Are we having another War of Currents? Nikola Tesla and Thomas Edison were two of electrical history’s most influential energy-related engineer/inventors. Their battle in the 1880s brought about controversy of AC vs. DC power transmission (See my article on EDN). Of course we all know how that turned out when we turn on a light in our home or even charge our Smart Phone or Tablet (Oh those ugly, inefficient wall warts!)

So much of what we have in industry and in our homes is powered by DC (Just look at what powers the ICs in 99.9 % of our devices, appliances, etc.) Plus we can eliminate inverters in UPS and PFC correction in AC power supplies which means better efficiency. Copper is expensive and transmitting at higher voltage means lower current so less copper is needed in transmission lines.

Compared to regular -48V DC, 400V DC reduces copper wire by up to 80 percent, reducing costs in installation and operations. (Image courtesy of Emerson Network Power)

It certainly appears the War of the Currents may not be over yet. But instead of continuing in a heated AC vs. DC battle, it looks like the two currents may end up working in parallel to each other in a sort of hybrid solution. (Tesla and Edison may now rest in peace)

Some key programs leading the charge
The Emerge Alliance, a member of the U.S. Green Building Council, is at the forefront of the effort to develop standards that will lead to the adoption of DC power distribution in commercial buildings.

I really like their vision of DC microgrids dispersed throughout commercial buildings (Starting with commercial buildings where DC can make the most difference in efficiency and I hope this effort will move to our homes as well) as a means to better efficiency by eliminating the energy loss in the AC to DC power conversion elements to power DC devices. See Figure 1.

Figure 1: The Emerge Alliance addresses Occupied Space with a 24 V DC microgrid; Telecom Data Centers with a hybrid approach of AC and DC power; Outdoor for lighting, signage and EVs and Building Services for loads like HVAC, motors high bay/industrial needs. (Image courtesy of Emerge Alliance)

The EU DC Components + Grid (DCC+G) project

The project, which began in 2012 and is funded with 18 M Euros, will end in 2015. They believe that the drawbacks of solely using the AC grid can be improved by changing to a mixture of AC and DC sources for electricity distribution in buildings.

Counting on recent advances in semiconductor technology, nanoelectronics and software will help manage the combined AC and DC distribution inside buildings. This effort and others like it will foster research activities in current sensors and 1.2 kV micro-pattern trench IGBT technology to make 380 V DC reliable, cost attractive and energy efficient.

California Public Utilities Commission (CPUC)

In 2013 the CPUC began an energy storage goal of 1.325 MW for the Pacific Gas & Electric Company (PG&E) by the year 2020. Storing energy means having today’s AC power converted to DC through rectification and storing in some sort of battery or other storage device. Then, when that stored energy is needed, re-convert that DC to AC through a power inverter. A better way is the Bi-directional power inverter. Quite a waste of energy---DC Power distribution would help immensely here. A bi-directional inverter is typically used for this process.
The Power players

In my experience, there are a number of key Power companies with an extensive group of power management solutions for DC Power Distribution in the industry. EnerSys created the OptiGrid Stored Energy Solution for just his purpose.

Vicor Corporation

Vicor kicked off their major efforts with a 2012 live demonstration, along with Emerson at the Intelec and Electronica shows in Europe that demonstrated how practical it is to use a higher DC voltage for distribution which improves the efficiency of converting and managing power from the DC distribution center to the load. I believe that 400VDC to Point-of-load (POL) conversion is Green Energy’s future.

There is still some difference of opinion between standards bodies as to the definition and range for levels of high voltage DC transmission. The ETSI EN 300 132-3-1 voltage range of 260V – 400V DC is one opinion. The IEEE Power & Energy Society (PES) says:

Standards bodies in Japan, Europe, and North America have blessed 380-V circuits for distributing dc power within commercial buildings. These promise to reduce losses in buildings with large and sensitive electronic loads, such as data farms, by centralizing rectification and also eliminating the wasteful cycle of inversion and rectification that is otherwise needed to charge their battery backup power supplies.

