DESIGN CONSIDERATIONS FOR DISTRIBUTED DC POWER APPLICATIONS IN TRADITIONAL TELECOMMUNICATION FACILITIES

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ABSTRACT

The increasing power demand for transport equipment is stretching traditional DC (direct current) power distribution topologies beyond their ability to power the new loads economically. This trend in larger load sizes is leading to a renewed interest in a distributed form of DC Power architecture where the DC source is located closer to the load. Compact switch mode DC power plants and current battery technology have matured enough to embrace a fundamental shift in equipment deployment strategy and practices. For this reason, Telecommunication Service Providers (TSP) are looking for DC Power equipment and battery technology that supports this shift in traditional deployment.

Through the maturity of DC power equipment, market acceptance, and availability of equipment/components, switch mode technology has become cost competitive and comparably reliable with past technology. Additionally the size, modularity, scalability, service and maintenance of the equipment has added to its convenience and acceptance. However, for the most part the smaller more compact switch mode power plants continue to be deployed in Outside Plant (OSP) and cell sites. With an increase in load demand and the costs associated to the delivery of more power, bringing the power equipment closer in proximity to that demands begins to make economic sense.

Most small DC power plants found on the market today were influenced by the OSP applications. Early on, these applications were not carrying the magnitude of services found in Central Offices and were not designed with a full featured alarm or telemetry architecture. Additionally, OSP locations typically serve the end user whereas Central Offices serve not only a larger base of customers but convergent technologies that may expose large scale risks and failures. Even though market growth in the OSP arena has been brisk, these small power plants have limited exposure to traditional Central Offices due to lack of features and limited battery choices. Today’s small DC power plant systems must be chameleon in design to support various applications and include full features not normally found in this size range of product.

Even though the concept of a distributed DC architecture is not new, battery technology has been a significant roadblock for distributed architecture beyond a very limited niche until now. With that said, this paper will identify the advantages of a distributed architecture and discuss application parameters with regard to equipment optimization as applied to traditional Telecommunication Central Offices. Additionally the paper will discuss trends and challenges both the DC Power and Battery Industry will face with regard to weight, dimension, density, and environmental issues in these type applications.

INTRODUCTION

For the purpose of this paper, a small DC power system and distributed architecture can be defined as follows: Small DC Power System; self contained DC Power equipment with capacities of 600 to 1200 amps of -48v power including primary distribution. With batteries included, the “system” shall not exceed the space of three standard network bays. Distributed Architecture; A defined floor space of network equipment that can be served by a conveniently located Small DC Power System within the same defined floor space.

In the early 1990's small power plants were introduced in the Central Office market through the use of a "distributed architecture" approach. This trend failed to evolve due to limited applications, the lack of battery products that were environmentally sound and power plant controllers that had limited telemetry and reporting architecture. Small power plants incorporating switch mode rectifiers found residence in the OSP arena and were commonly found in Environmental Vaults (EV's), Huts or equipment cabinets where they became widely accepted. However, this OSP market demand was primarily based on density. Control, Alarm and communication features found in Central Office power plants were not considered of high importance due to space constraints. Furthermore, OSP clients were willing to accept the greater risks associated with the current battery technology, (Valve Regulated Lead Acid) of the day where Central Office type applications could not show the same tolerance.

Through the late 1990's switch mode rectifier technology grew as a trend while shrinking in dimension. In the conservative nature of Central Offices, switch mode technology migrated into some applications but were still expensive compared to ferroresonant technology. By the early 2000's switch mode technology was well established in Central Offices and found their way into many midsize applications (1200 to 6000 amp power plants).

SIGNIFICANT FACTORS THAT WILL AFFECT THE DISTRIBUTED ARCHITECTURE DECISION

Copper

Traditional guidelines for Centralized DC plants include the placement of a Battery Distribution Fuse Bay or Battery Distribution Circuit Breaker Bay (BDFB/BDCBB) as the primary form of distribution from the power plant. These BDFB's may be located, on average, 100 feet from the power source. Longer distances require more copper. Until recently, this was never perceived as a significant problem; this changed when the copper commodity prices rose by 43% at the end of 2005[i] . Increased supplies and a moderate downturn in the US housing market has caused copper to drop by 17% since May of 2006[ii], however, China's voracious appetite long term may continue to effect the price of this commodity[iii]. These factors are cause for Telecom planners, capacity and budget managers to consider other options when adding DC power.

