Understanding Delta Conversion Online "Battery Charging" - Part 5

Introduction

This application note is the fifth in a series on delta conversion theory of operation. For complete understanding of the engineering benefits of this technology we recommend that you read all the series in order and any of the supplemental white papers found on the APC web site.

Delta Conversion OnlineTM Battery Charging Via Power Balance

Actually battery charging uses Kirchhoff's law of currents and the same power balance concept, where if we import more kW than the load can consume, the power that's not consumed by the load or dissipated as losses has to flow somewhere, i.e., in this case to the battery. The charging power available is 10% of the system power rating. For our discussion we'll use the same 40kW rating as in previous parts of this discussion. The battery charging power will be 4kW (40kW * .1 = 4kW). The unit does have programmable capability to double the charging power to 8kW by de-rating the output via setting the output current limit to 90% of the system rating (36kW).

Battery Charging at nominal Input Voltage

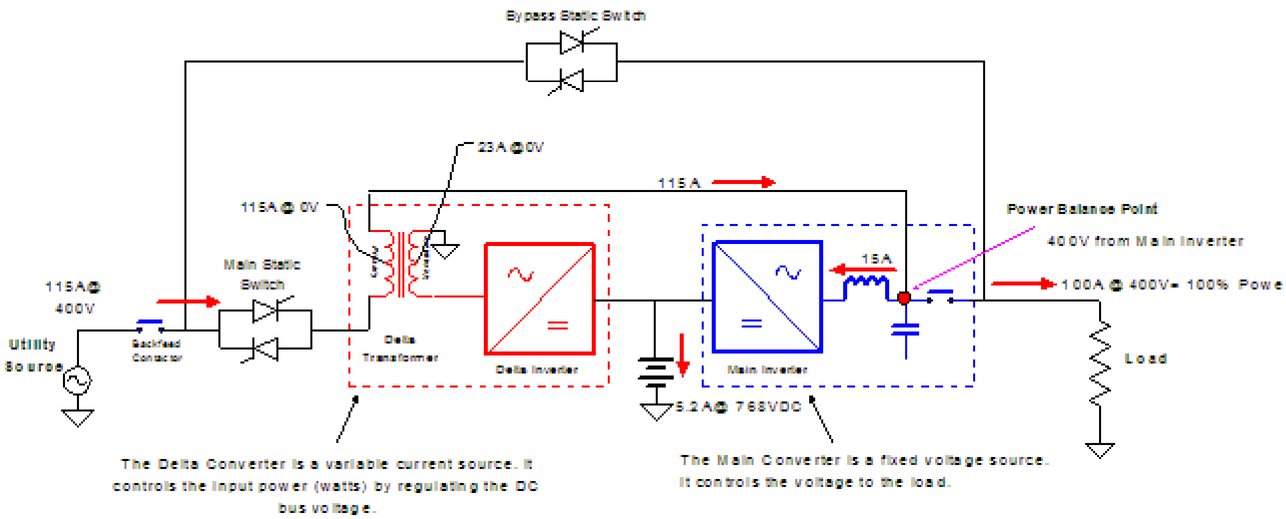

Figure 1: *Battery Charging Current at Nominal Input Voltage*

We also have the same 2kW of efficiency losses (5%) as in the preceding parts of this series of white papers. Therefore, to charge the battery we will need 46kW of input power. Please keep in mind Kirchhoff's law, i.e., the power flowing out of the power balance point

(PBP) has to equal the power flowing into the PBP. The delta inverter sets the input current to 115A(46000/400 = 115A). The power flows to the PBP where it splits, i.e., the load takes 100A and the remainder 15A takes the path back through the flyback diodes to the DC bus. The algebraic sum of the currents at the PBP is zero.

