



REDUCING CARBON DIOXIDE EMISSIONS AND ENERGY BILLS WITH 98% EFFICIENT RECTIFIERS

A White Paper on DC Power Efficiency

Introduction

The demand for mobile communication is continuously increasing worldwide. This trend has been obvious for many years, yet substantial investments are still needed to cope with increasing traffic and new services. This includes new sites, more telecom equipment and more dispersed network infrastructure. All of this equipment needs energy. New equipment normally is more energy efficient, but that doesn't offset the growth in traffic. Total power consumption still increases with the increase in mobile data traffic. According to Cisco, global mobile data traffic reached 7.2 exabytes per month in 2016 and is projected to reach 49 exabytes per month by 2021. That's equivalent to a text transcript of all the words ever spoken – 10 times over. That kind of traffic has a considerable environmental impact. In fact, greenhouse gas emissions indirectly caused by smartphones are expected to reach 125 megatons of CO₂ equivalent per year by 2020.

The trend of more power sources generating more carbon dioxide can't be sustained indefinitely. Therefore, system providers are working hard to reduce energy in every part of the network. The power systems and backup systems required for a reliable network are no exception. For nearly a decade, rectifiers with 96-97% efficiency have been available, helping to reduce the carbon footprint at many operator sites.

As we continue to focus on increasing efficiency and reducing energy consumption, a major milestone in rectifier efficiency has been reached. 98% efficient rectifiers with a flat efficiency curve are now available, optimizing energy consumption at every load condition. Thanks to technology advancements and components such as gallium nitride (GaN) that enable ultra-high 98% efficiency and improved power densities, power loss can be reduced up to 50% compared to 96% efficient rectifiers. With increasing energy costs becoming a global trend, the payback time for 98% efficient rectifiers is short. Being green has never been more affordable.

History

The guiding principle behind DC power systems feeding telecom networks has always been the reliable operation of sites and telecom equipment. Even in the harshest environments and most unstable AC grids, DC power is there to make telecom networks reliable. This is still the case.

Late 20th century technological advancements in electronics enabled vast efficiency improvements for rectifiers and DC power systems, starting at 80% efficiency in the 1960s and reaching 92% by the 1990s (see Figure 1). Back then, the focus was on reducing operating costs and to a certain extent making rectifiers more reliable by curbing excess heat. Only in the last couple of decades have we started striving to save energy in order to reduce energy usage and carbon dioxide emissions for environmental reasons – and to profile operators as “green” companies. The introduction of 96-97% efficient rectifiers enabled operators to reduce emissions to a greater extent than ever before.

The Technology Behind 98% Efficient Rectifiers

Achieving 98% efficiency requires next-generation technology and advanced, highly intelligent adaptive controls. At the heart of switch mode power supplies are the switching devices used to help transform power.

These switches account for the majority of power loss in a switch mode power supply. Today’s high-efficiency rectifiers utilize silicon-based switches known as MOSFETs (metal-oxide semiconductor field-effect transistors).

While there have been continuous incremental improvements to improve the switching efficiency of MOSFETs, the fundamental properties of silicon are such that losses exponentially increase with increased switching speeds. Countering these losses to achieve higher efficiency requires use of multiple MOSFETs in parallel and decreasing switching frequencies which results in higher costs and decreased power density. New 98% rectifiers utilize next-generation switch technology known as GaN FETs. The base material of GaN switches is gallium nitride, which exhibits superior switching properties compared to silicon. The result is a 3X reduction in switching losses and a 5X increase in switching speeds, resulting in power supplies that are more efficient, cooler (and thus more reliable) and up to 4X higher power density than those using traditional silicon-based MOSFET devices. Because operating conditions such as input voltage, load and temperature are constantly changing, advanced, intelligent adaptive control schemes are utilized to compensate for these variables. This ensures the GaN devices are switching at optimal frequency as needed to maintain high efficiency through a wide variety of operating conditions.

