White Paper

Reducing dissipation-induced dc power losses at macro cell sites

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Abstract

As the power demand of remote radio units (RRUs) has risen in the era of LTE—and will continue to significantly increase with the arrival of 5G—it becomes more important to find ways to improve power efficiency and minimize power dissipation in wireless cell sites. A key opportunity for increasing power efficiency is in the power cable between the base station and RRU. This paper will explore one method of reducing power loss in the cable and present supporting experimental findings.

Introduction

Direct current (dc) power is the preferred power delivery method for telecom equipment. One required element of dc power delivery, naturally, is the cable between the base station power system and the RRU. The cable length can be significant, ranging from 100 to 900 feet (30 to 275 meters). Though large-gauge cable is employed for the power delivery, cable resistance and the resulting voltage drop across this cable can cause significant power loss in the system. This is the challenge we must resolve.

Direct dc power model

A diagram showing typical dc power delivery is shown in **Figure 1**. The dc rectifier will have an output voltage (V_1) set to a level that will provide power to the RRU at a voltage (V_2) within its operational range. This voltage level must account for the voltage drop across the intervening cable (V_1-V_2). The differential between the dc rectifier output voltage and the RRU load voltage will be determined by the current flow through the cable (I_L) and the resistance of the cable (R_1). The current makes a loop through its return path so the total resistance of the cable is $2R_1$.

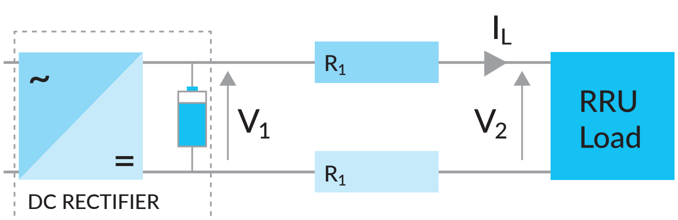


Figure 1. RRU dc power delivery

According to Ohm's law, the voltage drop will be $2(I_L)$ (R_1). Power loss through the cable will be voltage multiplied by current—or (V_1-V_2) (I_L). Substituting the previous equation, cable power loss ends up being 2 X (I_L X R_1) X I_L—or $2(I_L^2R_1)$. This equation highlights current (I_L) as the most significant contributor to cable power loss since it is proportional to the square of the current. Reducing current demand through the cable is the most important element in reducing power losses in the cable.

RRU power demand

The RRU is the primary driver behind the current demand. Again, the two components of power that must be delivered to the RRU are voltage and current. In Figure 1 above, these are designated as V_2 and I_L—resulting in P_{RRU} = (V_2) (I_L). For any given amount of power needed by the RRU, the amount of current that must be delivered is a function of the voltage provided at the RRU inputs.

A higher voltage at the RRU inputs means the unit needs less current for the same amount of power. Thus, if the dc rectifier can raise its voltage such that the RRU input voltage is higher, then the current through the intervening cable is reduced and there will be a corresponding drop in cable power loss proportional to the square of the current reduction. However, the rectifier voltage in this scenario can't be increased because the rectifier is also floating the battery, and also because it must provide -48VDC nominal voltage to telco equipment on the ground. In both cases, increasing the voltage would exceed specified voltage.

Quadratic equation

Consider a 600-watt RRU (P_{RRU}) that is being powered from the base by a standard rectifier whose output is set to 53.5 volts (V_1) over an 8 AWG pair of wires that are 555 feet long. The round-trip resistance of the cable is approximately 0.70 ohms ($2R_1$). The resulting power equation for this configuration is:

$$P_{RRU} = (V_1)(I_L) - (2R_1)(I_L^2)$$

This equation can be converted to a quadratic, which can be factored for calculating cable current (I_L). The resulting cable current is 13.65 amps. This produces cable power loss of 130.5 watts with a total rectifier output power level of 730.5 watts.

Standard rectifiers normally have a fixed output voltage level. So, in order to raise the RRU voltage level, a line drop compensating dc-to-dc converter—that is, CommScope's PowerShift® solution—is introduced between the dc system and the power cable as shown in **Figure 2**.