High Amperage Loads

Electronic equipment within the telecommunications industry continues to follow the path of Moore's Law[iv], which translates into increased power demand at the shelf or bay level. Traditional DC distribution in its current form is designed to support individual fused loads up to approximately 70 amps. Even though client carriers have worked with network equipment suppliers to limit individual power requirements in the past, new network elements will continue to entice Carrier Technologists to bring the latest and greatest services to the end user which will overshadow most powering infrastructure issues. Client carriers deploying equipment such as the Lucent VoIP equipment portfolio or Alcatel 7750 can well exceed embedded Distributed DC architecture found in place today.

Battery Technology

As non-related industry trends in automotive and electronics continue to demand greater power density from power storage devices (batteries), this impact will further influence the telecommunications market. In the last five years, strides in NiCad, NiMH, and Lithium are already making inroads. However, these new technologies have greater risks than previous technologies. As noted in "Advanced Electrochemical Energy Storage Technologies for Stationary Power Applications"[v], lead acid batteries currently outperform others in relative costs, recycling and safety. So the client carrier must determine if the reward is greater than the risk.

Watts, weight and power density per sq. ft. continue to entice the carriers into providing services that were difficult to provide with traditional batteries. With the new frontier of VoIP and video offering in various forms of deployment, the OSP environment has been one of the first to embrace the latest battery technology. However, the Central Office or MTSO's (Mobile Telephone Switching Office) continue to be ultra conservative.

Resistance to Change: It's the Batteries!

Many traditional Telco Engineering and Operation Standards groups continue to resist the change to distributed architecture. Relocating the power system, specifically batteries, into Network aisles opens up new opportunities for risk and failure that can cause unnecessary heartache. Some of the items listed are quantifiable, some are not, but in many cases perception can be reality.

- Risk is associated with change
- No one wants to be associated with an office failure
- Embedded practices and process are very entrenched and modifying them can be extremely laborious as well as adding risk
- Retraining technicians is expensive and absorbs resources
- Introducing batteries in the traditional network space could put the revenue generation equipment at a greater risk. Typically, battery failures are isolated due to technology compartmentalization. Placing batteries in close proximity with network equipment no longer isolates the batteries from the equipment which could enlarge the scope of a failure.
- If the technology has limited field experience, real time "in service" may reveal reasons to discontinue its use, and alternatives may be limited due to their location and floor space. This reversal could be extremely costly as well as add risk.
- Placing Power Systems and batteries in the network space may draw unnecessary attention from Building and Fire Code officials.
- Some of the new battery technology reduces failsafe operation found with lead acid technology by introducing electronics, LVD's (Low Voltage Disconnect) and fuses, none of which are typically found in Central Office applications.
- Acceptable voltage windows may not adequately match the battery technology.

Even though one group (engineering/capacity management) may see the monetary value in reducing capital expenditures associated with this change, others (local field operations) see greater potential for risk and impact to their expense budget. This natural conflict typically drives road blocks or compromise. So in many cases the resolve is to change little to nothing. However, some of the positive aspects of the non-traditional Telecommunications batteries may entice those that can recognize a larger reward over the perceived risk. But battery safety, failure and network risk will be greatly weighted in those decisions.

DISTRIBUTED ARCHITECTURE

Currently there are at least 3 different scenarios of distributed power architectures and can be defined as follows:

1. Bay Level Power (BLP): Very small power systems with inclusive modular rectifiers and DC distribution designed to support 1 to 3 bays of equipment. Batteries may or may not be included in this type system and require 5 rack units of space or less.
2. Aisle Powering (AP): Larger than BLP, entire system, batteries, rectifiers, AC input, DC distribution must be less than one rack. Additionally, rack depth may be restricted and contained at less than 15 inches.
3. Building Bay Power System (BBPS): Larger than 1 or 2 but smaller than most centralized power systems.

Even though this author recognizes the merit in all of the listed distributed power arrangements, this paper will concentrate on the Building Bay Power System (BBPS) as the first choice in distributed architecture. The BBPS scenario has recognizable traits that are less disruptive and more resembles centralized architecture. Additionally the BBPS could be converted back to centralized architecture with the least amount of retrofitting due to unforeseen issues.

Building Bay Power Systems

The BBPS style of Distributed Architecture would be to mimic the scope of a typical BDFB. With most Wireline Carriers, a single (multi-load) BDFB supports approximately 400 square feet of equipment space (typical 20x20 building bay). In this application a typical BDFB may be a 2,4 or 6 load BDFB with a design capacity of 600 amps for each load. This BDFB form of distribution has been in place since the 1960's and even though BDFB's have continued to evolve, the premise of their use is virtually unchanged.

