# Trends in Telecom Power: Efficiency gains when battery and power technologies intersect

**Paul Smith**
**Technical Marketing Manager**
**GE Critical Power**
**Plano, TX 75074**

## Abstract

Traditionally in large telecom facilities and central offices, the large DC power plant equipment and batteries were relegated to the basement or "off-floor" locations. The basement was a logical location for a number of reasons, not least of which is the physical size and weight of the batteries required to support eight hours or more of autonomous operation.

Today, however, many wireless and mobile telecom applications no longer require eight hours of reserve time. This is creating new opportunities – and some challenges – in how telecom engineers implement more energy efficient approaches to providing back up power and battery deployments.

The choice of battery location also affects the continual striving for improved power efficiencies and the associated operating expense (OpEx) reduction, which also influences major decisions in facilities and infrastructure.

The metamorphosis of telecommunications networks into information and communications technology (ICT) networks, with their reliance upon digital technologies, is also a key driver of battery deployments and capacity requirements.

Advances in both battery technology and power conversion technology and changes in back-up requirements, have reached a new critical junction that is fundamentally changing telecommunications power design. This paper looks at some of the ways that battery technology and power system architectures are interdependent and how the advances in both combine to create new capital expense (CapEx) and OpEx advantages. These advances will be examined with a view toward a better understanding of new opportunities and future trends in power architectures and battery deployments.

## Introduction

It used to be that the hierarchy between the central office telecommunications equipment versus its power and backup system was a relationship something akin to the popular PBS "*Upstairs – Downstairs*" series. Information technology (IT) and switching equipment was upstairs on the main floor where the "money" (a.k.a. "revenue producing") operations lived (See Figure One), while AC-DC power conversion systems and massive banks of batteries "served" in the basement, toiling to keep things running.

## Telecom Technology

### “Upstairs”


**Figure 1 - Telephone switching evolution**

Telecom central offices have traditionally been required to provide 4-8 hours of battery reserve[1], depending on the availability of a generator and specific regulatory requirements. Many of today’s telephone switching offices have gradually morphed into data centers, which may or may not require eight hours of power reserve. Some equipment is still subject to regulatory compliance and may still require 8-24 hours of backup power between batteries and generators. Much of the data center equipment however may not require this length of reserve time, especially if service can be maintained through spatial redundancy of server operations. It may only be necessary to have 10-15 minutes of reserve power to allow transfer of server operations, or to allow generator(s) to start and synchronize their operation.

### “Downstairs”

Lead acid batteries have been used in the telecommunications market for many decades, both in flooded, and more recently, in valve-regulated formats.


**Figure 2 - Lead Acid Batteries in Telecom applications**

There were good reasons for the batteries to be kept in the basement – the standard reserve time for a central office was eight hours or more, requiring hundreds of thousands of pounds of batteries. A large office could consume 10,000 amps (at 48 volts), which requires 80,000 ampere hours of reserve. The picture on the left in Figure Two is a KS-20472, L1S – Bell Labs “round cell” that is rated at approximately 1,600 ampere hours. Fifty strings of L1S round cells weigh almost 500,000 pounds[2] (220 metric tons) and occupy over 3,500 square feet! If it were placed “Upstairs” it would probably abruptly end up in the basement anyway!

## Battery Technologies – improving energy density

| Flooded Lead Acid | VRLA | Ni-Cd | Li-Ion | Na-Ni-Cl |
|---|---|---|---|---|
| **Flooded Lead Acid Batteries** | **Valve Regulated Lead Acid Batteries -"Sealed"** | **Nickel Cadmium** | **Lithium Ion** | **Sodium Nickel Chloride Battery** |

**Figure 3 - Battery chemistries**

Advances in battery chemistry are also translating to significant reductions in battery size and weight. It can be seen in Figure Four that advanced battery chemistries are capable of providing a two to eight times reduction in both volume and weight.

