# POWER AND BATTERY PLANT COORDINATION IN THE TELECOM ENVIRONMENT: CAN SMART TECHNOLOGY ENHANCE BATTERY LIFE AND REDUCE OVERALL COSTS?

**Stefano Rosellini – Voigt & Haeffner US / Gunter Schmitt – Voigt & Haeffner GmbH**
**Voigt & Haeffner US, Oviedo, FL 32765**

## INTRODUCTION

Starting with the basics of proper power and battery plant sizing, this paper analyzes how new smart switched mode rectifiers can help in reducing the risks of catastrophic failures, such as thermal runaways, and help with remote plant monitoring. Today's newly designed power plants for telecom installation comprise a number of modular switched mode rectifiers (n+1 configuration) linked by a common DC bus and a digital bus. The digital bus connects the rectifier to a microprocessor-based Central Control Unit (CCU) that supervises the overall functionality of the plant. Thanks to the flexibility of the microprocessor, the behavior of the chargers under specific conditions can be changed with the aid of just a few lines of software. This paper explores some of the possibilities that this technology allows to enhance battery life and possibly reduce the overall cost of ownership.
Some of the common mistakes affecting today's telecom power installations and the economics associated with power plant design are also analyzed.

## BATTERY AND RECTIFIER COORDINATION

Proper battery sizing and proper coordination between the battery and the charging plant is a must to assure a reliable backup power system. A number of standards [1] cover the different requirements for specific installations. In traditional telecom installations, the battery sizing can be generally achieved using the following formula:

$$C = L \bullet t \bullet 1.25$$

Where:
C ⇒ Battery capacity in Ah (for the hourly rate specified with "t")
L ⇒ Maximum load current in A
t ⇒ Backup time in h (usually 8h)
1.25 ⇒ Aging factor

Using a power plant that is based on modular switched mode rectifiers, proper reliability can be achieved adopting the n+1 configuration rule that is using a plant configuration with n rectifiers that can support the load and battery charging currents, plus 1 spare rectifier to cover for any possible module failure. The set up would look like the one in Figure 1.

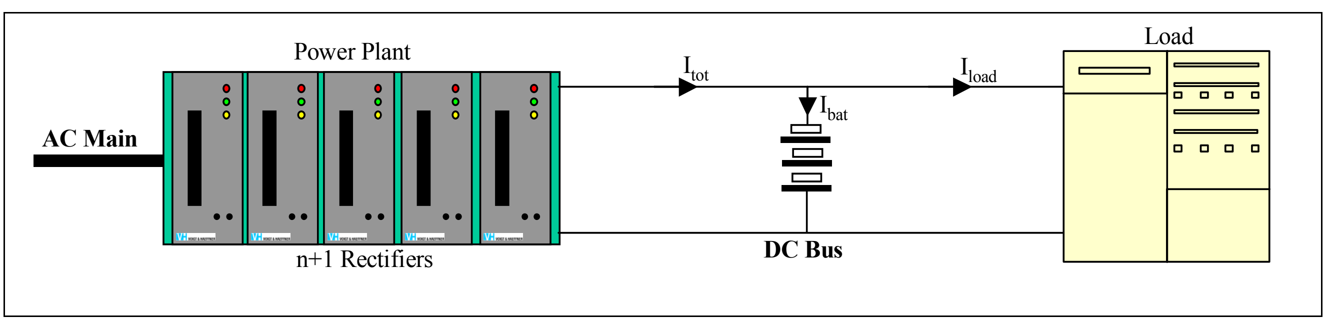


Figure 1

Assuming that we have a maximum load of 10A, the previous formula would suggest a battery capacity of 100Ah and a minimum rectifier configuration capable of about 25A (10A load + 15A to recharge the battery). If our plant were based on 10A rectifier modules, the proper configuration would be a 3+1 configuration with a total rectifier capacity of 40A. Supposing that we are just recovering from a power outage and the load is around 5A, the battery of our example will be recharged with a current of 35A.

