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Robust power feeds in the 5G era

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Abstract

Driven by rising traffic demand, wireless network providers are employing a variety of strategies in their efforts to increase capacity. Particularly attractive are "brown field" options that seek to leverage existing infrastructure—sites, structures and equipment—to deliver additional capacity while saving on capital investment and reducing deployment delays. Despite incremental improvements in equipment efficiency, the steady rise in data volume continues to increase the demand for more electricity and total power consumption. Power feed installations at cell sites, quite adequate a few years ago, are now straining under heavier loads.

This paper examines how new, higher-power radio equipment impacts the robustness of the power feed ("robustness" is defined here as the ability to deliver sufficient voltage to the radio equipment at all times in order to prevent power starvation or shut-down due to a power outage). We will see that, in a typical macro site, maintaining robustness in a conventional power feed requires upgrading the power trunks to a much heavier gauge—impacting cost and tower loading. The need to validate the design for each set of circumstances adds complexity and uncertainty.

As an attractive alternative, the CommScope PowerShift® dynamic power supply solution delivers an inherently robust power feed while reusing existing power trunks. In addition, it ensures a reliable and properly allocated voltage supply even during a power outage—eliminating any power fluctuations typical of a battery backup. The result is a standard and dependable solution that ensures a robust power supply for a variety of sites. It simplifies design and installation and enables wireless operators to add on-air capacity more quickly and with less manpower.

Introduction

The global appetite for mobile data is far from satiated; total mobile data traffic is currently expected to rise at a compound annual growth rate (CAGR) of 31 percent through 2024. This growth is driven in part by the increasing smartphone penetration within developing countries and, to a greater extent, the rise in the volume of global data consumption. Video content—which already constitutes a significant portion of the data used—will continue to be the leading driver of higher data demands in the years to come. Video sharing, pervasive video content on websites and social media, higher resolutions, and new formats contribute to the strong upward trend in the need for speed and throughput. Even in mature markets such as Europe, data demands are projected to be 5-6 times higher in 2024 than today.i The challenge for service providers is finding the right strategy to keep pace with the growing need.

Quest for capacity

The different ways to address this challenge have been categorized into three "capacity domains."

To learn more about options for capacity growth, download the CommScope white paper: "A planning guide to optimizing networks for capacity with practical field examples"

Densification: These are strategies that operators can pursue in the short term, and include reducing cell size in order to increase spectrum reuse. Densification can be realized by adding small cells to the network, by deploying indoor and venue coverage solutions, and by higher-order sectorization of macro sites. The latter is a favored option since it involves expanding the existing infrastructure, thus avoiding the costly and time-consuming process of acquiring real estate, building, and connecting new sites.

Spectral efficiency: LTE offers enhanced efficiency over prior generations and has become the dominant access technology. Many of the initial two-port transceivers have been replaced with four-port radios, enabling the use of multiple-in, multiple-out (MIMO) transmission to improve spectral efficiency. Using a basic beamforming technology, MIMO enhances signal strength and helps reduce interference. Eight-port radios take beamforming a step further to provide additional efficiency gains. The nascent 5G technology will take full advantage of beamforming by using 16 or 64 transmit/receive chains (16T/16R, 64T/64R) and radio-integrated antennas operating at 2.3 GHz and higher.

Spectrum: This domain focuses on bringing idle radio channels into service, thereby adding capacity without increasing interference. When compared to making incremental improvements to live channels, spectrum strategies can yield a better return on investment—making this domain highly attractive. It can prove especially valuable as a short-term option where traffic demand is low and the operator has unused spectrum available. Acquiring new spectrum in congested areas is more difficult as it is contingent on the standardization process, issuance of new licenses and availability of equipment. Long term, however, additional spectrum—and lots of it—is essential to fulfilling the 5G promise. Higher frequencies such as centimeter wave and millimeter wave will be of limited use on macro sites.