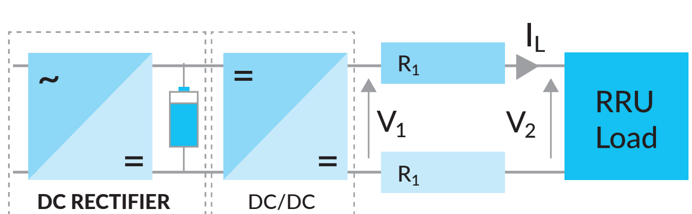


Figure 2. Introducing a line drop compensator in RRU applications

PowerShift is a line drop compensating dc-to-dc converter that can receive the dc output of the dc rectifier, then raise the output voltage (V_1) to the cable in order to reduce cable current as a result of a higher RRU voltage (V_2). Through a proprietary initialization algorithm, PowerShift determines the cable resistance to the RRU and adjusts its output accordingly; as the RRU load current varies—driven primarily by the RRU power amplifier response to active call traffic—PowerShift dynamically varies the output voltage (V_1) to maintain a specific set point voltage at the RRU. The nominal set point target is 56 volts.

Given an RRU set point voltage of 56 volts, then, for a 600-watt RRU, the current required is 10.7 amps. With the reduction in cable current, the cable power loss is reduced to 80.4 watts, a 38.4 percent power savings. At 97 percent efficient, the PowerShift product will consume about 21 watts of power. System power savings will then be 130.5 watts – (80.4 watts + 21 watts), or 29.1 watts of savings.

This represents a total rectifier output power savings of 4 percent (730.5 watts versus 701.4 watts)—a significant amount.

Experimental verification

Experimental test results were collected for a variety of loads and cable lengths for the PowerShift solution. An Agilent N3300A electronic load was used to provide a load at a fixed wattage and a cable simulator unit with selectable in-line power resistors was used to set the cable resistance. A scenario similar to one described above was one of the test cases for which rectifier output power was measured in a standard configuration without PowerShift and a configuration with PowerShift in-line with the rectifier.

The resistance selections of the cable simulator were used to set the cable resistance to 0.70 ohms between the rectifier or PowerShift and the electronic load. The electronic load was used to provide a fixed 600-watt load in both the standard rectifier and rectifier-plus-PowerShift configurations. Cable loss for the standard configuration was measured at 133.9 watts with the cable loss reduced to 84.5 watts in the PowerShift configuration (a 36.9 percent savings).

Overall rectifier output power was reduced from 738.3 watts with the standard configuration to 706.2 watts with PowerShift, a savings of 4.35 percent. These results track closely with the theoretical test case given above; in fact, they exceeded the theoretical result by 8.75 percent.

Test results summary

The chart below compares rectifier power output of standard versus PowerShift configurations with measured data from selected cable resistances of 0.45, 0.57, and 0.69 ohms. For 8 AWG cable, these resistances are equivalent to approximately 360, 455 and 550 feet of cable. The bar chart shows the increased system power savings with PowerShift as the load power and cable resistance increase. When compared to calculated power consumption estimates, these measurements are within 3 percent.

In this chart, PowerShift savings started at 500 watts for 550 feet; 600 watts for 455 feet; and 650 watts for 360 feet.

