

What Does A Telco Need for 400 VDC To Find A Place In The Central Office

400 Volts: Even though the technology isn't quite here yet, it's not just for data centers anymore

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Abstract / Digest

There's little doubt that 400 volts (nominal) is coming. Which architecture wins the race depends on the lifecycle cost of deploying the system. Very clearly, one of the weightiest factors in total cost of ownership is the system end to end efficiency. The number of power conversions figures mightily in overall efficiency. Since most electronic circuit boards utilize 5 volts, 12 Volts or some similar potential, virtually all electronic systems employ a power supply to convert whatever is the supply voltage to the board level voltage(s). For data center systems the source voltages are 120 VAC and 208 VAC or other potentials depending on where in the world the systems will be deployed. The development of embedded dc to dc converters that will convert a nominal 400 volts dc to server board level voltages paves the way for high voltage dc data centers and as of this writing it's believed that such soon will be the case.

The advantages of such a topology are well known to those who have been around INTELEC for more than a few years. Improved end to end efficiency through reduced power conversion stages plays a major role in reducing the overall energy cost and environmentally, the carbon footprint. Not only is the cost of powering the electronics tamped down, but also the cost of cooling the facility. To paraphrase Mr. Mayagi in the movie Karate Kid the line "Wax on, wax off" to teach his young student Karate while waxing a car. In our world, Watt in, Watt out becomes the watchword for controlling environmental cooling costs.

With all that said, in discrete numbers there aren't all that many data centers in the world as compared with the plethora of telecommunications central offices. Therefore, improving efficiency and reducing the cost of power systems feeding the telecommunications network – including central offices might just be the Holy Grail of the telecommunications energy business over the next decade or so.

The commodity cost of copper aside, the sheer volume of cable, the space it takes up and the effort needed to install and one day remove it all result in a fairly high

lifecycle cost of the traditional 48 volt energy system. Further, as will be shown herein, providing a high voltage dc potential and then converting it to an intermediate 48 Volt potential comes at a very high operating cost for "extra" conversion equipment and the energy lost in converter inefficiency and added cooling cost.

What's new really isn't all that new

As a practical matter, higher than 48 Volt systems with intermediate converters stages has been used in telecommunications long before now. During the 1970's the AT&T Network Systems #4ESS® switching system was a Tandem switch powered by a +140Volt system that was called the 415A Power Plant at the time. The 415A plant employed a 70 cell Vented battery floating at 2.17 Volts per cell for a bus voltage of 152V. The intent of the higher voltage was to reduce the density of copper conductors between the power plant and the switching system – a key driver in today's high voltage architectures.

The switching system itself utilized mostly 48 volt technology but it also used 24 volt and 130 volt powered subsystems. Accordingly, the basic topology of the power system was to cable-bus 140 volts from the power room to a bulk 140 to 48 Volt dc to dc converter plant located with the switching equipment. Rather than develop 140 to 24 or 130 Volts for the subsystems that needed those potentials, conventional off-the-shelf 48 to 24V and 48 to 130 Volt bulk dc to dc converters were collocated with the 140 to 48 volt converters and embedded converters in the various network elements converted the input source voltage to the required potential – usually 5 Volts or 12 Volts. Figure 1 is a block diagram of the topology used for that system.

As is readily evident in the sketch, 48 Volt systems "saw" transformer losses plus 3 power conversions between the building Service Entrance and the electronics that ultimately would consume the power. The 24 and 130 Volt subsystems would "see" perhaps four or in some cases five power conversions plus the transformer losses. Given the efficiency of power

conversion equipment at the time, this topology was somewhat lossy and increased the cooling load. While the architecture did in fact save some first-cost money by reducing the amount of copper needed between the power room and the switch room, the lifecycle cost was high. Also, the more conversion equipment placed between source and load the more points of failure exist in the system sacrificing reliability to some degree.