Macro site growing pains

Whether operators choose to add cells to densify, add radio ports to leverage MIMO, or add radios to overlay new bands, additional equipment—antennas, transceivers, power and transport—will be needed. This also compounds the ongoing challenge of finding space on the macro tower and accommodating the increased weight. Technology advancements have provided some help: Multiport antennas with upwards of 20 ports are becoming more available, and multi-frequency radios are now smaller and lighter. Power amplifier efficiency has improved significantly, as well, due in large part to more sophisticated linearization techniques and higher output power capabilities. However, next-generation “massive MIMO” active antenna unit (AAU) radios will require a large number of lower-power amplifiers for each AAU radio. Linearizing each small amplifier would be costly and marginally effective since the additional circuitry would itself consume much of the power it could save. In this case, power efficiency could quite possibly take a turn for the worse.

This much is certain: Each user served and each megabit of data transmitted requires RF energy. With or without mitigation, macro base station power demand is on an upward trend. Shown in Figure 1, power consumption of macro cell radios has increased steadily as access technologies have evolved through generations and the release of new standards. At the site level, the curve is multiplied by radio additions due to densification and new spectrum bands.

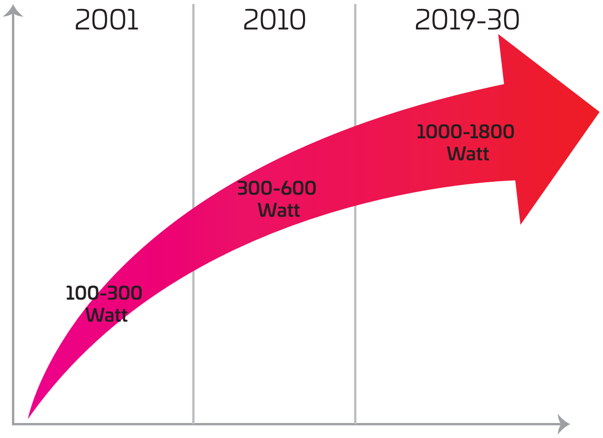

Figure 1: Evolution of macro cell radio power consumption

Over the past decade, migration from rack-mounted radios on the ground to tower-mounted remote radio units (RRU) has helped put more RF energy into the antenna by reducing RF transmission line losses. Power must still be supplied from the ground to the tower top, however. The challenge now is how best to conduct dc power from the rectifiers and batteries at the base of the tower to the radios near the antennas. Given the finite overall efficiency of the remote radio head, the ratio of dc supply power to RF output power can be as high as 8:1. Seen in this light, a well-engineered dc power transport solution is imperative in order to ensure robust operation, control energy costs and meet green site objectives.

Immediacy of the 5G power challenge

On multiple fronts, the world is marching toward the next generation of wireless. Operators in different regions have chosen a variety of entry strategies according to their individual strengths, resources and business opportunities. Initial deployments of fixed wireless access (FWA) services using millimeter-wave bands are already underway, as are the rollouts of wide-area coverage solutions using sub-1 GHz frequencies. The latter makes it possible to better support the internet of things (IoT) and provide broadband access to underserved communities. In Europe and other regions, the initial focus will be on enhanced mobile broadband utilizing mid-band frequencies in the 2- to 4-GHz range.

As mentioned, 5G will make extensive use of beamforming antennas. For deployment on macro sites at 3.4-3.8 GHz, beamforming is a key technology that will help compensate for the higher propagation loss in the upper mid-band frequency range. At the same time, it reduces interference while boosting MIMO performance. Because accurate beamforming is facilitated by integrating the radio circuits within the antenna, the AAU is a preferred architecture. In commercially available AAU equipment, the 1 kW mark has already been surpassed and the 5G power challenge is now upon us. All the while, 4G LTE continues to evolve as dual-band radios with similar power demands are introduced.

If the industry is to maintain the current pace of radio innovation, the development of power delivery solutions must keep at least one step ahead. To analyze the robustness and efficiency of current power delivery systems, we have created a few use-case examples that enable us to make some basic calculations. We have omitted the finer details for the sake of brevity; however, a more comprehensive description of the calculations can be found in the two CommScope white papers cited further below.