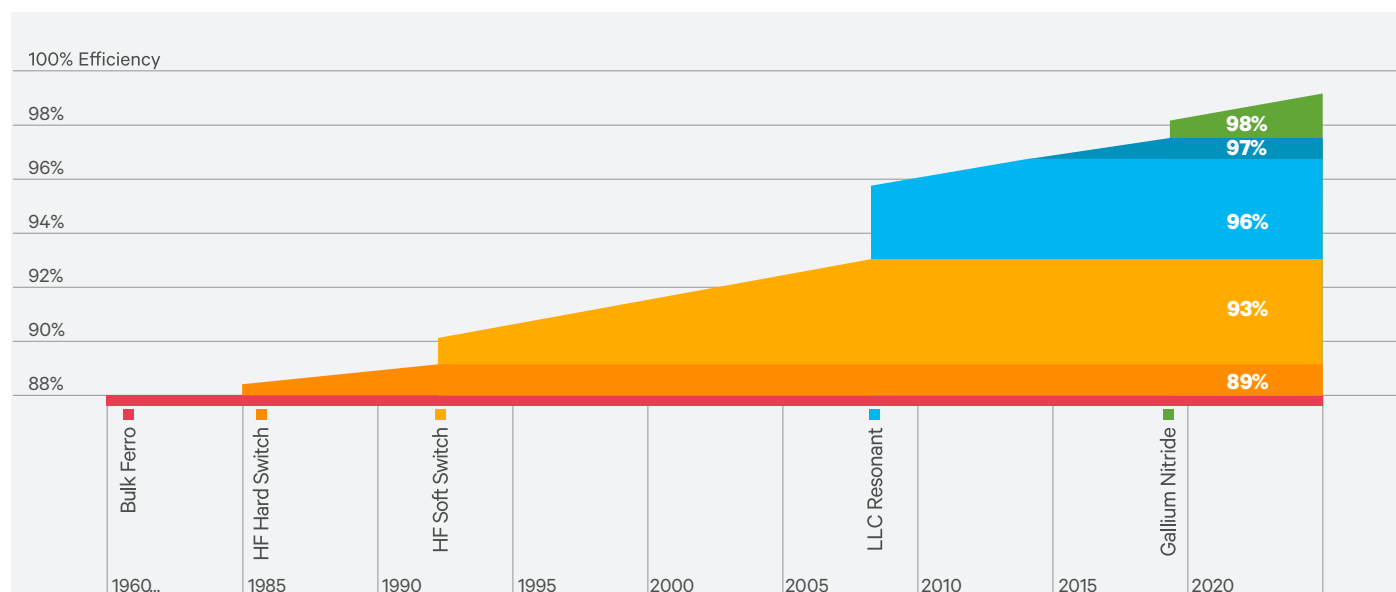


Figure 1: DC Power Rectifier Efficiency Trend

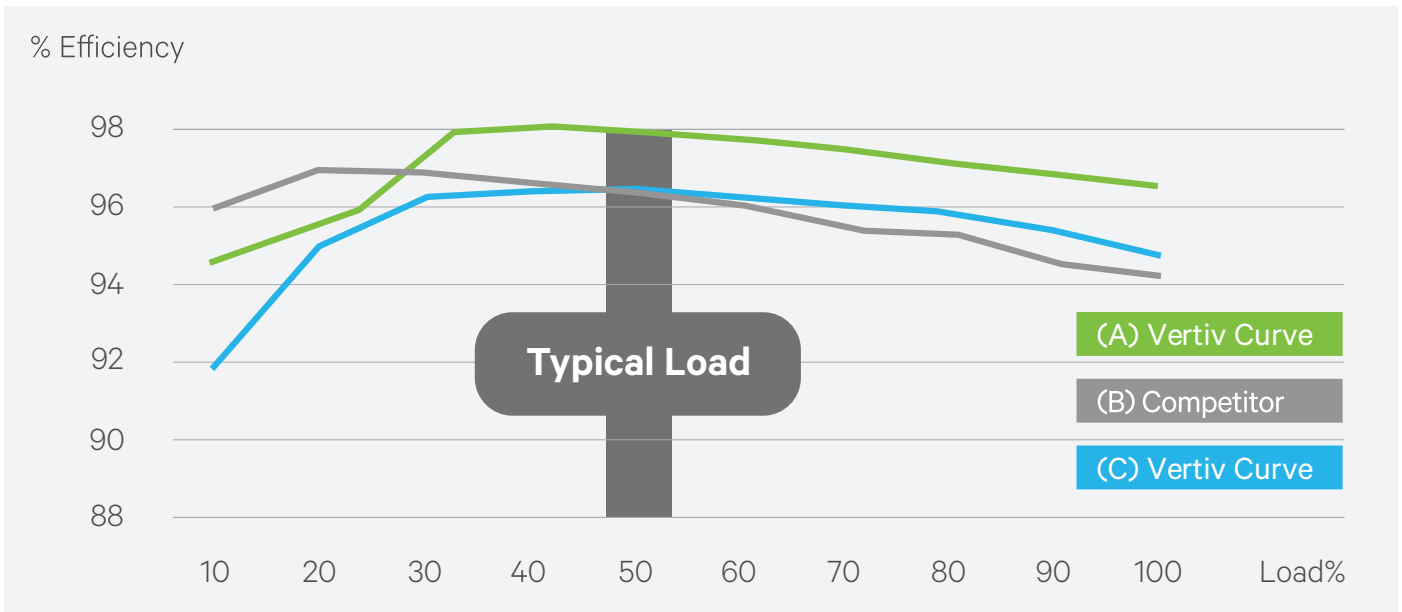


Figure 2: Vertiv Rectifier Efficiency Curves Vs. Competitor

Peak Efficiency Vs. Practical Efficiency

Whether you are upgrading from 92 or 96% efficiency to 98%, beware of making decisions based solely on the peak efficiency advertised. The most important factor when comparing rectifier efficiency in real life is the shape of the efficiency curve. It's imperative that the peak of the curve is close to the load level where the system normally operates.

A peak efficiency doesn't mean anything if it can't really be accessed. Figure 2 compares a competitor's advertised 97% peak efficiency curve (Curve B) with a Vertiv 96% efficiency curve (Curve C). As the curves demonstrate, the 96% rectifier delivers higher efficiency when operating from 50-100% load compared to the 97% rectifier of the competitor. Just as with any advertised efficiency, when considering 98% efficient rectifiers (Curve A), one should review the efficiency curve to understand where the peak is occurring and consider whether it occurs at practical operating load conditions. To help ensure operation at peak efficiency and maximize energy savings, Vertiv has integrated an ECO mode algorithm into our system controller.

ECO Mode – Maximizing Energy Efficiency While Minimizing Investment

The return on investment for high-efficiency rectifiers depends on energy costs, but long-term, there will always be a positive impact and de facto energy savings from day one. That means reduced energy consumption and, in many cases, a lower CO₂ emission level (depending on energy source).

In theory, it is an easy decision to upgrade all sites that currently have less than 98% efficiency rectifiers. The issue is the upfront investment needed. With the demand from owners to show financial results every quarter, it can sometimes be difficult to optimize both long-term OPEX and short-term CAPEX.