Battery manufacturers prefer to specify a maximum charging current between 10%-20% of the rated capacity. For the 100Ah battery of our example, this current translates to 10A-20A.
There are multiple reasons for such a limitation, with the most important being:

- Concern that the battery temperature can rise more than 10$^{o}$C over the ambient;
- Concern that loose connections can overheat;
- Concern that a higher current can trigger thermal runaway on older VRLA batteries.

In our experience, the thermal runaway concern has proven to be particularly true, with the great majority of occurrences happening during a high current recharge after a power outage.

While the recharge current of our example is not outrageously greater than the one specified by the battery manufacturers, it is certainly higher than what it should be. This is worrisome, considering that we have applied all care possible to size our plant correctly.

The reality of today's telecom installations is such that for many different reasons:

- Oversizing;
- Redundancy;
- Equipment retrofitting;
- Load smaller than anticipated (especially for newer installations).

It is common to have a rectifier capacity capable of a recharge current 10-15 fold higher than the current specified by the battery manufacturers.

In all these cases, the only way to reduce the pitfalls of such currents, especially the risk of thermal runaway, is the monitoring of the recharge current that flows into the battery(s) and the adoption of a control mechanism that adjusts it to the optimum level. We call it CHARGE-SAFE® procedure.

## THE BENEFITS OF A MICROPROCESSOR

The flexibility associated with the availability of a microprocessor-based CCU and the availability of a digital bus translates in a high degree of monitoring functions. While is not advisable to exaggerate the quantities monitored, there are a number of features that come a little or no extra cost and are worth considering, as they certainly increase the power plant reliability.

***Monitoring of the battery recharge current***

The CHARGE-SAFE® procedure works thanks to the interaction of the Central Control Unit (CCU) and a shunt(s) (or other equivalent device(s)) that measures the current flowing in to the battery(s). During the installation process, the operator sets the maximum current allowed to recharge the battery(s). If, during the recharge process, the charging current exceeds the set value, the CCU instructs the rectifiers to drop the voltage to a value more sustainable for the battery(s). In order to avoid any problem, the voltage adjustment is always made within a fixed voltage window, with the lower voltage being around 95% of the nominal charging value.

***Low and High Voltage Supervision***

A threshold is set for a high voltage (around 58V for a 48V plant) and low voltage (around 45V-48V for a 48V plant). If the battery voltage reaches one of the two values, an alarm is triggered.

***Battery Symmetry Supervision***

To protect against cell short circuits, the system measures the voltage of the middle point of the battery string(s). If the voltage difference between the two battery halves is greater than a preset value (usually around 1.5V), an alarm is triggered.

***Temperature Compensation***

The Temperature Compensation feature has shown to be one of the most effective ways to enhance battery life. The graph in Figure 2 shows the life expectancy of a VRLA battery with and without temperature compensation. Assuming that at 25$^{o}$C (77 $^{o}$F) the charging voltage is set to 2.27V/Cell, at higher temperatures the output voltage is decreased; at lower temperatures the voltage will be increased. The temperature coefficient can be continuously adjusted between 0mV/Cell/K to 9.9mV/Cell/K to accommodate the different battery manufacturers specifications. Usually it is within a range between 4mV/Cell/K and 5mV/Cell/K.