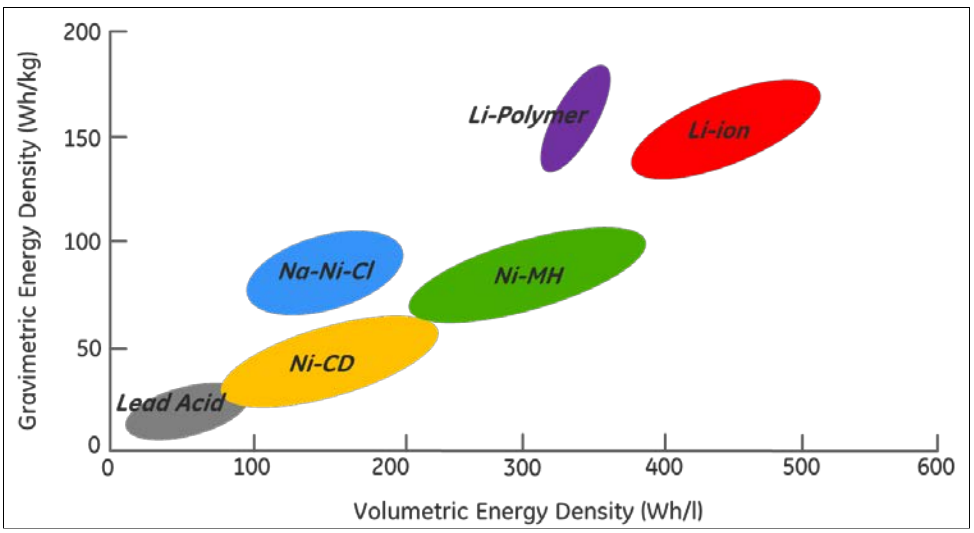


**Figure 4 - Battery Energy Density Comparisons**

With reduced reserve time requirements and advanced battery technologies, it now becomes practical to put reserve power equipment on the upper floors with a reasonable expectation that the average floor is capable of supporting it.

## Rectifier Technologies – improving density

We have just illustrated that we could see up to a 256X reduction in battery "size" (32x from the reserve time reduction and 8x from battery technologies), but what about the power conversion equipment? When the batteries occupied thousands of square feet there was little incentive to reduce the power conversion equipment's size by a few square feet. Now the pressure is on for rectifier size to reduce as much as possible to minimize the space occupied in the "upstairs" environment.

Rectifier technology has stepped up to the challenge. In the last few years we have seen rectifier sizes reduced by one to two orders of magnitude.

| 1970 | 1990 | 2008 | 2014 |
|---|---|---|---|
| **Ferro 200A** | **SMR 220A (Gen 1)** | **SMR 220A (Gen 2)** | **SMR 100A (Gen 3)** |
| **Size:** 72" x 12.5" x 16" | **Size:** 8.9" x 17.8" x 18.2" | **Size:** 8.9" x 10.3" x 18.2" | **Size:** 1.6" x 7.9" x 17.4" |
| **Volume:** 14,400 $in^3$ | **Volume:** 2,883 $in^3$ | **Volume:** 1,668 $in^3$ | **Volume:** 218 $in^3$ |
| **Density:** 0.8 $W/in^3$ | **Density:** 4.42 $W/in^3$ | **Density:** 7.64 $W/in^3$ | **Density:** 26.6 $W/in^3$ |
| **Weight:** 725 lb. | **Weight:** 59 lb. | **Weight:** 50.5 lb. | **Weight:** 4.1 lb. |
| **Efficiency:** 88% | **Efficiency:** 92% | **Efficiency:** 96% | **Efficiency:** 97% |

**Figure 5 - Three Phase Rectifier Technology Evolution**

## Intersecting Technologies

Clearly the physical size of 15 minutes of battery reserve is significantly smaller than that required for eight hours. Using the same battery model as the previous example would give a mere 15,625 pounds (seven tons) and 110 square feet for the flooded lead acid battery example.