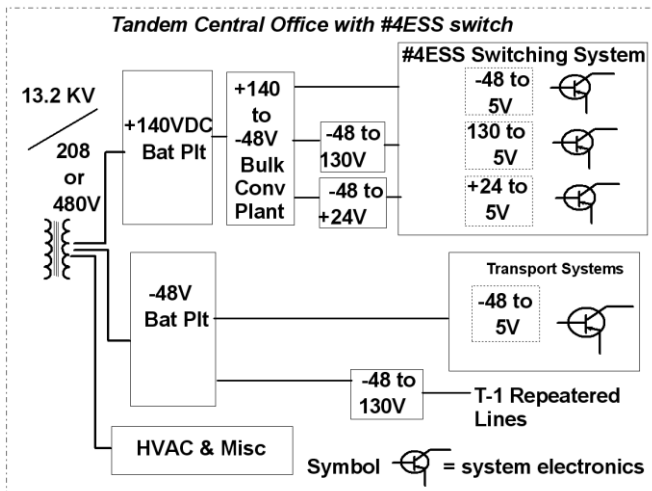


Figure 1 The #4ESS power topology used intermediate dc to dc converters which reduced copper cabling but consumed more energy due to conversion losses

Virtually any system topology that relies on intermediate dc to dc converters is doomed to repeat the inefficiencies realized in the 1970's system illustrated above.

Wizard wars

In many ways it's like our industry is reliving the 1880's ac versus dc "War of the Currents" bitterly waged between Thomas Edison and Nikola Tesla, (then employed by George Westinghouse). History tells that at one point, Tesla worked for Edison but quit after Edison, allegedly reneged on a promised bonus. Tesla then hired on with George Westinghouse who provided backing for Tesla's legendary ideas about ac and high voltage power distribution to reduce the required wire size for transmission and to eliminate the network complexity.

Ultimately, Tesla's design proved substantially less expensive to deploy and the world's power distribution network evolved around his fundamental design principles.

The decades long dc plant versus ac UPS data center battle has been a hard-fought one and given the reliability shown for dc, the potential is winning that battle. The key to making dc cost effective for data centers and for telephony is to keep the reliability but reduce the cost and so now, the argument is over which dc voltages and how best to deploy them.

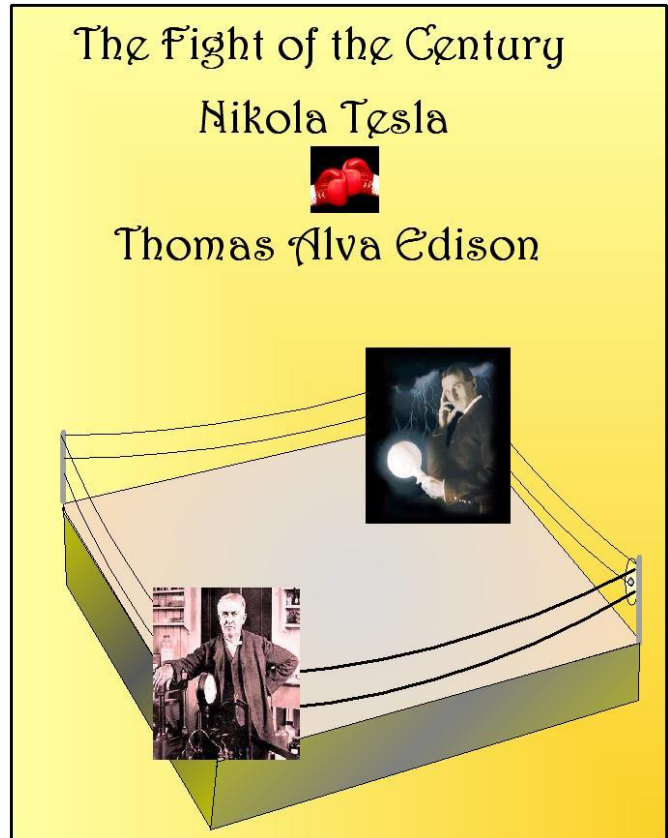


Figure 2 The dc plant versus ac UPS isn't terribly different from the hard fought "War of the Currents" waged between Nikola Tesla and Thomas Edison in the late 1880's

Today, companies are developing effective technologies that would create a nominal 400 Volt dc battery plant probably running at 384 Volts to the load and feeding that potential directly into data center servers where embedded converters would reduce the voltage to the board-level potentials needed by the electronics. This is a simple and efficient design, free of the intermediate conversion stages that add operating cost to systems that resurrect the #4ESS power architecture mentioned above and simply using higher voltages.