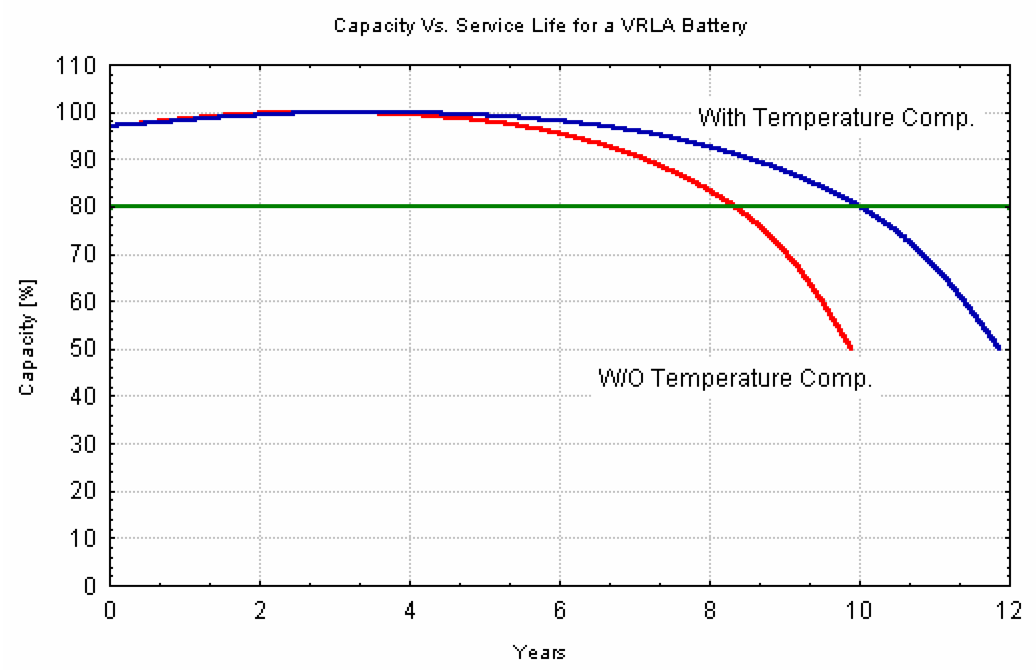


Figure 2

***Capacity Test***
Even if a full fledged test still requires the use of appropriate test equipment, new "intelligent" power plants allow a basic feature that can check the battery capacity and inform the user of unusual battery behavior. The capacity test can be conducted by dropping the voltage of the power plant to a voltage compatible with the equipment but lower than the nominal battery voltage (for a 48V plant usually around 45V). At that point, the load is entirely supported by the battery. Once the total battery voltage reaches the end of test voltage, the system records the battery capacity, the plant is automatically restored to the nominal voltage, and the battery is recharged. If the battery capacity is lower than a preset value, an alarm is triggered. There are different ways to initiate the test: manually at the site, manually from a remote location, or automatically if a battery parameter (for example the battery symmetry) is outside the proper limit.

**EFFICIENCY AND POWER FACTOR: HOW MUCH DO THEY COST?**

A typical switched mode rectifier module can be represented with the block diagrams of Figures 3 and 4.