This is where the ECO mode function plays an important role. We already highlighted the importance of having a peak efficiency at the load level where the rectifier and DC power system will operate.

With a flat efficiency curve, this is less critical. Most sites will operate with a load of 50% or less most of the time. The remaining 50% or more of available power may be needed for redundancy purposes, peak loads or battery recharge, but it will be used only a fraction of the time. That raises the question: why should we invest in premium 98% efficiency rectifiers if they will only be needed for a very short time? By using ECO mode we can actually minimize this investment. With ECO mode, the system can be equipped with e.g. half 98% efficiency rectifiers and half lower efficiency rectifiers. For as long as the system operates at 50% capacity or less, the controller will put the lower efficiency rectifiers in stand-by mode as illustrated in [Figure 3A](#). When more power is needed – for a peak load, battery recharge or some other reason – as many rectifiers as needed are taken into operation again (see [Figure 3B](#)). During the short process to start up additional rectifiers, the battery bank will safeguard the operation.

The result of ECO mode operation is that the system will run only 98% efficient rectifiers at normal operation. This minimizes energy loss and CO₂ emissions – but with only 50% investment in 98% efficient rectifiers. The savings are obvious when looking at the efficiency curves. [Figure 4](#) shows the difference in efficiency between a system with only 96% rectifiers and a system with a 50-50 mix of 96% and 98% rectifiers. While the mix alone delivers energy savings, the efficiency boost with ECO mode function activated – especially at lower load – truly maximizes the savings.