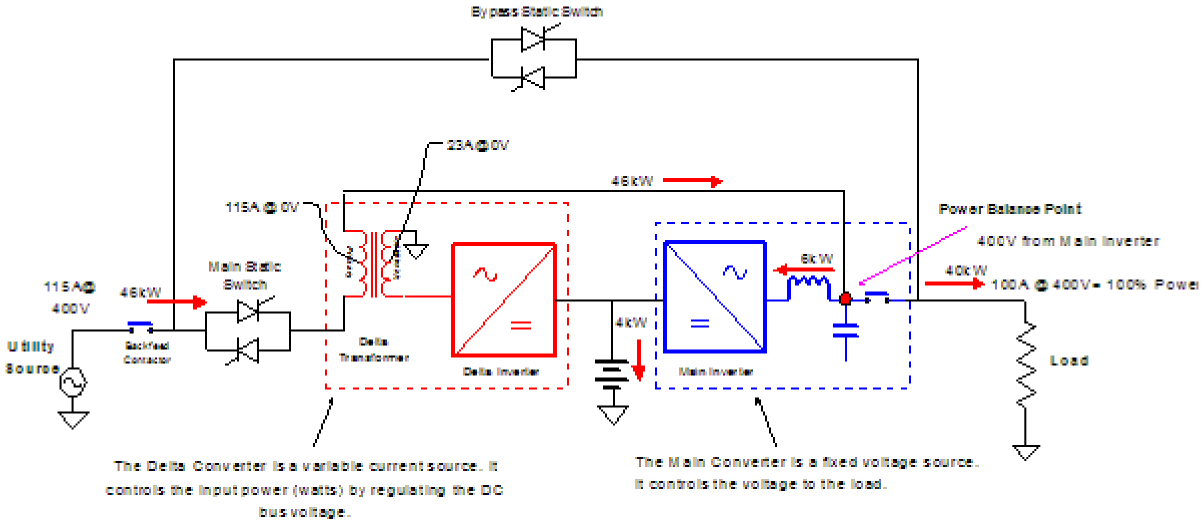

Figure 2: *Battery Charging Power at Nominal Input Voltage*

Because there is zero power transfer in the delta transformer, the 2KW losses are dissipated and the battery absorbs the remaining 4kW as charging power.

Battery Charging at -15% input Voltage

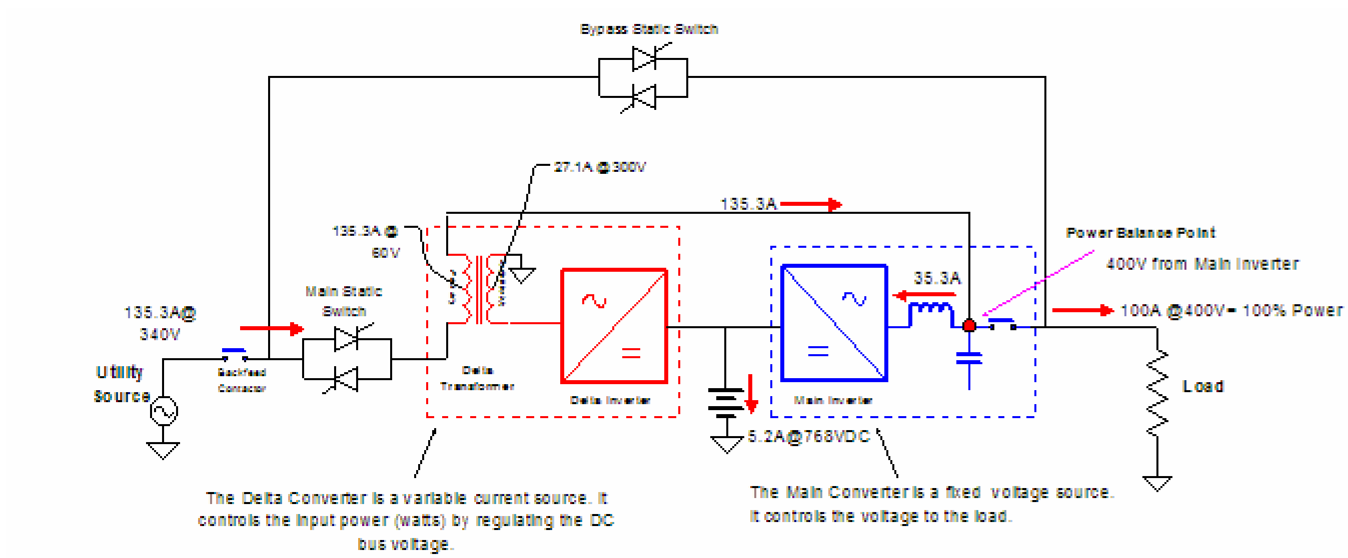

Figure 3: *Battery Charging Current at -15% Input Voltage*

Here again, the delta inverter adjusts the input power to maintain the power balance. It looks like we again have more power coming into the PBP (136.3A * 400V = 54.1kW) than was imported from the Utility Source. See Part 4 of this series.

