A White Paper from the European Data Centre Association Technical Committee

Battery Technology Opportunities for Data Centres

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Introduction

Lead Acid batteries have historically been the battery of choice for Data Centres. The development of new battery products suitable for larger loads is being driven by the electric vehicle industry with Lithium-ion batteries in particular are now becoming a viable option for Data Centre use. Lithium-ion batteries bring a number of benefits and remove a number of the constraints imposed by lead acid batteries to create new opportunities for the Data Centre operator to review their electrical distribution topology and potentially generate additional income from their battery investment.

What is changing?

1 - Cost

The cost of Lithium-ion batteries has dramatically reduced over recent years, as illustrated below the $/kWh cost in 2019 is forecast to fall below $150 representing a reduction of over 80% since 2010.

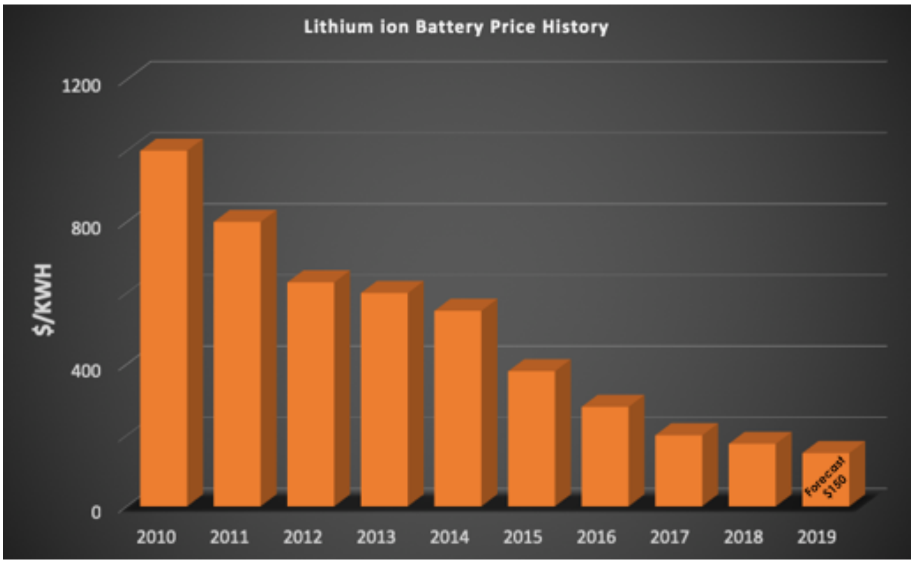

Figure 1 - Lithium-ion Battery Price History [Source: Bloomberg New Energy Finance]

The reduction in capital costs for Lithium-ion battery solutions means that Lithium-ion battery capital costs are now in the range of 1.2-2.0 times greater than the equivalent Valve Regulated Lead Acid (VRLA) solution (the range being dependent upon the actual configuration used) but with a payback period of less than 5 years when the operational cost savings are considered. Within the US market the capital cost differential has reduced even further with Uninterruptible Power Supply (UPS) vendors offering their larger clients Lithium-ion battery solutions for the same price as VRLA based solutions.

2 – UPS functionality

Many of the UPS vendors are incorporating grid support functionality into their UPS units either as a standard feature or through an optional firmware upgrade. This allows the UPS and batteries to provide demand side response or frequency response services to the grid as explored in more detail within later sections of this paper.

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3 – Growing Customer Confidence

Data Centre operators are becoming more confident in Lithium-ion battery technology as it is adopted by a growing number of sites.

What are the key differences between Lithium-ion and VRLA?

When we compare Lithium-ion and VRLA battery technology the key differences between the technologies are:

- **Physical Size** – Lithium-ion batteries have a significantly higher power density so an equivalent amount of energy can be stored in a smaller footprint – up to 80% smaller with an equivalent saving in weight.
- **Service Life** – Typical service life for VRLA batteries is 3-6 years; the equivalent for Lithium-ion batteries is 10+ years.
- **Environmental conditions** – VRLA service life is quoted at 25°C with dramatic reductions caused by any increase in temperature (an 8°C increase in temperature will halve the expected service life). Lithium-ion service life is quoted at 40°C.
- **Capital Cost** – Typical Lithium-ion capital cost is 1.2-2 times greater than VRLA (dependent upon configuration).
- **Total Cost of Ownership** – Payback for Lithium-ion batteries is less than 5 years when compared with VRLA.
- **Cycle life** – VRLA batteries are typically capable of 200-400 charge/discharge cycles while Lithium-ion batteries are capable of 1,000+ cycles.