The intersecting technologies of improved energy storage density and power conversion density are allowing alternative power architectures to become feasible now that reserve time requirements are being reduced. Centralized systems with eight hours of backup belong in the basement. If the power requirement is divided up into smaller pieces, the power equipment and battery capacity needed by each section is dramatically reduced. This is the basis for distributed power architectures.

## Distributed Architectures

Moving power processing and reserve "upstairs," with the objective of placing it as close as possible to the load it will serve has spawned the notion of "distributed" power architectures.

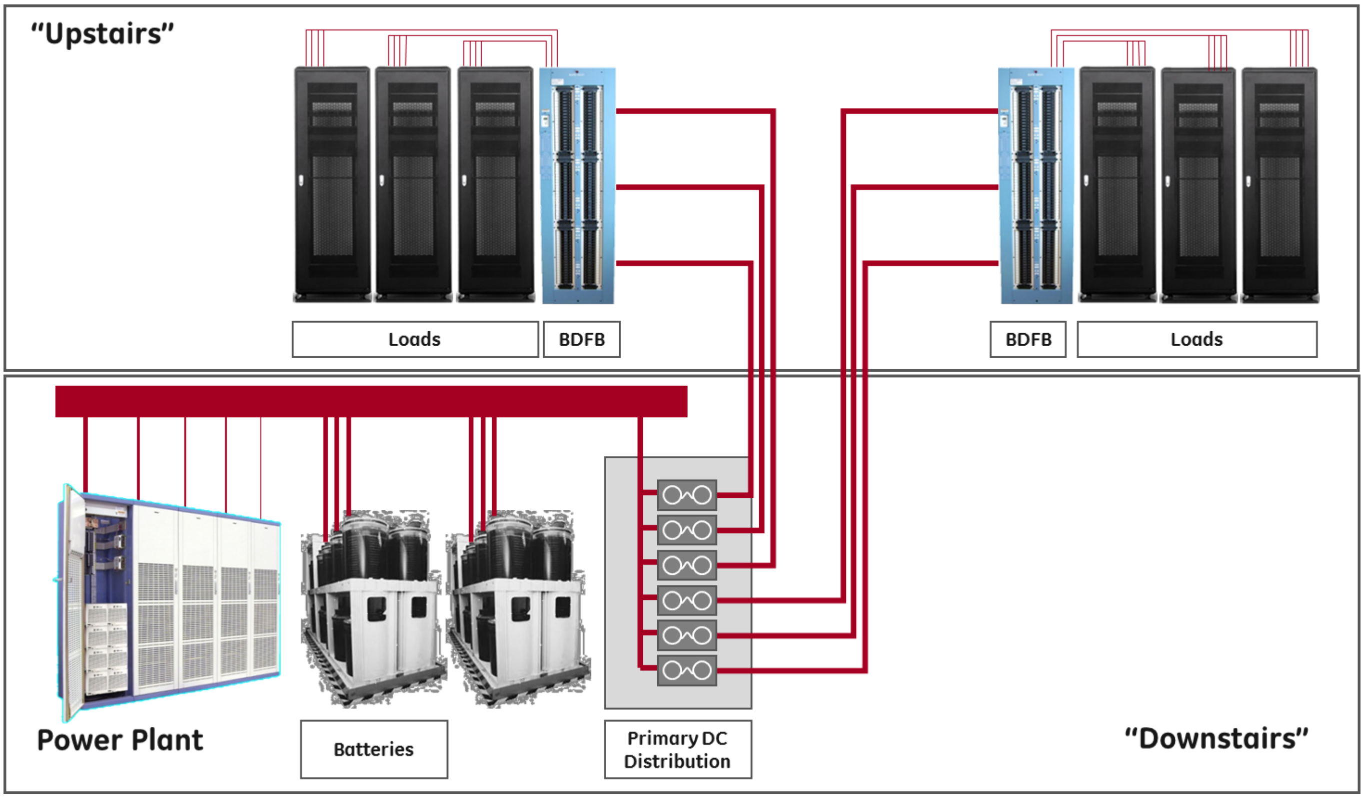


**Figure 6 - Centralized Architecture**

Instead of having a single, large power plant, we break it into many smaller power plants and place each plant alongside the equipment that it will serve. In some implementations a power plant is placed at the end of a row of load equipment, serving all the cabinets in that row, as shown in Figure Seven.