As is mentioned herein in the Digest, the number of central offices in telephony is huge compared to the number of data centers, developing a telecommunications central office topology utilizing this new architecture would reduce the deployment cost of 400 Volt systems by increasing dramatically the scope and scale of mass production.

For the 400 volt topology to become a ubiquitous potential for central office deployments, the real issue lies in creating embedded dc to dc converters that will accept the high voltage dc input and produce telecom circuit board level potentials in one fell swoop. Additionally, there also is a need for the related components that would distribute the 400 volt potential in the central office environment in a manner that is safe and cost effective. Finally, the overall system needs compatibility with the exacting requirements for Grounding (Earthing) in the central office to assure safety and network reliability.

Safety

Speaking firstly to safety, there is no good reason to think that 400 volts can't be deployed in an environment where technicians have become used to potentials that are touchable. Over the years open power board architectures have given way to dead-front architectures and busses and battery intercell connectors are often covered with insulating covers. These architectures are safer because they reduce the number of electrical faults caused when people drop conduits, light diffusers, tools, paint cans and other conductive items onto energized equipment. The trick is to develop or deploy power distribution architecture and hardware able to provide for a safe connection interface between the 400 volt systems and the telecommunications systems.

Beginning with the source, one concern about 400 volts as a central office potential is the possibility of lethal electrical shock. One beauty of dc is that when human tissue comes into contact with it, the tendency is for muscle contractions to let go and move people away from the potential. This is advantageous as compared with ac where the tendency is for the hands to grab onto components when being shocked. Accordingly, dc is considered safer than ac for electrical potentials capable of shocking human beings. What else can be done to build safety into the system?

When one side of a 400 volt circuit is grounded, the other polarity is potentially lethal with respect to that ground. Why not halve the available potential by grounding the mid-point of the 400 volt system (Figure 3)? As a practical matter, a mid-point ground isn't really new to telecom. Since the mid 1960's the repeatered span lines for T-Carrier multiplexed systems are powered by simplexing energy out from the central office across the cable pairs that also convey the digital bitstream. For long spans, 260 volts was used to provide the needed power but due to the architecture deployed there was only 130 volts to ground out on the spans. This was achieved by using two 130 Volt power sources, one with the positive (+) side grounded and one with the negative (-) side grounded (Figure 4).

Similarly, 200 volts to ground is much less problematic from an electrical shock hazard and also from an arc flash perspective than is 400 volts. Therefore, a center tapped battery makes sense for this application. Obviously, it makes sense to provide insulating covers over all Intercell connections and termination plates in accordance with NFPA 70E and other applicable safety standards.

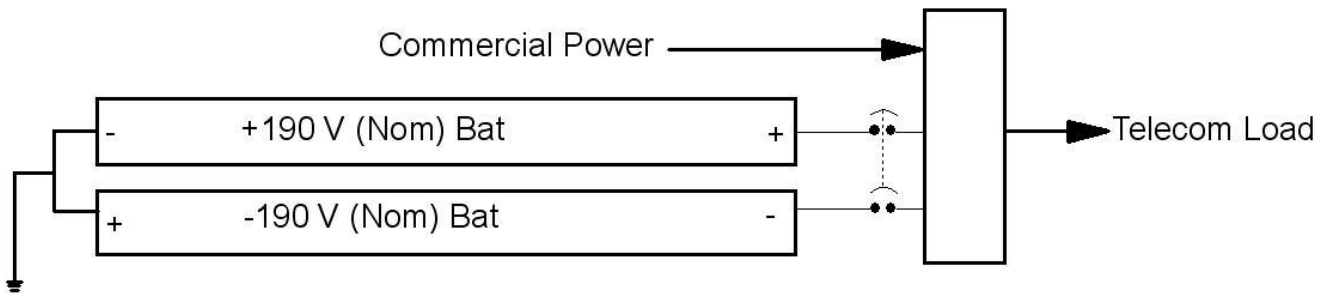


Figure 3 A center tapped battery offers a relatively safe approach to 380 Volt power.