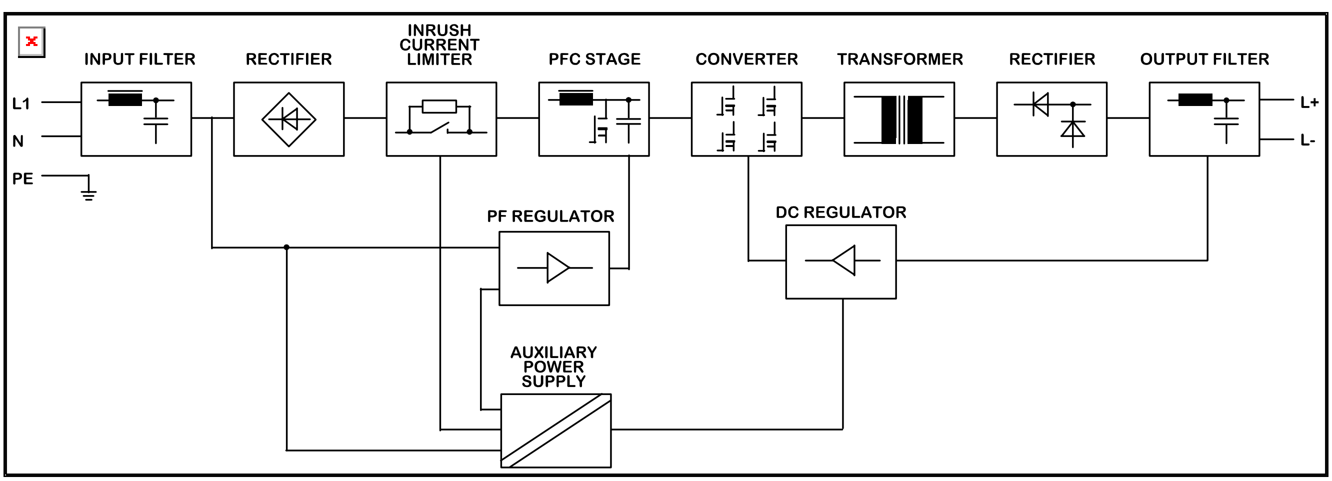


Figure 3

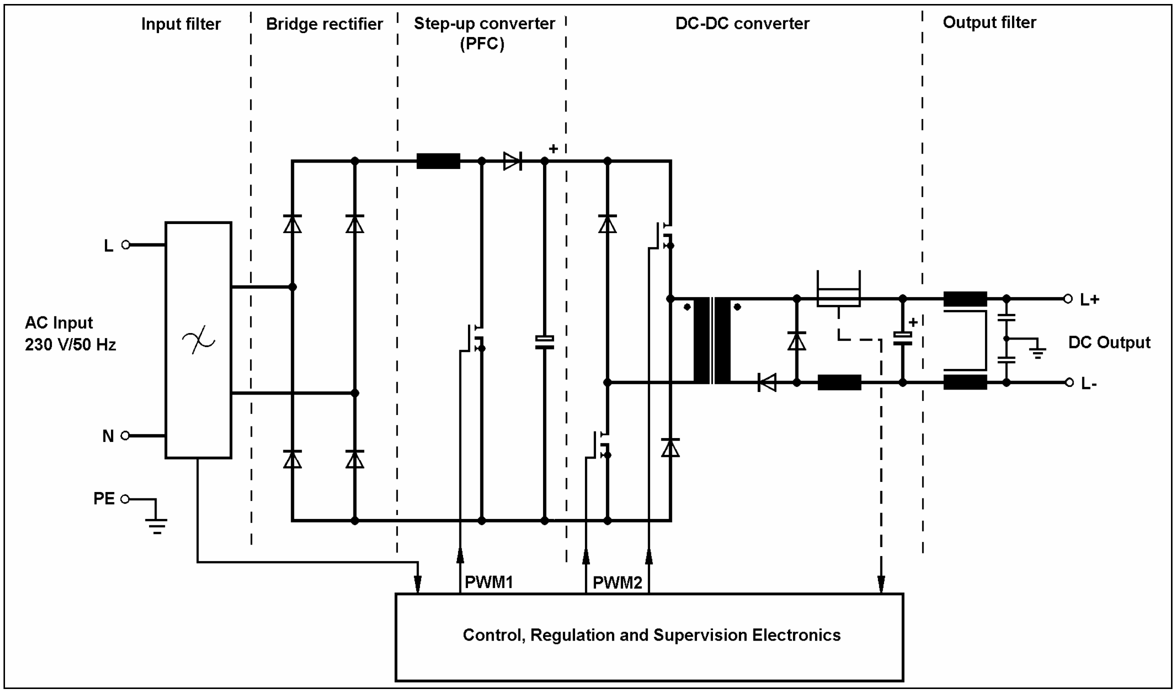


Figure 4 Rectifier Stage

Even if more complex than traditional technologies (especially if compared with ferro-resonant), this configuration is extremely compact and efficient.

As can be noticed on the graph of Figure 5, it is normal to have a 5% to 7% energy efficiency difference when the ferro-resonant rectifier is operating at optimum load levels (between 50% and 70% of the rated output), and 10% or more if outside the optimum area.

| | Energy Efficiency % | |
|---|---|---|
| Load % | Switch Mode | Ferro-resonant |
| 5 | 82 | 50 |
| 10 | 87 | 63 |
| 20 | 91 | 78 |
| 50 | 93 | 89 |
| 80 | 93 | 88 |
| 90 | 92 | 86 |
| 100 | 92 | 84 |