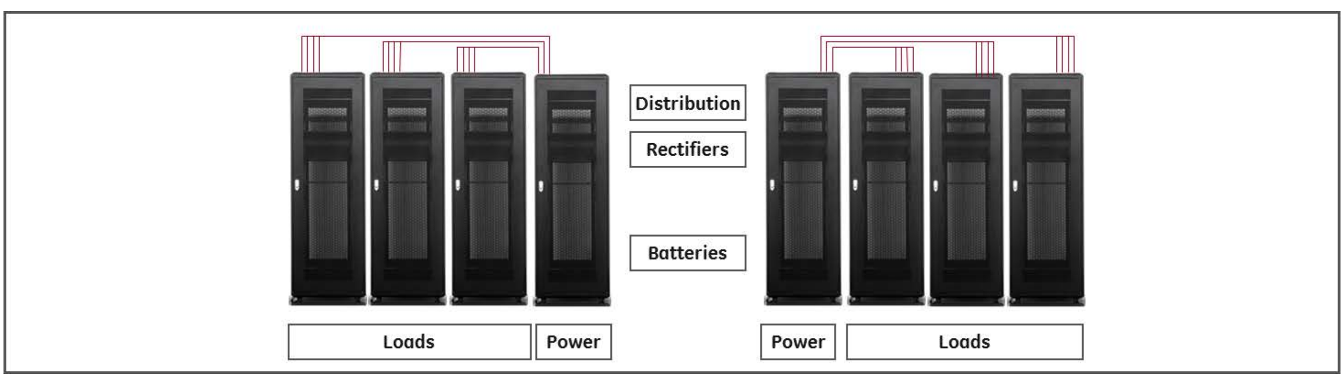


**Figure 7 - Distributed Architecture**

The logical extension of this idea is to break the power plant down in to even smaller units and embed each power plant in a single cabinet, which it will power, as shown in Figure Eight.

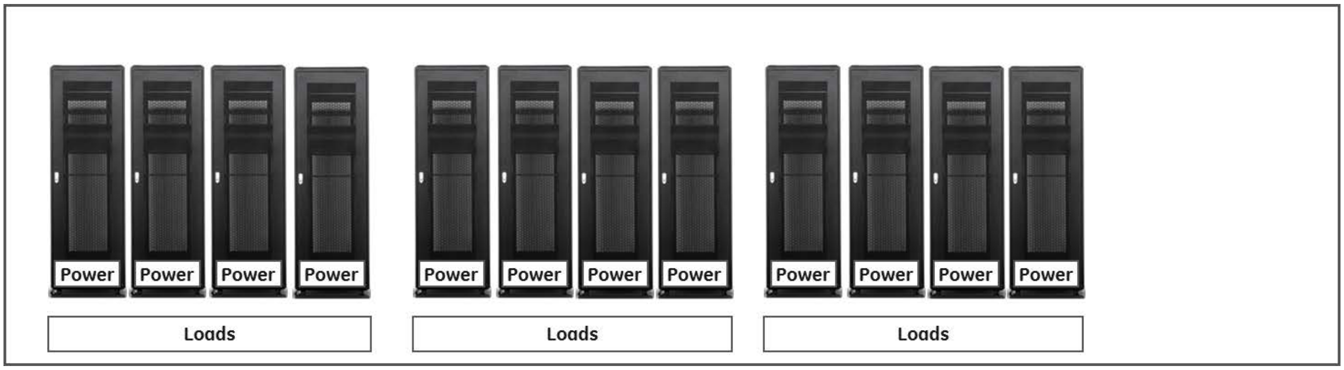


**Figure 8 - Distributed Architecture**

Clearly, if the power unit is to be embedded in a cabinet, small size is even more important to minimize the space consumed. This is implemented by putting the power unit in the top or bottom of the load rack. Each of these iterations has brought the power conversion successively closer to the load equipment, reducing distribution losses with each step.