Based on trends previously mentioned, load demands are challenging the distribution circuit protection options (typically 1-70 amps) found in most embedded BDFB's. In fact some new network elements have DC demands in excess of 200 amps per bay which can quickly consume a BDFB based on current Wireline capacity standards.

Advantages of a Distributed DC Architecture

DC Power Plants designed for distributed architecture are gaining momentum in the market place. As technology evolves, these smaller plants can provide some distinct advantages over a traditional single source DC Power Plants. Some of the reasons associated with a change may include:

1. Reduced First Cost: Typically, a power plant used in a distributed architecture would serve a new growth area. The new DC power plant would be equipped to initially support only the equipment installed by providing limited rectifiers and batteries. As actual demand increases, additional rectifiers and batteries may be added as required. This "just in time" type of deployment can be more cost conscience than the full capital outlay of a 2 load 600 amp BDFB. Most carriers employ some form of capacity management software system that provides electronic alerts when additional equipment is needed.
2. Reduced cost of DC Distribution: Due to the recent upswing in copper prices, locating the power plant closer to the network load can further reduce the CAPEX (Capital Expense dollars) of copper currently being placed in a traditional DC architecture. Traditionally, a 2 volt, voltage drop calculation is used within the distribution system. Retaining this engineering standard while shortening the distance through BBPS will further reduce CAPEX expenditures.
3. Limited exposure to risk and service outages: Distributing power via multiple power plants may also reduce service outages by isolating failures to limited areas. Regardless of the cause, isolated failures can reduce impact and opportunities of a complete office failure.
4. Higher Ampacity Loads: As equipment density continues to rise so does equipment power demands. In some cases, these increased fuse requirements can exceed the existing BDFB distribution architecture. By utilizing a distributed architecture power plant, no secondary distribution (BDFB) is necessary. By equipping the DC Power Plant with the appropriate output choices, circuit protection sizing can be less constrained than a BDFB.
5. Capacity management by application: As technology offerings by the Wireline Carriers become more complex, service obligations may differ. In other words, a non-regulated service may not require the same level of back up or battery reserve found in more traditional or regulated services. The use of a small distributed power plant can further minimize the cost by providing limited back up as defined by the carrier.
6. Alternative battery technology: As non-traditional battery technology continues to mature, some of these products could be placed in the transport space without limitations currently associated with flooded or VRLA (Valve Regulated Lead Acid) products. However, product weight, density capacity and ventilation will continue to impact the application.

Risks, Limitations and Disadvantages to Distributed Architecture

From a Carrier perspective, placing traditional DC power equipment and batteries in a distributed architecture may be a difficult decision as the risk may be viewed greater than the reward. Additional reasons may include:

1. In certain types of facilities, including batteries in active floor space may require the site to meet certain national and local codes, including the adopted fire codes and NEC (National Electric Code).
2. Some carriers continue to support full compartmentalization.
3. Facilitating power down sequences (where required by local codes) of multiple plants may require additional equipment and telemetry.
4. Equipment may exceed certain floor loading limitations.
5. In some cases floor space ownership can be considered "sacred" and moving away from traditional basements or dedicated power rooms can complicate future growth and changes in technologies.

Distributed Architecture Design Criteria

Even though definitions may vary, to optimize the application, distributed architecture applications must employ some form of design criteria creating an application standard for the Carrier. Currently there are at least 3 different deployment methods currently under consideration.

Based on interviews of various industry representatives, the Building Bay Power System appears to have greater appeal as it represents the smallest step of change compared to the other two. The following information is representative of a Building Bay Power System and the application considerations that appear to be most conducive to this arrangement.

1. Less than 50 feet, point to point distribution.
2. Provide for all distributed DC requirements within a given square footage (e.g. 20x20 building bay).
3. Complete Power Plant, including AC input, DC Power and batteries, will consume no more than three 7'x 23" standard relay racks. Total depth of equipped bays shall not exceed 24".
4. Total loop voltage drop for power conductors shall not exceed 2 volts from the batteries to the final power termination point.
5. Acceptable float voltages between -52.08 to -54.5 Vdc.
6. All network equipment loads are served directly from the power plant.
7. Interdependent A/B power plants in the same given building bay may be included for added reliability .
8. Equipment operates within an integrated ground plane.
9. Large secondary distribution products (BDFB, BDCBB) are not required outside the 3 bay foot print, however small rack mounted power distribution units (PDU) may be used throughout the serving area for various applications.
10. Recognized floor space assignment in column lineups.
11. Non Traditional Battery Technology (e.g. Lithium Ion, Lithium Metal Polymer, Nickel Metal Hydride); Battery technology utilized in the network space must conform to different requirements than found in traditional power rooms. Those restrictions may include but not limited to these conditions:
    a. Limited Hydrogen gassing
    b. Acid spill containment addressed per code
    c. Rack mounted battery system
    d. Loaded weight limitation of 150 lbs. sq. ft. or less for complete package, but local variance could apply when equipment can be placed in close proximity to building columns.
    e. Fused disconnects in battery systems are not recommended
    f. Battery technology requiring Low Voltage Battery Disconnects operating above -32VDC are discouraged.
    g. Battery monitoring at the container level
    h. Fail safe battery operation
12. Common telemetry for alarming and plant communications may be defined in one of two ways.
    a. OSMINE/TL1 protocol (Operations Systems Modification Intelligent Network Elements, Transaction Language)
    b. Distributed power plants may communicate to a collective microprocessor, for reporting and capacity management