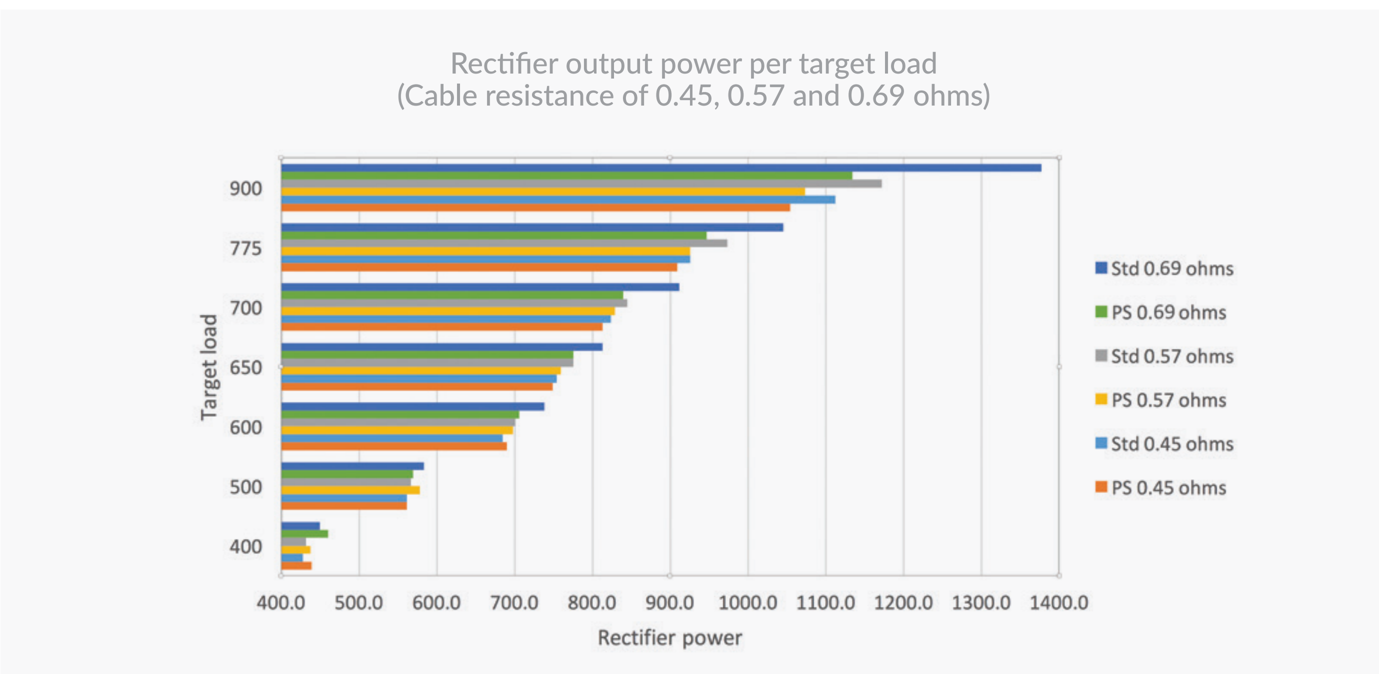


Figure 3. Power consumption comparison with (PS) and without (Std) PowerShift solution

Figure 4, below, is a line chart showing curves of the measured data adjusted by a polynomial curve fit. The line plots are not linear, since the power loss through the cable is proportional to the square of the current. They show power savings trends with PowerShift for selected target loads over a spectrum of cable lengths. It gives a general sense of the load-cable combination that produces power savings with the addition of PowerShift between the rectifier and RRU.

Since PowerShift itself will consume 3–5 percent of the rectifier output, benefits from its increased voltage output will not be seen until this parasitic power loss is overcome by power savings in the cable as a result of reduced current at the load with the higher load voltage. PowerShift regulates the load voltage between 53 volts and 56 volts.

The rectifier power savings plots demonstrate the benefits of voltage boost as the power and cable resistances increase after PowerShift's parasitic losses have been overcome. For a 400-watt load, 0.85 ohms of cable resistance (675 feet of 8 AWG round trip) is needed to overcome the parasitic losses, but, for loads 700 watts or greater, PowerShift's benefit kicks in even at the lower resistances—around 0.35 ohms (275 feet of 8 AWG round trip).