Figure 3A: NetSure™ system with ECO Mode activated; 98% rectifiers running, 96% rectifiers on standby



Figure 3B: When more power is needed, both 98% rectifiers and 96% rectifiers are operating and sharing the load



Figure 4: Upgrading 96% Rectifiers to 50-50 Mix (96% + 98%) with ECO Mode Activated

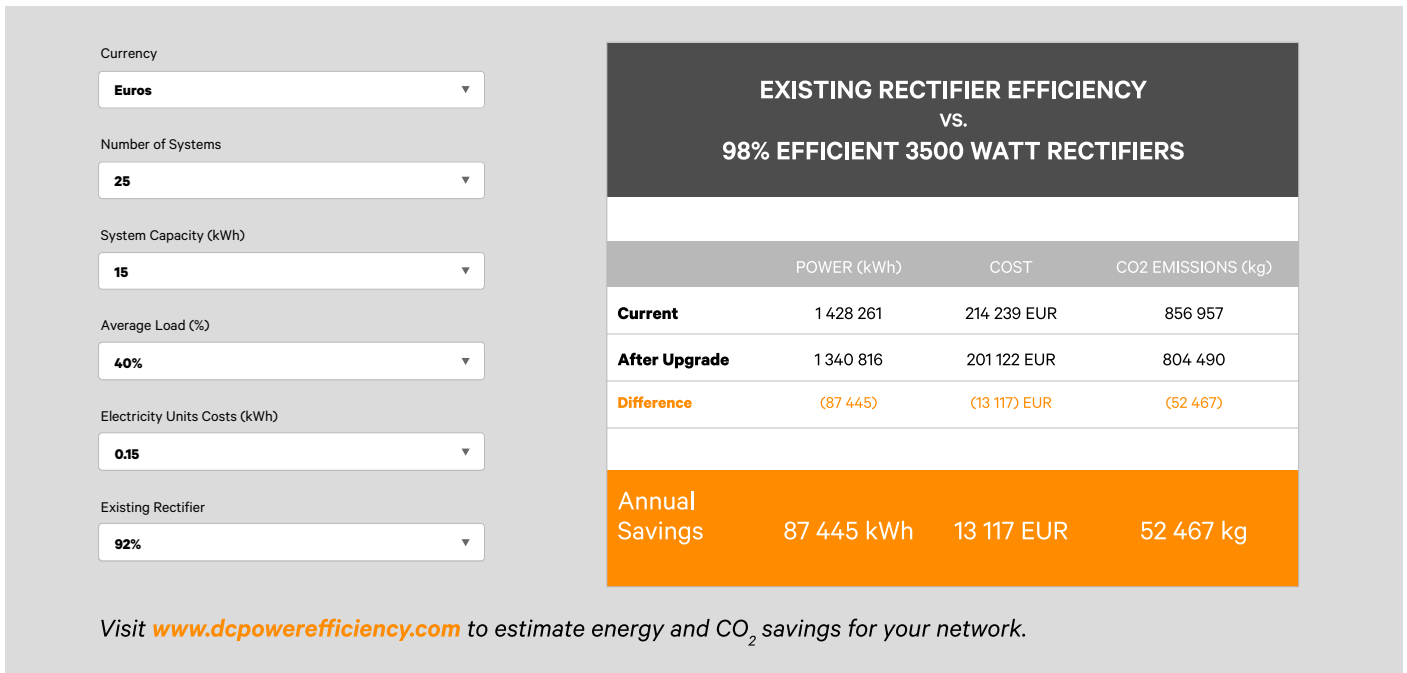


Figure 5: Upgrading from 92% Efficiency to 98% Efficiency

Upgrading to 98% Rectifiers Makes Sense

A significant percentage of all sites worldwide still operate with 92% efficiency rectifiers or lower. These sites waste a substantial amount of power and contribute to excessive heat and CO₂ emissions. It's a good thing from financial and environmental perspectives to change this, but there are many additional reasons why an old power system should be upgraded.

Legacy systems operating in old telecom sites are likely to suffer from one or more of these issues:

- Increasing failure rate when design life is past
- Limited spare parts availability
- Low energy efficiency
- Insufficient power capacity
- Tight floor space

The example in Figure 5 shows the cost of 25 systems equipped with 92% rectifiers and the savings achieved by upgrading to 98% rectifiers. System capacity is 15 kW and average load is 40%. The savings in both energy cost and CO₂ emissions are substantial. The energy cost savings obviously depend on the cost of electricity for each operator and country, but the CO₂ and energy savings remain consistent regardless of locale.