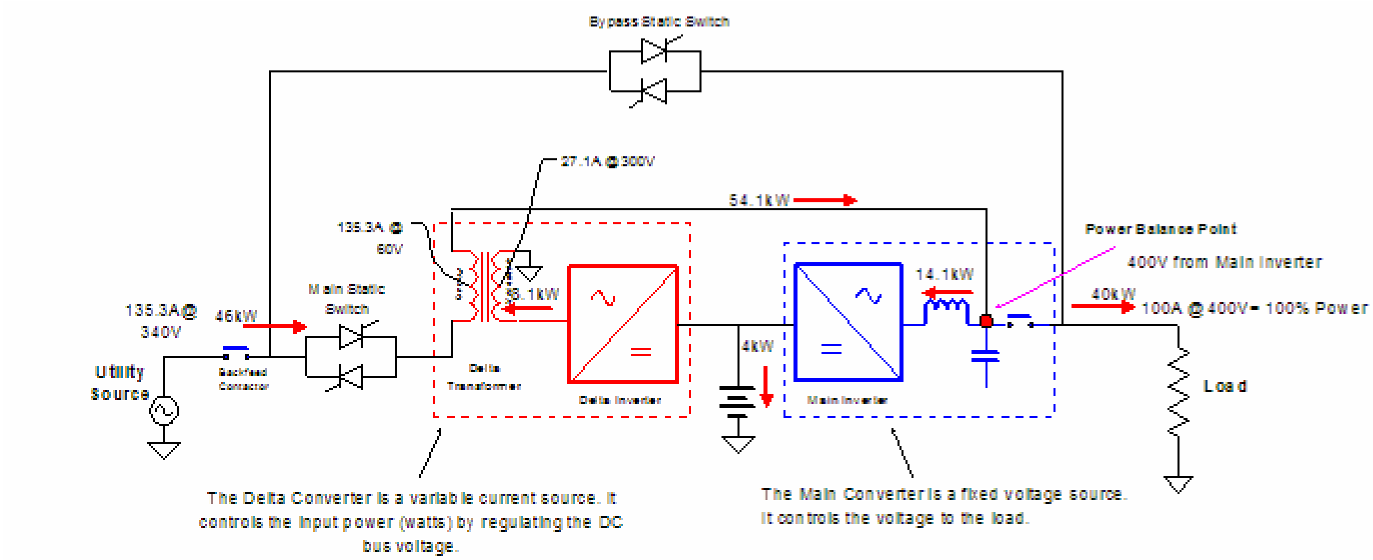

Figure 4: *Battery Charging Power at -15% Input Voltage*

In figure 4, we again see that there is both voltage and current on the windings of the delta transformer. This means there is power transformation between the windings. In this case 8.1kW of control power is flowing in the delta conversion power loop. Once again as shown in figure 4, the control power is not power that is being consumed. The load gets 40kW, the battery gets 4kW of charging power and 2 kW is dissipated as losses. Therefore 40kW+4kW+2kW = 46kW, and we can account for all the power imported by the delta converter.

Battery Charging at +15% input Voltage

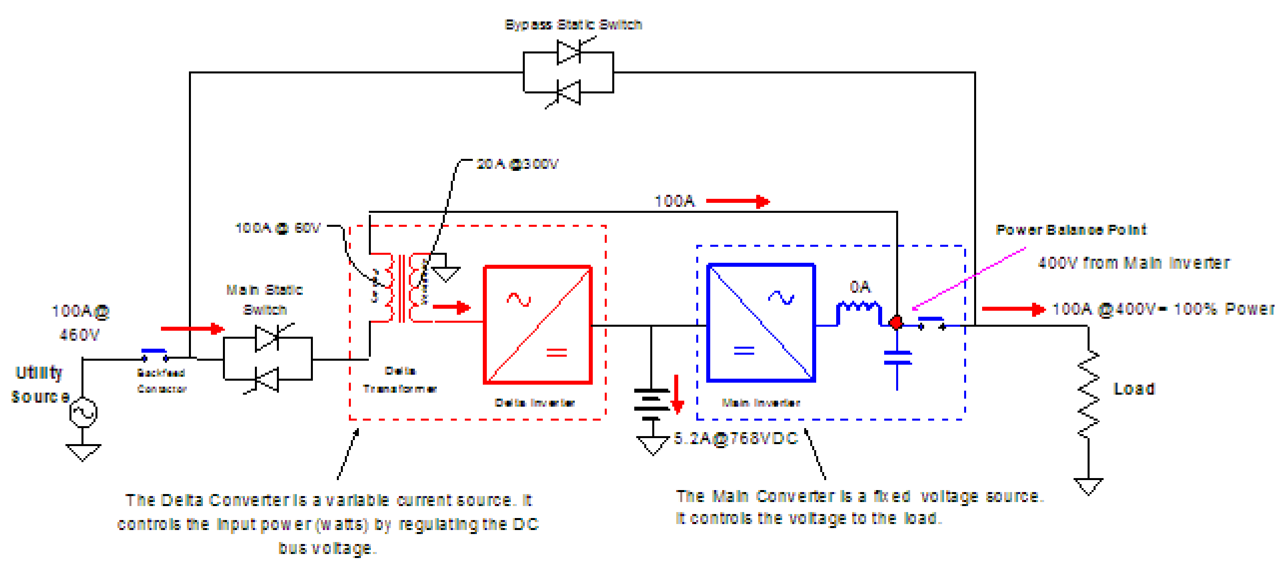

Figure 5: *Battery Charging Current at +15% Input Voltage*

To maintain the power balance the delta inverter must lower the input current to maintain the power input at 46kW (460V* 100A= 46kW). Again as in Part 4, we have power transformation that is reversed in the delta transformer. The load gets 100% power via the pure power path and the battery charging + losses flows through the delta transformer, i.e., from the primary winding to the secondary winding where it then is taken through the delta inverter flyback diodes to the DC bus.