Key areas of concern when considering the use of Lithium-ion batteries

There remain concerns within the industry regarding the adoption of Lithium-ion batteries for Data Centres with fire and recyclability being the most commonly raised concerns:

Fire

Fire is the most common concern for Data Centre operators considering the use of Lithium-ion batteries. All batteries pose a significant fire risk due to their high energy content; the increased energy density associated with Lithium-ion batteries (which are the reason behind the savings in footprint and weight) mean they are considered to pose a greater risk compared to VRLA type batteries.

All Lithium-ion battery installations include a battery management system to monitor and maintain the batteries and prevent thermal runaway (considered to be the greatest risk of fire for a Lithium-ion battery installation).

The limited deployment of large format Lithium-ion batteries within buildings means that fire officers and insurers often have limited experience and there is a lack of clear guidance and standards that define the risks and identify the fire related installation and management requirements. There are standards under development that will provide greater definition of the fire protection requirements such as NFPA 855 and these will define more clearly the requirements for siting and separating banks of batteries as well as defining fire suppression requirements.

Recycling

Recycling processes and facilities for VRLA type batteries are well established and readily available at scale. For Lithium-ion batteries the processes have been developed but the capacity of the facilities that can recycle Lithium-ion batteries remains fairly limited. The recycling capacity will need to increase to meet the anticipated growth in demand for recycling of large format Lithium-ion batteries to support the electric vehicle industry as well as the demand from increased use in Data Centre facilities.

What are the opportunities?

Reduced Footprint

The reduced footprint required for Lithium-ion batteries to deliver the same capacity creates a number of opportunities for the designers of Data Centre facilities:

- **Increase white space** – the reduced footprint of the batteries allows battery rooms to be reduced in size allowing an increase in white space/rack numbers.
- **Increase autonomy** – if the same footprint is maintained the use of Lithium-ion batteries would allow an increase in the autonomy of the system within the same room size.
- **Increase load** – if the same footprint and autonomy is maintained the use of Lithium-ion batteries allows an increased load to be supported such as an increase in IT load or the backup of additional non-IT systems – this idea is further investigated in later sections of this paper.

Increased Environmental Range

The increase in the allowable temperature range for Lithium-ion batteries allows us to consider alternatives for the battery location and environment:

- **Remove battery room cooling** – the increase in allowable temperature range means that battery rooms no longer require the same level of cooling and in many climates a fresh air based solution is sufficient to meet the demands of the batteries.
- **Relocate the batteries** – as the batteries no longer have strict temperature requirements, they can be relocated to areas that may not have been considered in the past, for example:
  - **Locate within UPS rooms** – reduces cable lengths and reduces overall footprint as walls separating UPS and batter rooms are removed.
  - **Locate closer to the load** – UPS and batteries could be relocated within the data hall, within the row or within the rack.
  - **Locate externally** – products have been developed for grid connected storage applications where battery cabinets are located externally without the need for structures or covers.

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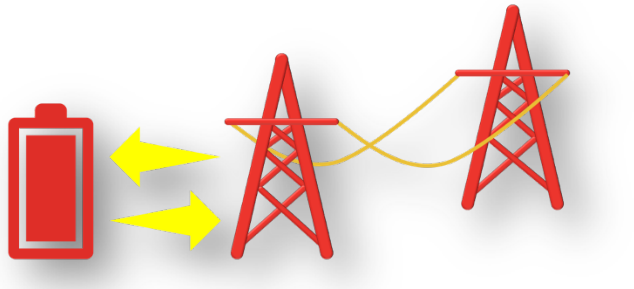
Increased cycle life



The ability of Lithium-ion batteries to accept a significantly greater number of charge/discharge cycles without impacting battery capacity/life allows the batteries to be considered for a range of functions that would not previously have been considered acceptable with VRLA type batteries:

- **Combine with on-site or off-site renewables** – increase the capacity of the battery system to store energy generated from renewables for use during periods when the renewable source is not available e.g. photovoltaics, wind turbines, tidal lagoons, etc.
- **Peak Lopping functionality** – energy is stored when cheaper or loads are lower for use during peak periods to reduce the peak demand from the supply grid.
- Grid support functionality:
  - **Demand side response** – taking a proportion of the site load off the local distribution grid and supporting with battery power.
  - **Frequency response** – being able to absorb excess power from the grid to assist in stabilising the network.