Figure 2: Mainstream industry applications range from 270 V to 800 V (Image courtesy of
Vicor is using the 60 V to 1 kV range as their target for solutions in the high voltage realm. Stephen Oliver, Vicor VP of the VI Chip Product Line, makes a statement about the utilities transmitting via DC power lines vs. the situation within equipment seen in Figure 2:

*Utility companies, however, have a completely different perspective: the grid is adopting DC power transmission for long-distance links because it is more economic than AC. Using DC also makes it easier to interface the inherently DC outputs of renewable power such as wind and solar. But the voltages used in the electrical grid are hundreds of kilo volts and transmit thousands of megawatts.*

You can view Oliver’s video presentation of [Strategies for High Voltage DC Distribution](#) on Vicor’s website.

Take a look at how Vicor solutions work off the 380 V DC line to convert and adapt to many architectures in Figure 3.

![Figure 3: Typical applications using Vicor solutions on the 380 V DC bus going into the High Voltage Bus Converter Module (HV BCM) and being converted to 48V to the load or through a PRM® Module, a family of zero-voltage switching (ZVS) buck-boost regulators or even one more step through a VTM®, a family of Point-of-Load (PoL) current multipliers which operate from a primary bus to deliver a wide range of isolated outputs. A proprietary ZCS (Zero Current Switching)/ZVS (Zero Voltage Switching) Sine Amplitude Converter™ (SAC™) topology provides the capability to transform input voltages down to fractional voltages very efficiently](#)

Vicor also has a wonderful, insightful collection of [video webinars](#) as well as tech documents on High Voltage DC (HVDC) Distribution and Power Conversion on their website.

**Ericsson Power**

**Ericsson Power**

Patrick LeFevre, from the Ericsson Power Modules group, has contributed some really good insight into “Stepping Down From the 380V DC Line”. Since there are so many step-down options available as well as maybe an intermediate bus voltage, how do we choose?
Some possibilities LeFevre suggests are to convert down to 48 V DC, the standard telecoms main, which exists worldwide with a huge amount of infrastructure in place today. But what about systems that would be better suited for 12 V DC (a commonly used telecom intermediate bus voltage)? An example of this type of equipment is in 19” rack system architecture.

![Image](data-center-hvdc.jpg)

**Figure 4: The Data Center is an excellent example of a case where HVDC makes sense**
*(Image courtesy of Ericsson Power)*

Next, LeFevre comments, how do we go from 400 V to 12 V with maximum efficiency while also meeting isolation needs? Multiple steps via 48/54 V? Or should we instead be addressing the needs of processors, ASICS and FPGA types of 1 V and below needs at high current? Can we effectively do this from a 400 V line?

We do hope to see some standard consensus by industry leaders soon.

**Infineon**

A modern transmission system needs adequate and modern electronics.

- **Voltage Source Converter High-Voltage DC-Transmission** (VSC-HVDC)
- **Line Commutated Converter High-Voltage DC-Transmission** (LCC-HVDC)
- **Ultra High-Voltage DC-Transmission** (UHVD)
- **Flexible AC-Transmission Systems** (FACTS)

These solutions significantly reduce losses in long distance power transmission, enable the integration of more renewable energy and ensure high power quality.
Figure 5: Thyristors have dominated this Transmission and Distribution application for many decades. Nowadays thyristors as well as IGBTs are used in HVDC systems and FACTS to fulfill different needs. Especially grid access systems for offshore wind farms far away from the coast require the turn-off capabilities of IGBTs. Thyristors are targeted at bulk power transmission, such as UHVDC systems with up to 800 kilovolts. (Image courtesy of Infineon)

Siemens

What does Siemens bring to the HVDC party?

The next generation of HVDC called HVDC Plus. See Figure 6.