Pushing the limits of copper cables

The power delivery system at our example cell site is depicted in Figure 2. Grid ac power is rectified and regulated to a nominal 48 VDC (actually, -48 VDC, but polarity has been omitted here), then fed to one or more strings of backup batteries and to the trunk cables leading to the radio equipment at the tower top. While several battery technologies are available, this example uses the commonly deployed lead-acid batteries. The rectifier unit includes circuitry to keep the batteries fully charged and ready in case of a power outage. At full charge, a typical lead-acid battery string is kept at a "float" voltage of about 54 volts. This is the voltage supplied to the bottom end of the power trunks.

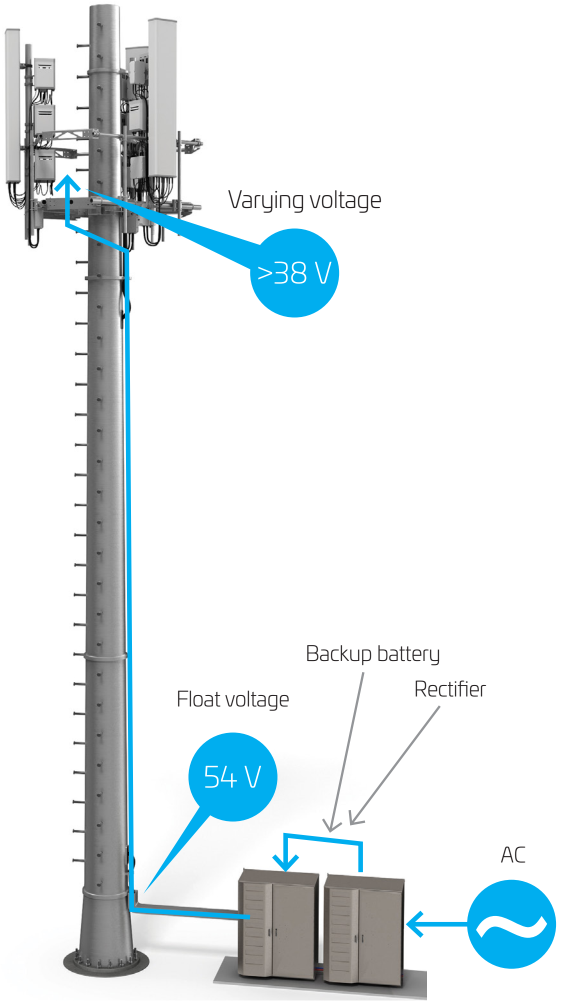

Figure 2: Conventional power feed scenario—normal operation

At the top end of the trunk, a tail (jumper cable) connects to the radio. The voltage at the radio will be reduced by the "line drop" resulting from the flow of current and the resistance of the trunk and tail conductors. Longer and/or thinner cables as well as higher current will result in a greater line drop and lower voltage to the radio. The radio will typically accept supply voltage between 38 and 57 VDC and will draw more current at lower voltage in order to obtain the power it needs. If the voltage drops below 38 volts, the radio would shut down; robust operation requires that this be avoided. Higher current causes a larger line drop, which will further reduce the voltage at the radio. Thus, proper dimensioning of the power feed involves a quadratic equation, the solutions to which are graphically illustrated in Figures 3 and 6 below.

Our example assumes an existing older RRU and compares it to a 64T/64R AAU with 200 total watts of RF output—an option for 5G. In terms of power consumption, the AAU is similar to newer dual-band RRUs, making this example helpful also for understanding the change in power requirements when adding a band by replacing the RRU. Robustness dictates that the power feed be dimensioned for the maximum power consumption. This is estimated at 1400 watts for the AAU and 650 watts for the older RRU. The length of the trunk in this example is 60 meters plus a five-meter tail with 12-AWG (3.3-mm^2) conductors.