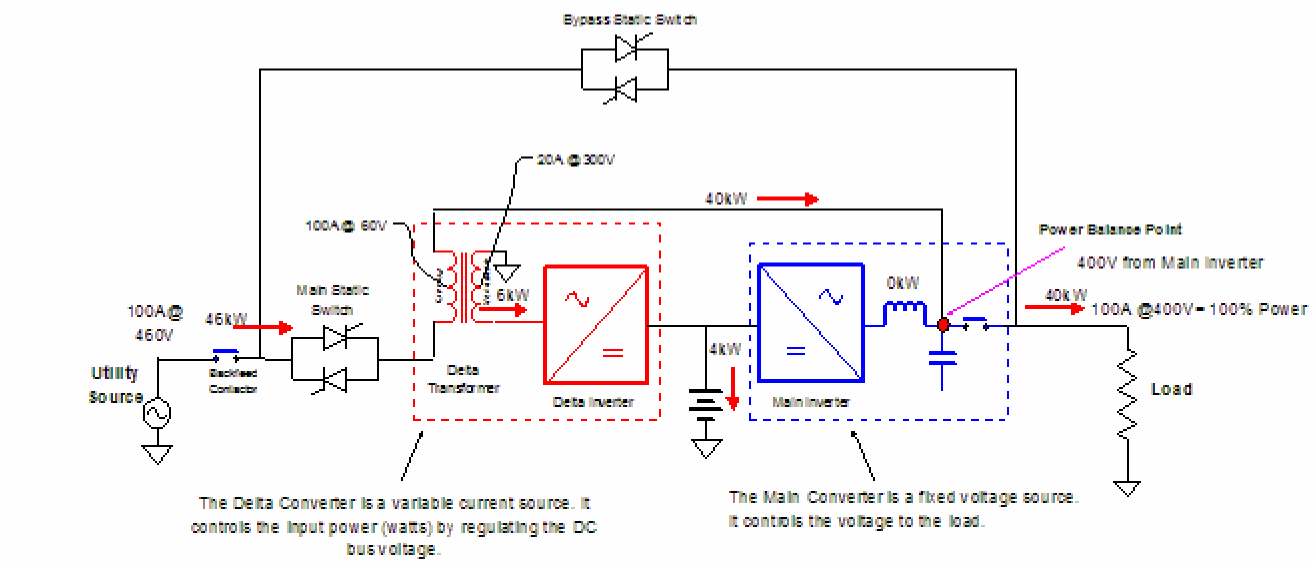

Figure 6: *Battery Charging Power at +15% Input Voltage*

As shown above in figure 6, we again satisfy Kirchhoff's law at the PBP. The main inverter is not providing any current/power in this situation. All current to the load is through the pure power path and the charging power + losses flow through the delta converter to the DC bus. The two inverters working together regulate the power to the load, i.e., the delta inverter importing current and the main inverter regulating the output voltage.

Delta Conversion Power Balance Review

The fundamental concept behind power balance is that the delta converter maintains the imported power to support the load, maintain the battery and provide for system losses under all conditions of the input voltage window (+/-15% of nominal) and load. It maintains the power balance by regulating the DC bus. This is no different than a double conversion charger/rectifier. The delta conversion process uses a bi-directional double conversion power path, i.e., where only the control power needed flows and is converted AC to DC and DC to AC to maintain the load power, plus charging, plus losses.

Thus we only convert the difference between the bad power and the good power, i.e., from the Greek symbol "Delta" meaning difference. Delta conversion is simply converting the difference in power to maintain control of the power to the load and the system needs, i.e., losses + battery charging.

The Utility Source voltage controls the magnitude and direction of the delta conversion control power process. . As you have seen it is feasible to precisely regulate the bulk power to the load via the pure power path, without converting al the power AC to DC, then DC to AC. The main inverter regulates the voltage to the load. Therefore it precisely regulates the load power. This is the same as a double conversion main inverter's voltage regulation function. If we regulate the input current using the delta inverter and regulate the output voltage using the main inverter we are performing the same function(s) as the double conversion system, i.e., regulating/controlling the power to the load. The operation of the Delta Conversion OnlineTM UPS satisfies all of Kirchhoff's laws. It also has many engineering benefits. Those will be discussed in the following parts of this series of white papers. This concludes Part #5.