Figure 6: HVDC PLUS reduces the time and resources expended during the project development phase. The relatively low number of components simplifies design, planning, and engineering tasks. Thanks to the modular design with fewer elements than Conventional HVDC systems, installation and commissioning also require considerably less time and less space than conventional systems. (Image courtesy of Siemens)

Emerson

Figure 7: Emerson Network Power 380 VDC Systems Roadmap (Image courtesy of 2013 interlec conference presentation by Emerson Network Power, HP, Juniper Networks, Vicor and StarLine DC Solutions)

BJ Sonnenberg, Manager Business Development, Emerson Network Power and David Geary, Director of Engineering, StarLine DC Solutions have details on the topic of 380V HVDC Datacenter Infrastructure: An Engineering Perspective

HP
Fraunhofer Institute

Professor Lothar Frey, Director of Fraunhofer IISB, says this regarding the present Power Distribution System through to electronic devices:

Changes will have to be made on numerous levels, from the major European power grids and the distribution networks to factories, homes, and electric vehicles. When you think about it, the way we do things today is crazy. Electricity is supplied by the grid at 230 volts and used to power electronic devices such as computers, printers, TVs, hi-fi systems and fluorescent lighting. Almost all of these devices have their own internal power supply unit (PSU) that converts 230-volt alternating current (AC) into the direct-current (DC) voltage required by the device. Because these PSUs are usually made of cheap components to minimize costs, their conversion efficiency is relatively low – in other words they transform part of the electricity into unwanted heat. This is a huge waste of energy.

A recent [Fraunhofer press release](#) states:

Electrical losses from connecting electronic devices to the AC grid supply via a PSU are 40 to 80 percent higher than if they were connected directly to a DC supply. Moreover, the internal PSU makes the devices bigger, heavier, and more expensive.

It would make more sense to convert the 230-volt AC grid supply into direct current at a central point inside the building and then provide DC power to specific circuits and types of load at, say, 24 or 380 volts. Furthermore, an increasing number of buildings are now equipped with solar panels, which natively generate DC. Rather than converting their output into AC, as it is now, it could be input directly to a DC network. The same applies to the DC output of solar storage batteries.

Please view this [webinar](#) from Vicor’s website on 380V HVDC in Commercial Buildings and Offices by Dipl.-Ing. Bernd Wunder from the Fraunhofer Institute.
The controversy

Although I do believe that DC power distribution will improve in efficiency over the next few years and that it will ultimately be some combination of AC and DC power that will win out, I want to provide a balanced view of this topic of AC vs. DC distribution. A white paper by The Green Grid and APC by Schneider Electric challenges the 30% claims of Data Center efficiency improvement using DC over AC power. Schneider Electric claims only a 0 to 1% edge for DC. Eaton published a paper as well regarding problems with DC. See References 1, 2 and 3 and a Data Center Journal article by Jeff Clark and give us your opinions by commenting on this article so the EDN audience can discuss this in an open forum.

Conclusion: The compromise

So put your differences aside Tesla and Edison fans—Without both of these men, who were ahead of their time, we would not be having the immense opportunity of the best of AC and DC power transmission because of their works of genius in these areas of Electric power. We will certainly see a way that AC and DC power distribution can finally be morphed into a single solution using the benefits of both methods. Stay tuned for some pretty rapid progress in this area in the very near future.

References

1 A Quantitative Comparison of High Efficiency AC vs. DC Power Distribution for Data Centers, Neil Rasmussen and James Spitaels, White Paper 127, 2012


4 High-voltage DC distribution is key to increased system efficiency and renewable-energy opportunities, Stephen Oliver, Vicor Corp., Vice President, VI Chip Product Line, 2012

5 Bi-Directional Inverter and Energy Storage System, Derik Trowler, Bret Whitaker, University of Arkansas, May 2008, TO Analog Design Contest submission
High-voltage DC distribution is key to increased system efficiency and renewable-energy opportunities

Has Thomas Edison ultimately won the DC vs AC power transmission controversy against Tesla?

DC Power Gains Footing in Data Centers

DC distribution in your house and 42-V cars

Vicor Corp VIB0002TFJ: Bus converter completes power-train conversion in dc-distribution data centers

New DC power distribution scheme aims for greater data center efficiency

Case study: DC power uses 15% less electricity than AC power system

How do we get to a DC-powered home?

Echola Systems Introduces 380V Direct Current Smart Power Distribution Units for Energy-Efficient Data Centers