Figure 3 models the expected power feed when using a lead-acid battery string at 54-volt float voltage with four different thicknesses of power cable. The graph plots indicate the current (vertical axis) as a function of the voltage at the radio (horizontal axis), determined by the maximum radio power. The answers to the quadratic equations mentioned previously can be found at the intersecting points on the graph. This is where radio voltages for the RRU and AAU meet the current supplied by the 4-, 6-, 8-, and 10-AWG (21.1-, 13.3-, 8.4- and 5.3-mm^2) trunk cables. Based on these plots, we know the RRU will operate with any of the four trunk cables, but the AAU requires at least an 8-AWG as the 10-AWG cannot meet the minimum radio voltage (38 volts).

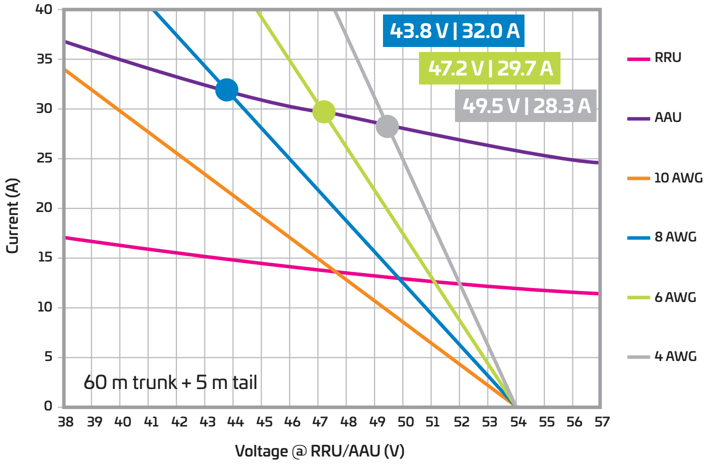

Figure 3: Conventional power feed dimensioning—normal operation

Power outage and coup de fouet

A robust power feed must also operate dependably during a power outage when relying on battery-supplied power. The backup scenario is illustrated in Figure 4. As the battery strings switch from float charging to discharging, there is an immediate drop in the battery voltage. Assuming a moderate rate of discharge, the voltage remains nearly constant until the batteries start to run low—at which time the voltage will drop fairly rapidly.

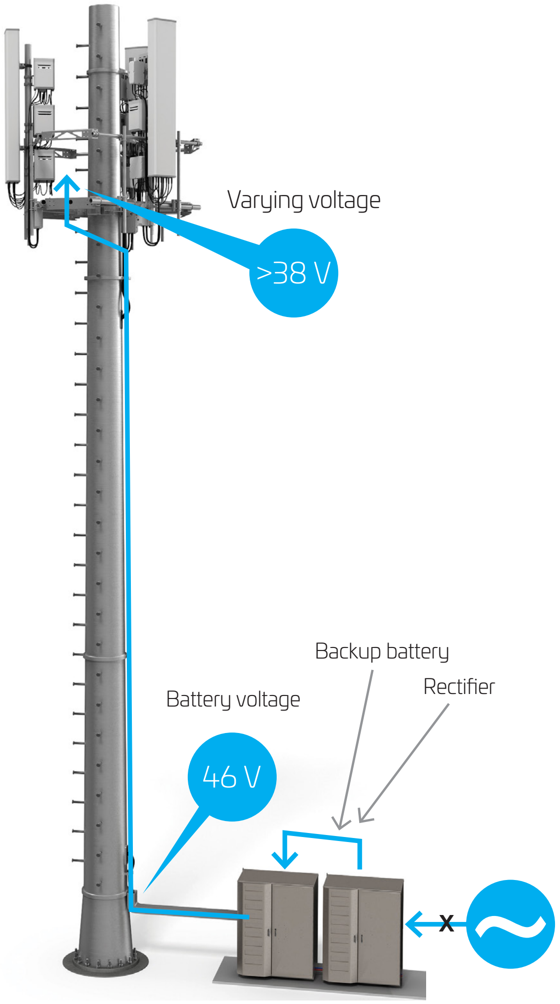

Figure 4: Conventional power feed scenario—backup operation

Another factor critical to the dimensioning of the power feed for robustness is coup de fouet, a phenomenon exhibited in lead-acid batteries. Translated as "whiplash," coup de fouet is a temporary drop in battery voltage that occurs during the initial minute of a power outage, as shown in Figure 5. The degree of voltage loss depends on various factors, including battery age and service history, temperature and discharge rate, etc. A field study on a live installation measured close to 46 volts at the bottom of the dip before the voltage began to rise toward a stable value. The dip could be deeper still, depending on circumstances.