## Advantages

***Efficiency*** - By moving power conversion closer to the load, DC distribution losses are dramatically reduced. They are replaced by much smaller AC losses, due to the higher voltage and lower current of the AC distribution system. This improves the “end-to-end” efficiency and will result in a reduction in a facility’s OpEx.

***Copper Cable*** - The reduced distance that the lower DC voltage has to travel requires many times smaller conductors carrying current over much reduced distances, resulting in enormous reductions in CapEx required to purchase and install the copper cable.

***Cooling*** - Similarly, improvements in conversion efficiency will reduce wasted energy and further reduce OpEx. Improvements in efficiency also reduce the heat dissipated in the power conversion equipment, which in turn reduces the load on the HVAC system, further reducing OpEx.

***Flexible Energy Reserve*** - By distributing the power conversion equipment to feed a portion of the load equipment, it is possible to provision reserve time appropriate to that load equipment. This means that if one load needs a longer reserve time, it can be provisioned without encumbering the entire facility with the cost of the longer reserve time. The reserve time can be matched to the load in appropriate increments.

***Reliability*** – Grouping smaller loads with smaller power plants decreases the size of a given failure group, due to power issues, resulting in an overall increase in reliability.

***Scalability*** – Power equipment is added incrementally along with load equipment, minimizing initial power equipment and installation costs (CapEx).

## Further Improvements

As we look back at the evolution of rectifiers, increasing density has required the addition of fans to enable more heat to be removed from increasingly smaller spaces. Looking ahead we can see that if rectifier efficiency continues to improve, less waste heat is generated, potentially leading to the fans no longer being required. Removal of the fans themselves will increase efficiency because they consume power. Every incremental improvement in efficiency also decreases waste heat and the HVAC load on the facility, further reducing OpEx. Removal of fans also has the potential to improve the reliability of the rectifier and certainly can be expected to improve the overall mean time between failures (MTBF) of the rectifier significantly.

The progression of the power conversion closer and closer to the load equipment can be expected to continue since it produces reductions in both OpEx and CapEx.

The cost of newer battery chemistries lowers as technologies become more mature, but battery cost is only one dimension of a total cost of ownership (TCO) view. If the new batteries last longer but also cost more, there is a point at which the TCO is minimized.

## Conclusion

We have seen how evolving ICT technology ("upstairs") has allowed reserve time requirements to decrease, which, combined with the improvements in battery technologies, allows power equipment to move from "downstairs" to "upstairs". This in turn puts pressure on the power conversion technology (primarily rectifiers) to occupy less space. The net result is smaller power systems that can be located closer to the load equipment with commensurate improvements in end-to-end efficiency. The shorter distances greatly reduce the size and amount of copper cabling required. These changes lead to significant reductions in both OpEx and CapEx.

These changes are enabled by the changes in load requirements, improvements in battery technology and power conversion density increases. Which of these technologies are the primary drivers in new power architectures? I am not sure, but at the end of the day, reductions in OpEx, CapEx or TCO make us all winners.

[1] Based on information from AT&T standards for central offices

[2] Based on the size and weight of a 2 tier, single row battery stand configuration loaded with 50 strings of KS-20472, List 1S (Bell Labs "round cell") flooded lead acid batteries.

**About the Author**: Paul Smith, technical marketing manager at GE's Critical Power business, works with telecommunications and data center customers to build and sustain massive communications, network and data capacity with reliable and energy-efficient power. To learn more about GE's Critical Power business, visit www.gecriticalpower.com.