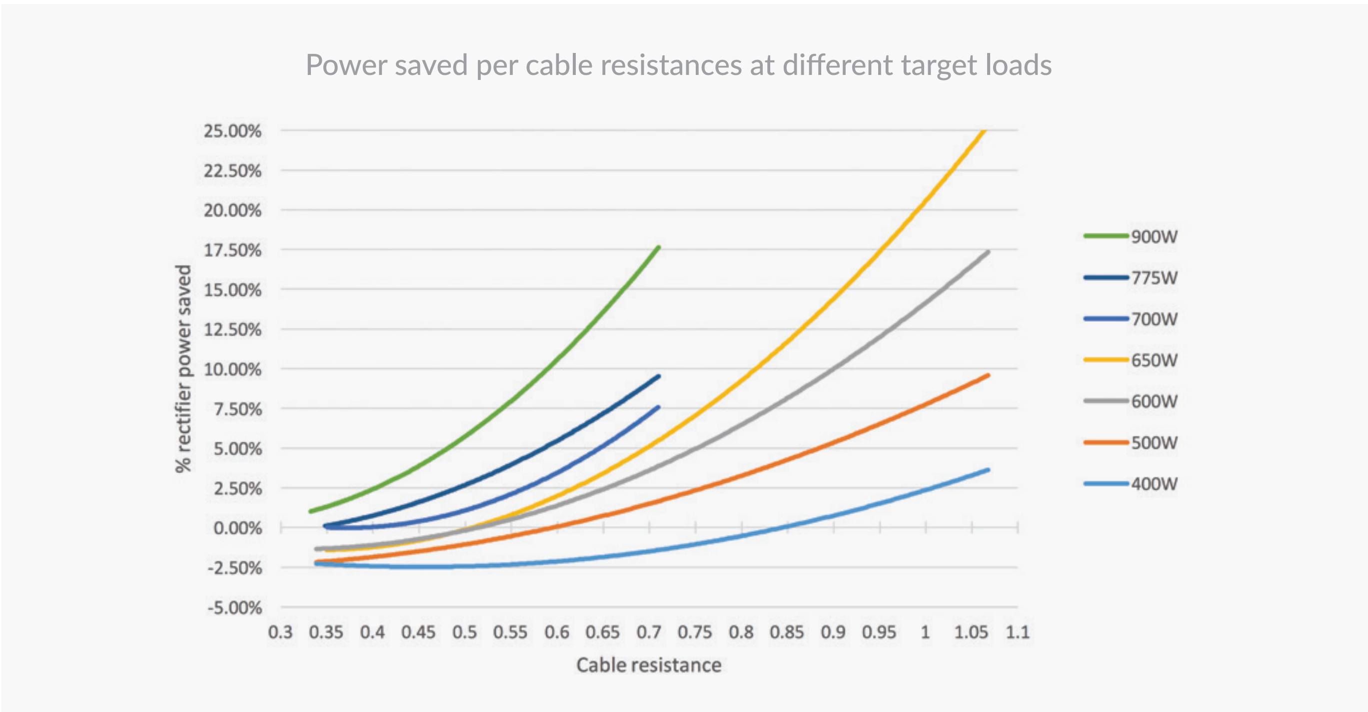
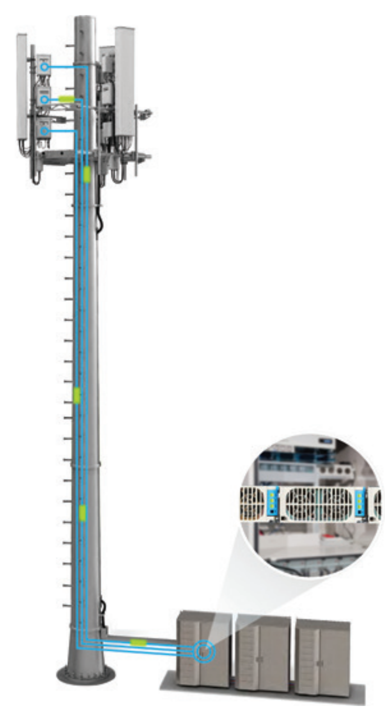


Figure 4. Rectifier power savings with PowerShift solution



Conclusion

The benefit of voltage boost to overcome line drop loss has been demonstrated in both the theoretical and practical worlds. By increasing load voltage, the load current can be reduced, which produces a corresponding drop in cable power loss that is proportional to the square of the current.

Measurements taken with CommScope's PowerShift product, once its parasitic losses are overcome, verifies that it produces real system power savings in its ability to boost the load voltage using its proprietary line drop compensation technique.

Contact your local sales rep or visit our website to learn more about PowerShift solutions.

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