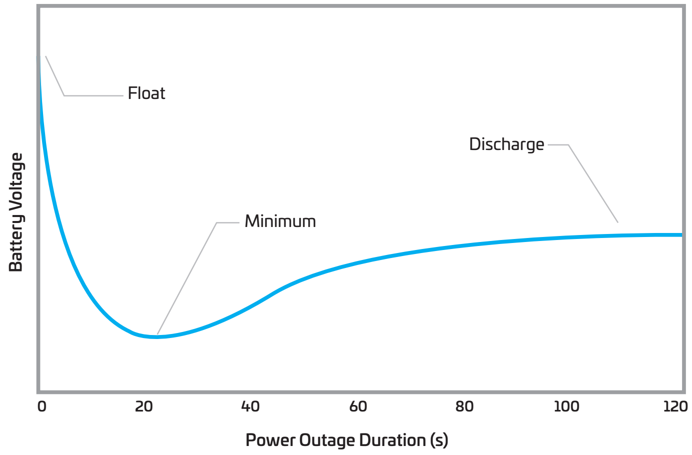

Figure 5: Coup de fouet—battery voltage dip at initial discharge

To ensure the radios in our example remain operational during coup de fouet, it is necessary to re-graph the power feed scenario in Figure 4 using the assumed minimum voltage of 46 volts. Assuming a reasonable power consumption level, on the other hand, involves multiple factors. Radio power consumption is partially traffic dependent and will peak when traffic demand is at its highest. This typically occurs only at certain predictable times—but not always.

There are at least two scenarios in which a power outage that affects the cell site and coverage area will trigger an unexpected peak in traffic demand. First, when normal activities are interrupted, many people will engage with their smartphones while waiting for power to be restored. Second, if Wi-Fi access points aren't functioning, mobile devices will use the cellular networks instead.

So, in re-calculating our power feed scenario from Figure 4 to account for coup de fouet, we should assume the maximum power consumption when dimensioning for power outage. This case is plotted in Figure 6. Here, the 10-AWG trunk is pushed to the very limit by the RRU, while the 4-AWG remains the only viable option for feeding the AAU.