For existing sites with 96% rectifiers, the business case to change out or retrofit is more difficult to make compared to legacy sites with aging rectifiers such as the previous example (Figure 5). In such instances, Vertiv recommends taking advantage of ECO mode and only replacing some of the rectifiers. With a plug compatible 98% rectifier, it's easy to replace some of the existing 96% rectifiers to boost efficiency, save energy and decrease emissions. ECO mode enables existing higher-efficiency sites to deliver attractive energy savings at a minimized investment.

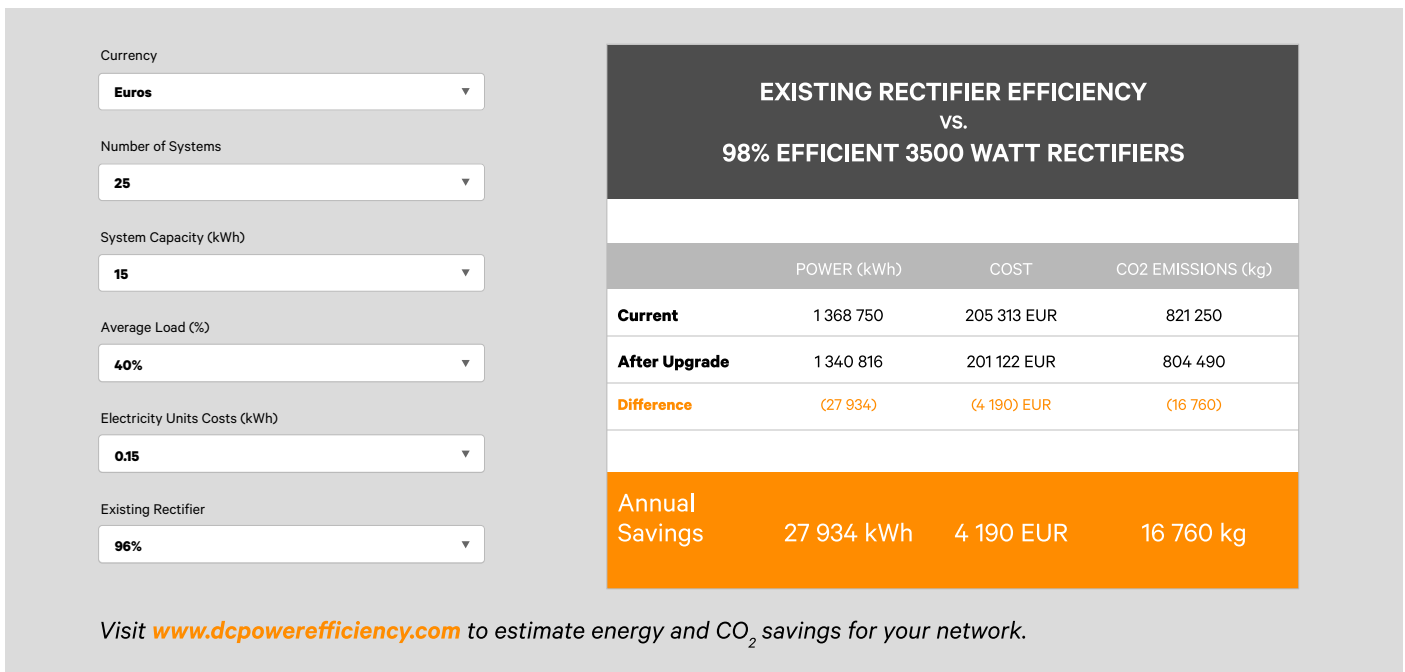


Figure 6: Upgrading from 96% Efficiency to 98% Efficiency

To keep things simple the example in Figure 6 uses all the same input data as Figure 5, except the existing rectifier efficiency is now 96%. Even without ECO mode activated, the savings in both energy cost and CO₂ emissions are still sizable. Whether you're upgrading a core site with large power needs or multiple access sites that require less power, upgrading your infrastructure to 98% efficiency can make a big impact on the environment and your bottom line.

Simplified Upgrade of Existing Sites

For small access sites, sometimes the simplest approach may be to change out the entire power system. For larger core sites, retrofitting rectifiers, controller and other electronics is a viable option. This is because it's costly, risky and time consuming to replace existing systems during operation.

