then reuse the materials of the lithium-ion chemistry (i.e. for LFP, the materials are lithium salts, iron, and phosphate) to manufacture new battery cells.

What To Look For In A Lithium-Ion Battery Provider

When evaluating lithium-ion batteries, you should first look at the battery provider and what they offer to their customers. Look for a provider that offers multiple lithium chemistries for UPS applications, specifically LFP and NMC. A battery provider can help your company to conduct a power survey of each individual 5G or IT network site to determine the best chemistry for your application.

The provider should offer a safe, reliable, and well-tested lithium-ion battery system. The batteries themselves should be well-manufactured using quality materials, and made to comply with top industrial and safety standards. Also, the batteries should have a proven track record of reliable usage in mission-critical facilities, and in both indoor and outdoor deployments.

Of premium importance is the Battery Management System (BMS). For each individual battery, the BMS should monitor data and conditions at the cell level, including temperature, voltage, current, State of Change, State of Health, and historical usage. The BMS should offer remote monitoring and configuration of lithium-ion batteries, enabling you to track the status of all batteries in all deployments across your distributed wide area network from a single portal.

Also, the BMS should include intelligent energy balancing technology, to equally distribute the discharge current across all batteries in a pack. If one battery fails, the BMS will automatically redistribute current flow across the remaining batteries, to prevent a potential cascading effect that causes all lithium batteries in that pack to overload and shut down. The energy balancing technology also controls the recharge current into each battery, optimizing charging of battery packs, mixing batteries of a different age or capacity within the same pack, and enabling battery-to-battery balancing to prevent overcharging.

Conclusion

As we go forward, our reliance on 5G and edge networks will only increase. The continuous evolution and adoption of technologies (mobile, IoT, transportation, etc.) that rely on localized, latency-free application processing is a guarantee that distributed high-speed networks will become more prolific. Also, as the global COVID pandemic proved, our workforce is becoming more dependent on technologies that enable us to work from anywhere at any time. The reliability of distributed networks will be key in ensuring that these technologies are available when we need them.

Lithium-ion batteries have proven their capability as a backup power source for UPS systems, with a longer lifespan and cycle life and reduced maintenance needs, resulting in a significant ROI. With smaller size, lower weight, and greater tolerance to temperature changes, plus a BMS that monitors parameters and ensures safe operation, these batteries are the better choice for use in remote and space-constrained micro sites. The combined advantages of performance, safety, and cost effectiveness make lithium-ion batteries well worth the initial investment, as a dependable, long-term solution for ensuring uptime of mission-critical infrastructure in your 5G or IT network deployments.

WANT TO LEARN MORE?

Want to learn more about how to use lithium-ion batteries in your 5G deployments, edge data centers, server rooms or data closets? Looking for assistance in determining which battery chemistry, LFP or NMC, is the best fit for your deployment plans? Contact Green Cubes Technologies today for more information, or visit us at greencubestech.com.

ABOUT GREEN CUBES TECHNOLOGY

Green Cubes Technology harnesses over 30 years of industry experience to ensure we design, develop and deliver solutions for the most challenging energy needs. We offer battery technology innovation, application design and performance management to drive productivity, scalability and sustainability.

For more information, email **contact@greencubestech.com** or visit **greencubestech.com**

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