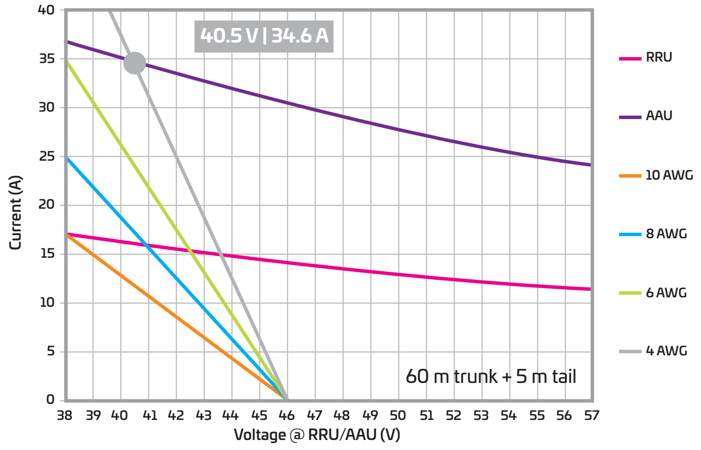

Figure 6: Conventional power feed dimensioning—backup operation

One option—upgrade the power trunk

Robustness is one aspect to take into account when dimensioning the power feed; others may include energy efficiency, battery runtime and cost of equipment. (For a more thorough discussion of these, we recommend the CommScope white papers cited in the next section.) A key parameter that reflects multiple aspects of dimensioning is the voltage at the radio. If, for example, an 8-AWG trunk is used with the RRU in Figure 3, the radio voltage becomes 49.8 volts. To maintain a similar voltage (49.5 volts) after substituting the AAU, a 4-AWG trunk will need to be installed. One consequence will be increased weight on the tower, as indicated in Figure 7. The cost to purchase and install the heavier trunks must also be considered. The incremental adjustment in size and cost will depend on the scenario; on a shorter tower, an upgrade from 10-AWG to 6-AWG may be appropriate given the same RRU and AAU as used in our example.

Figure 7: Approximate weight of 60-meter power/fiber cables for 12 RRUs

PowerShift®—a better plan

As described above, installing a bigger, heavier power trunk is one way to maintain robustness with rising radio power consumption. Another, more elegant, solution is PowerShift. A key feature of PowerShift is the ability to keep the radio voltage at a constant level, ensuring it never drops below the shut-down threshold—38 volts, in our example. It is normally set to maintain a voltage in the upper part of the radio operating range, typically 54 volts. The higher voltage also improves efficiency by minimizing the energy loss in the trunk cable.

The operating concept of PowerShift is simple. It connects to the power feed between the batteries and power trunk as shown in Figure 8. The output voltage adjusts dynamically to keep the radio voltage constant regardless of the radio power consumption, the size and length of the power trunk, or the battery voltage. There are three limits to consider in dimensioning: the PowerShift maximum output voltage (73 volts), maximum current (31 amps) and maximum output power (2000 watts). PowerShift can boost a battery voltage as low as 38 volts (residual voltage of a discharged battery string).

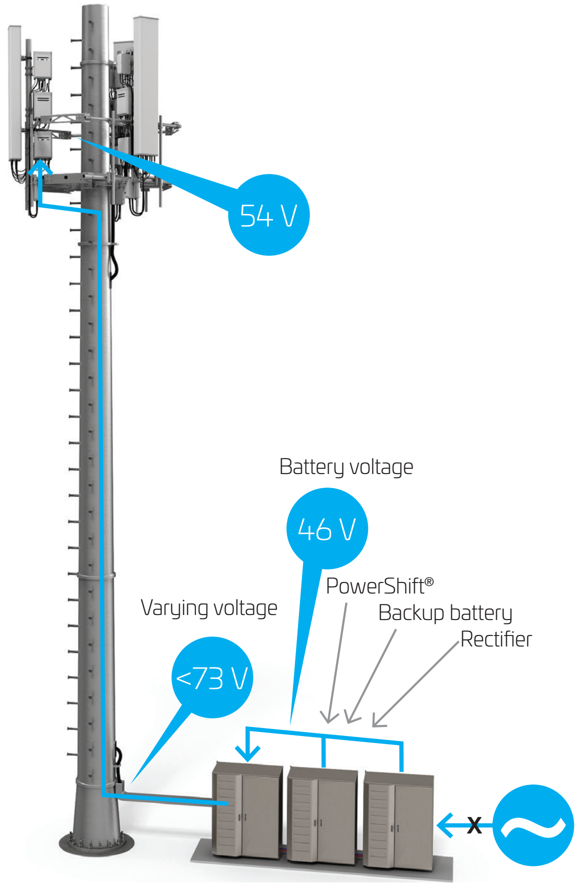

Figure 8: Power feed scenario with PowerShift—backup operation

The results of inserting PowerShift into our power feed example can be seen in Figure 9. Voltage at the radio remains constant at 54 volts while the PowerShift output voltage varies as needed. The PowerShift output voltage, plotted on the horizontal axis, ranges from 54 volts to 73 volts and the current (A) is on the vertical axis. Using the (constant) radio currents at the respective maximum power consumptions of the RRU and AAU, we have plotted the output voltage for the four power trunk gauges. The black curve indicates the 31-amp, 2-kW PowerShift output limits. Even with the higher power consumption of the AAU, a 10-AWG power trunk can now be used while staying well within the limits of PowerShift operation.