The sizing of UPS and battery systems needs to be carefully considered for the above applications to ensure the site maintains sufficient battery capacity to achieve their Service Level Agreement (SLA) commitments but these operating modes would generate an additional income stream or operational savings – could this support business cases for installation of UPS strings ahead of customer demand and reduce lead time for new customers?

In a recent trial application of UPS use for Demand Side Response Basefarm's Data Centre in Norway achieved the fastest response time of all operators following a power station failure event. The income from offering this type of service to the grid is expected to achieve an annual income of between €50-100k/annum per Megawatt of capacity that the operator is willing to make available for Demand Side Response.

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Alternative Electrical Distribution Topologies

The following diagram illustrates a typical Data Centre electrical topology with the UPS and batteries located between the LV intake switchboard and the Data Hall Power Distribution Units (PDUs):

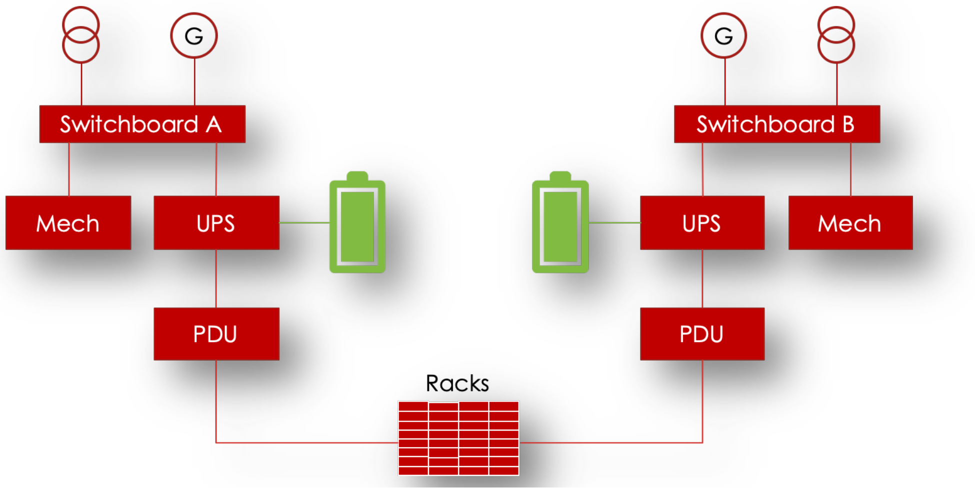

Figure 2 - Typical Electrical Infrastructure

Moving Batteries Upstream

If we make use of the reduced footprint associated with Lithium-ion to install an increased capacity can we move the batteries further upstream and protect more of the site?

If we move the batteries one step further upstream, to the LV intake switchboards we would be supporting all loads on that switchboard rather than purely the IT loads, avoiding the need for dedicated mechanical UPS systems and providing sitewide backup for non-critical services. As a further variation on this we could also consider increasing the autonomy of the batteries to 4 hours or more - would this allow some operators to remove the need for standby generators? Removing the generators would bring significant benefits by removing one of the longest lead-time items from the critical path but also removing the associated capital and maintenance costs, emissions permitting, fuel storage requirements and acoustic impact for the site.

If we take this idea one more step could the batteries move further upstream and sit at the site or campus level High Voltage distribution? Grid connected battery technology is available and used to provide support to national distribution grids in several countries so we could apply the same technology at a site HV distribution level. Alternatively, could we integrate the batteries with a campus level microgrid combined with on-site renewables? This could allow an overall reduction in the total battery capacity required rather than requiring multiple sets of N+1 batteries directly associated with each LV switchboard.

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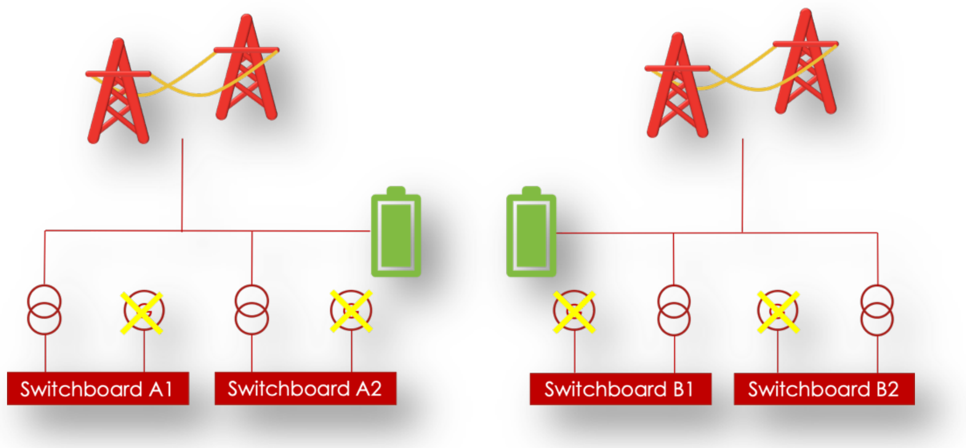