Figure 1 depicts a conceptual rendering of a distributed architecture facility. The author believes distributed architecture may be employed within existing floor space and could somewhat co-mingle with existing DC power served via existing BDFB's or other forms of secondary distribution.

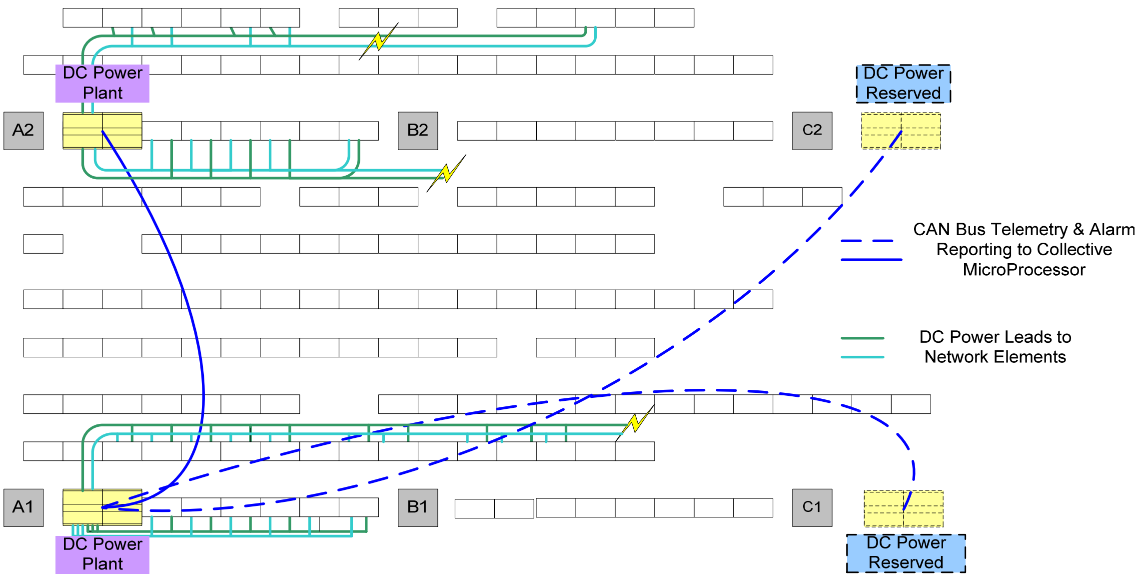

Fig. 1. Distributed Architecture

SUMMARY

For the RBOC power equipment engineer and capacity manager, obtaining capital for new equipment has always been a challenge. Typically, new power technology introductions can be traced to internal triggers usually associated with new switching technology of the past (i.e. Cross-Bar, Step, Analog, Digital) as many times those triggers identified inadequacies that may have existed in the power equipment that was currently employed at the time (i.e. motor generators, SCR (Silicon Control) rectifiers, product density). Furthermore, financial considerations associated with fewer dollars spent on power cable, smaller incremental CAPEX on power equipment and just in time growth may be the compelling features of distributed architecture. Even though not technically viewed as a trigger, high current demand and a stressed capital budget may be the only trigger associated with the trend toward a distributed architecture.

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[i] December 17, 2005 Milwaukee Journal Sentinel
[ii] January 9, 2007 Mineweb.com Commodities Outlook 2007
[iii] September 20,2005 Zellllc.com Copper Bull Market
[iv] Moore's Law: The doubling of the number of transistors on integrated circuits (a rough measure of computer processing power) every 18 months. At the end of the 1970s, Moore's Law became known as the limit for the number of transistors on the most complex chips. However, it is also common to cite Moore's Law to refer to the rapidly continuing advance in computing power per unit cost.
[v] Battcon 2006 Advanced Electrochemical Energy Storage Technologies for stationary Power Applications; Stephen L. Vechy