To simplify upgrading with minimal investment, Vertiv has made our next generation 98% efficient rectifier plug-and-play compatible with our existing 96% rectifiers. We are also developing plug-and-play solutions that are backward compatible with earlier generations of our rectifiers. This makes partial site upgrade an easy task. Furthermore, replaced rectifiers can be used as spare parts. In most cases, Vertiv can work with your existing solution to provide a customized plug-and-play retrofit solution.

In a retrofit, normally all DC load and battery cabling can remain intact, while the rectifiers and other electronics are replaced.

The result is a system with a life expectancy and functionality like a new system but with a lower cost and a much lower risk compared to a complete changeout of power systems. Using 98% efficient rectifiers from this point forward will help speed up return on investment and save energy faster.

Tracking the Energy Savings

There is an upfront investment in 98% efficient rectifiers needed in order to minimize energy loss in a power system, but that investment will always result in lower OPEX and reduced CO₂ emissions. To justify the spend, it's important to be able to validate and track the real savings the investment delivers. In some countries, governmentally-sponsored saving programs exist where tax credits are given for certain energy efficiency improvements and emission reductions. To earn these credits, savings need to be properly measured and reported. However, determining efficiency savings is not always straight forward, especially when comparing current energy use to historical trends.

Measuring site load or site efficiency before and after the upgrade will give an indication of savings, but total energy consumption can be impacted by a variety of factors including newly added equipment, site load variations that may change rectifier efficiency, temperature, etc. To get a more accurate picture, Vertiv recommends measuring the actual consumption of the new 98% rectifiers compared to the old benchmark rectifier efficiency (96%, 92%, etc.) at the current conditions.

To make this process easy, Vertiv has encrypted an Efficiency Tracker tool into the NetSure Control Unit (NCU). The operator simply selects the benchmark rectifier from a drop-down menu and the NCU calculates instant savings and trends over time vs. the new 98% rectifier. If the ECO mode function is enabled, the NCU will consider that and will report the higher efficiency. Savings are shown for the last 24 hours, week, month, 12 months and total running time, as illustrated in Figure 7. So, whether you need instant information or trends over a period of time, proper reporting is an easy task.

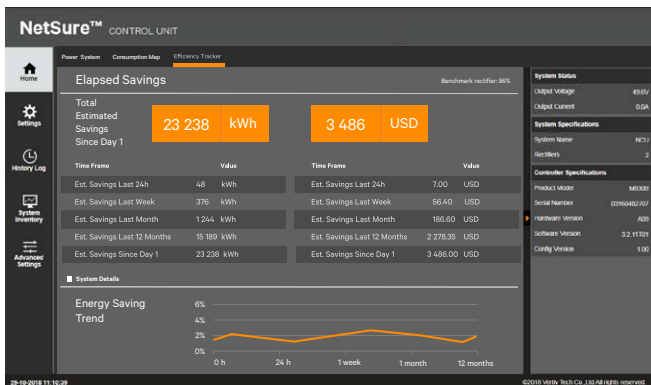


Figure 7: Efficiency Tracker Tool in NCU Controller, depending on region

In addition to the built-in efficiency tracker in the NCU controller, Vertiv has developed an online efficiency calculator at www.dcpowerefficiency.com. Here you can input your existing system parameters to pre-determine how much energy you will save with 98% efficiency. As mobile data generation is only increasing, now is the time to implement an energy efficiency strategy that keeps operating costs under control.

Conclusion

Mobile computing, the proliferation of more robust edge computing sites, ongoing expansion of the Internet of Things, and the onset of 5G networks all are driving massive demand for computing resources closer to the end user. That means more sites, drawing more power, with no signs of this trend slowing anytime soon.

In this environment, energy efficiency is more important than ever. The introduction of a DC rectifier capable of 98% efficiency is a meaningful breakthrough after a decade that saw efficiency efforts plateau at 96-97%.

When you consider the sheer volume of new sites and others facing equipment refreshes, efficiency gains that might seem incremental in the micro add up to deliver significant OPEX savings and reduced greenhouse gas emissions in the macro.

How significant? It depends on a number of factors, but today's technologies eliminate the guesswork by tracking savings and emission reductions to make it easy to calculate your return on investment.

Bottom line: In today's environment, every opportunity to increase efficiency and reduce energy consumption is important. For the first time in a decade, there is a technology breakthrough that reduces power losses up to 50% over a wide load range optimizing CAPEX and OPEX.