Figure 3 - Batteries installed on High Voltage network

Clearly there are risks associated with this approach, moving the batteries further upstream means that any distribution faults between the battery location and the critical loads are not protected by the UPS. Other risks to consider are the physical security risk associated with locating the batteries externally (but is this worse than the situation with external HV switchgear, transformers or HV switchgear?). We should also consider that historical data relating to Data Centre outages, such as the Ponemon Institute reports, consistently identify the UPS system as more likely to be the root cause of Data Centre outages than generators.

Moving Batteries Downstream

We could also consider relocating the batteries downstream of the typical installation location. The wider acceptable environmental range mans the batteries batteries could be relocated into the data hall and installed at PDU, row or even individual rack level. Locating the batteries this much closer to the IT load creates a range of further opportunities:

- 48V DC distribution - Locating within close proximity of the IT load would allow the use of 48V DC distribution similar to the historical approach used by telcos, many of today's server manufacturers offer a range of power supply units for this market without the need for further step up/down in voltage. Modular 48V DC rectifier solutions are readily available allowing capacity to flex to match IT load changes.
- Rack/Row Level Peak load lopping – Peak lopping functionality could be applied at rack or row level to help smooth the increasingly peaky loads associated with modern servers (created by the reduction in idle state energy consumption).
- Variable Resilience Levels - Resilience levels could be tailored to individual customer or application needs with multiple variations achievable within the same data hall.

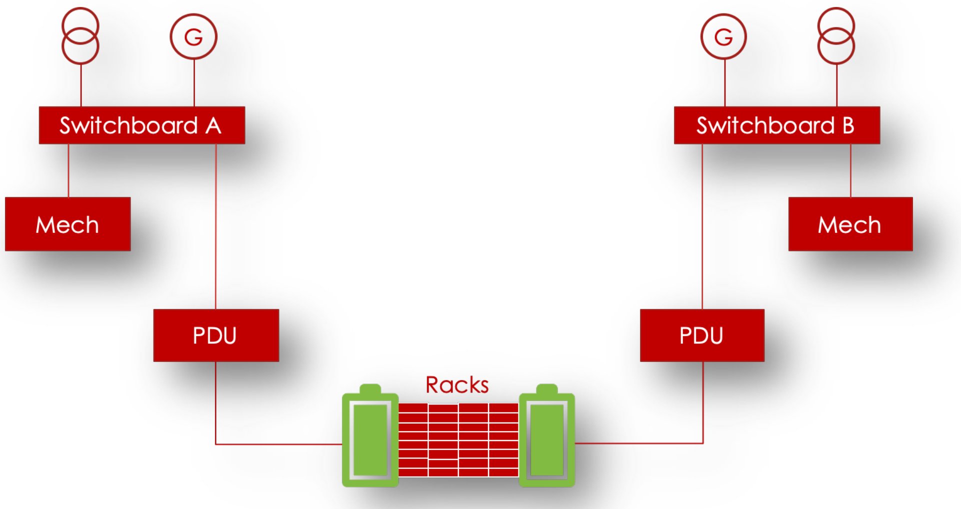

Figure 4 - Batteries installed at row or rack level

The Open Compute Project has a range of equipment specifications available that incorporate battery provision and DC distribution at row and rack level.

Software Defined Power

Rack level battery capacity is also an enabler for software defined power, the definition of Software Defined Power is still evolving but example use cases include:

- allowing power to be diverted or reserved to meet the demands of specific applications, racks or rows.
- Power allocation based upon priority level of the application during failure scenarios.
- Multiple Service Level Agreements within the same data hall.
- Peak load capping at rack level.

Software control will be critically important and needs to link into both the power and software application management systems, requiring greater collaboration between the teams responsible for the software and hardware within the Data Centre but this also opens up the opportunity for continuous improvement through machine learning.

Conclusion

Lithium-ion batteries make it possible for Data Centre operators to develop a range of alternative distribution topologies, increase available white space, reduce or eliminate the need for dedicated cooling for batteries. The smaller footprint and increased cycle-life options provide opportunities to generate additional income through the provision of grid support services and relocating batteries downstream creates alternative opportunities for Data Hall level distribution.

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