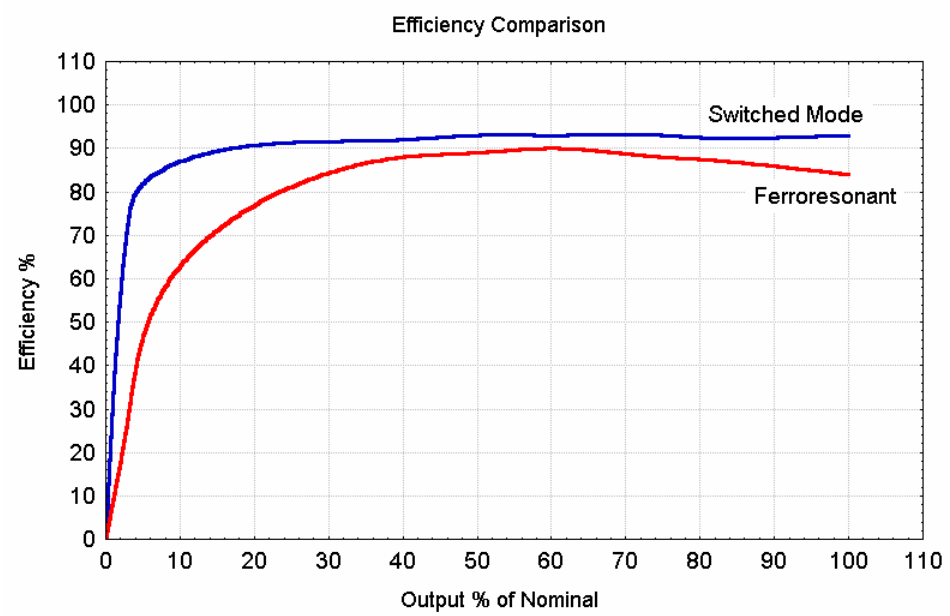


Figure 5

The more the rectifier is working outside the optimum operating area, the higher the energy losses and, consequently, the operating expenses to run one technology over the other. If we assume a 200A load at 54V, the power output would be 10.8 kW. If we are operating at the optimum level, we have a difference in efficiency between the two technologies of 756W. That translates in an energy loss of 18kWh/day or 6600kWh/year. The energy loss is dissipated as heat that is normally dealt with using an air conditioning system. If we include the AC consumption, the energy loss is close to 16,500 kWh/year. Assuming a cost of energy of $0.10/kWh, the yearly economic loss is $1,600.00. On a ten-year period, the operating loss reaches $16,000.00.

The graph in Figure 6 repeats this exercise throughout the whole output range:

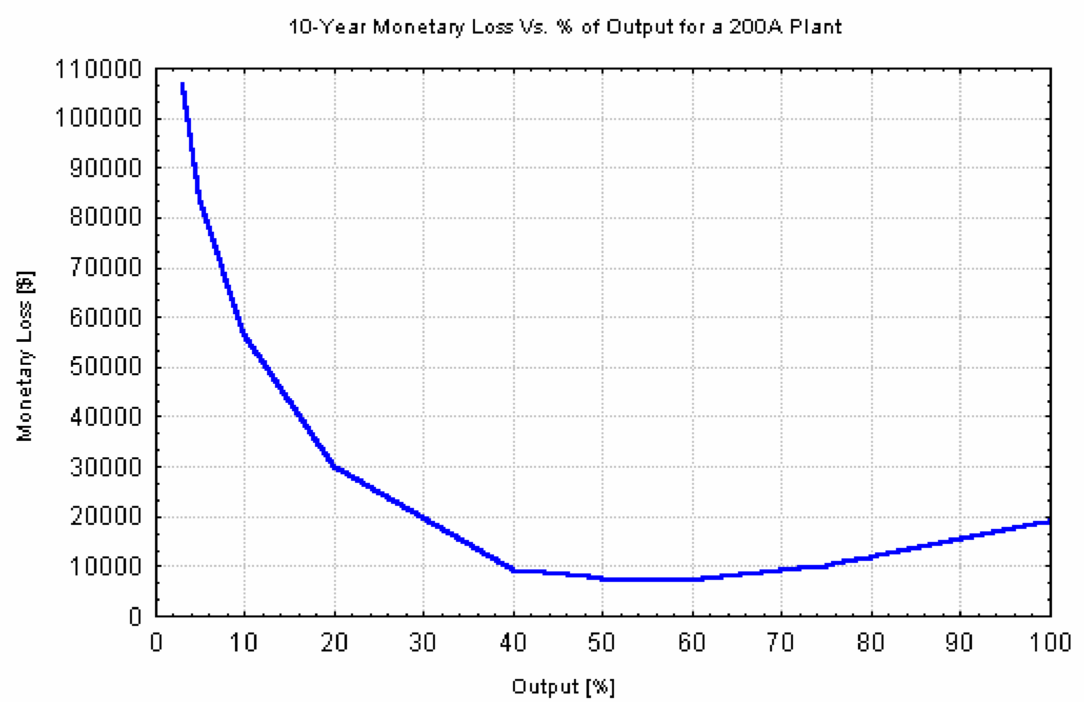

Figure 6

Another major difference between a switched mode rectifier module and a ferro-resonant one is on the AC power factor. Using a PFC circuit, it is possible to maximize the power factor throughout the whole operating spectrum.

While it is more difficult to compute the economic advantage associated with using the switched mode technology over the other, it is clear that a lower power factor increases the energy losses and can have a major impact in all those cases where the electric utility charges for reactive power.

Figure 7 shows the difference in power factor between the two technologies.

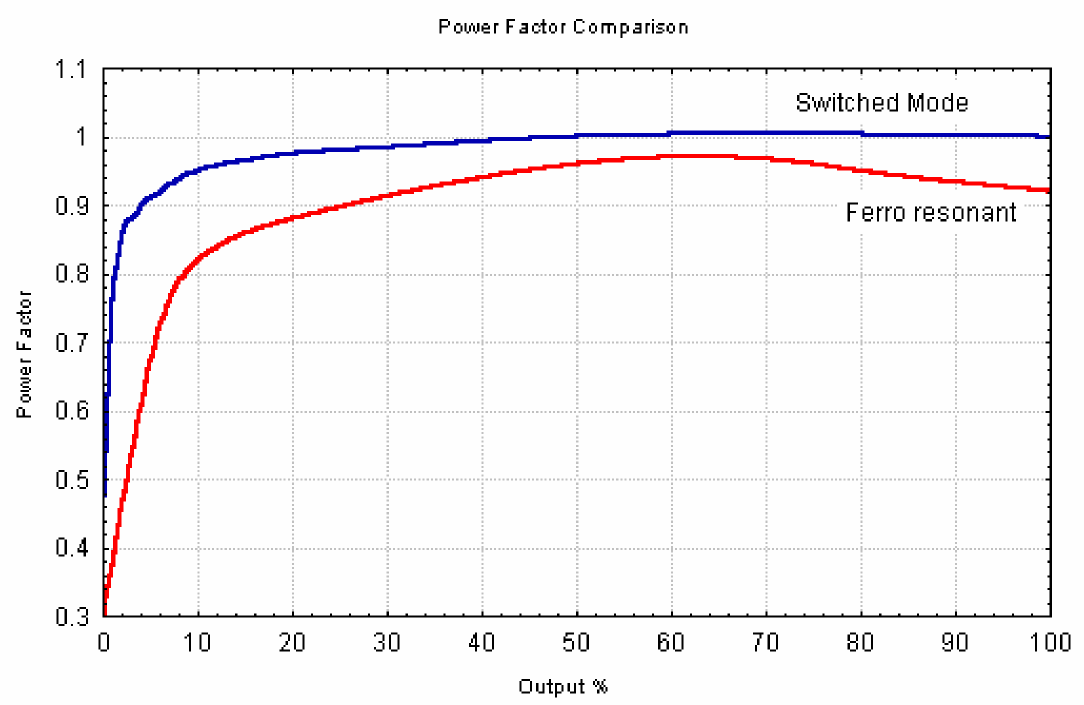

Figure 7

## CONCLUSION

Using some basic computations, it is possible to properly coordinate the battery plant with the appropriate power plant. The advancement in power plant technology and the use of digital, microprocessor-based central control units (CCU) allow the adoption of a number of monitoring features that enhance the battery life and improve the power plant safety without increasing the overall cost. When compared with older designs, the switched mode technology looks certainly more complex, with a larger number of conversion steps involved. However, thanks to the power electronics advancements, it performs extremely well from an operating cost point of view. If we then add the modularity, the ease of maintenance, and the high reliability achieved, it is not difficult to understand why all modern installations call for switched mode rectifiers.

## REFERENCES

1. IEEE Standards 535, 485, 450, 1184

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