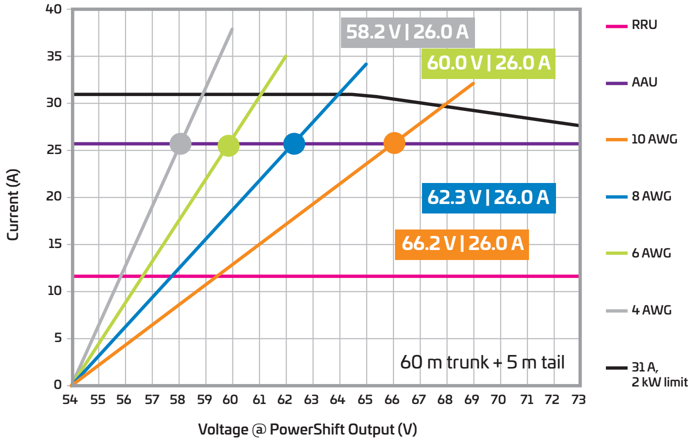

Figure 9: Power feed dimensioning with PowerShift

To learn more about calculating potential energy savings with PowerShift, download the CommScope white paper: "Reducing dissipation-induced dc power losses at macro cell sites"

Figure 9 demonstrates that PowerShift provides an immediate and robust power feed that is guaranteed to weather a power outage without service interruption. It also enables operators to eliminate the costs and potential structural impacts incurred by upgrading the power trunk to a heavier gauge. Additionally, the PowerShift module (Figure 10) is compact and easy to install, along with required capacitive jumpers at the RRUs. Overall energy efficiency is determined by trunk size and the PowerShift power conversion efficiency, typically 97 percent.

Figure 10: PowerShift base unit

To learn how PowerShift enables extended backup battery runtime, download the CommScope white paper: "Maximizing cell site reliability"

PowerShift also provides greater flexibility in designing the optimal power feed system. The dimensioning exercise presented in this paper demonstrates that only a 4-AWG power trunk can be used with the conventional power feed. PowerShift, however, enables operators to use any of the four gauges in order to strike the optimum balance between energy economics and capital expenditures. Other benefits include simplified logistics and increased flexibility to enable remote backup, very long power trunks and other challenging installation scenarios.

Summary and conclusions

As higher-power radios are deployed at cell sites—whether to add new frequency bands, enhance MIMO performance or deploy 5G services—network operators must re-evaluate their power delivery systems. These systems must be dimensioned to ensure that tower-mounted radios receive sufficient voltage—not only during normal operation, but during power outages when the cell site must rely on backup batteries, especially during hours of peak traffic loads.

Properly dimensioning the system for adequate voltage supply and cost efficiency is challenging. Increased power demand at the tower top results in a larger line drop along the existing power trunk cables. This often leads to insufficient voltage at the radio—requiring thicker and heavier power trunks to reduce the line drop and restore the radio voltage. If relying on the backup batteries alone, dimensioning must also account for variations in battery performance, which is dependent on battery type and age, temperature, rate of discharge and other factors. Uncertainties about these factors can lead to an over-dimensioned power feed. As a result, operators may incur increased costs to purchase and install the heavier power trunks, as well as the structural challenges of higher tower loads.

An alternative design that includes PowerShift eliminates the impact of many of these uncertainties and greatly simplifies the design. PowerShift maximizes the utility and performance of any size power trunk, enabling the delivery of substantially more dc power to the tower-top equipment. The example presented in this paper shows that more than twice the power can be delivered through an existing trunk cable simply by adding PowerShift. Because radio voltage is maintained at a constant, optimum level, PowerShift ensures the robustness of the power feed and extended battery runtime. With a few simple calculations, PowerShift can be evaluated and dimensioned for a wide variety of site configurations. Simplicity and uniformity make PowerShift the optimum choice as a standardized component at macro and micro sites, as well as in centralized radio access network (CRAN) applications.

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