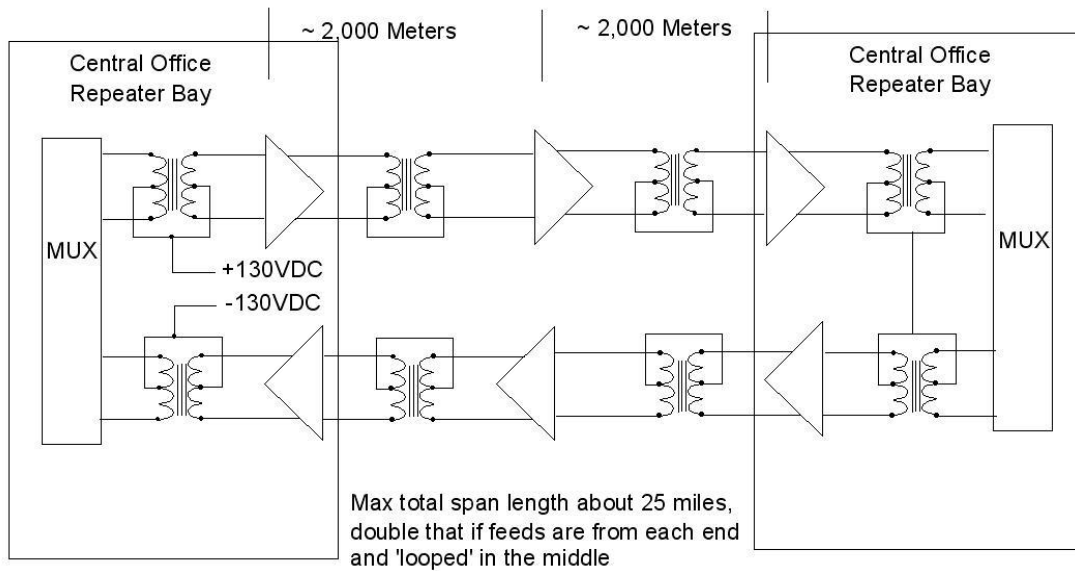


Figure 4 The erstwhile, Simplex copper T-1 Repeater line, now in service for approximately 45 years has been a reliable architecture for safely reducing the available voltage to ground for technician safety.

Establishing a 400 Volt power scheme in an existing base of central office equipment would have to rely on a safe, seamless migration strategy that leaves no room for error, either at the time of the migration or later in time. It is likely that for an extended period of time – perhaps years - both the 400 Volt and 48 Volt systems will be in service. One critical requirement is that there may be no path for a 400 Volt feeder to feed through some piece of equipment to the 48 Volt bus. Accordingly, isolation is critical to success.

Most telecommunications equipment relies on the ubiquitous -48 volt rail. Within the equipment itself at the circuit level, the system typically runs on 5 volts, 12 volts and sometimes as much as 300 Volts dc for line insulation tests in wireline systems. For most systems, embedded dc to dc converters are used to convert 48 Volts to the secondary voltages required by a particular system. In most cases, one or more such ‘power units’ are plug-in circuit packs and the power input and output connections and any control, monitoring or alarm leads all connect via pins that deliver power etc to a backplane that distributes that power to other circuit boards on the shelf (Figure 5).

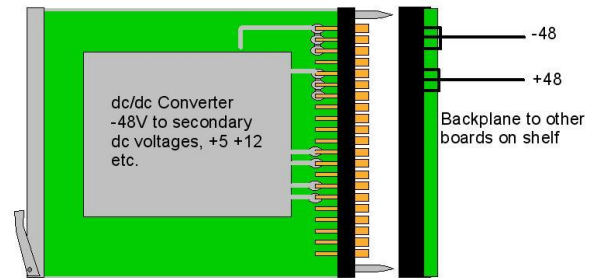


Figure 5 Using an embedded converter ‘brick’ telecom equipment manufacturers can readily develop new and legacy system retrofit power supply boards to utilize the 400 Volt topology

One approach to a dc power migration strategy is that a “400V “brick’ power supply from manufacturers might receive a wide audience from telephone equipment OEMs who would need to develop only one circuit new board to make their product line amenable to either 48 or 400 Volts (Figure 5).

This new circuit board might have the input 400 V connector on the front faceplate of the board and have no connecting pins going back into the rear socket where 48 Volts once inputted. With such an approach, the 400 Volt distribution wiring could be placed above equipment aisles to be migrated. In

order to complete the migration, a simple power-down procedure followed by the replacement of the power unit with a 400 Volt model and then a power-up procedure and the job is done. For equipment with A&B input power supplies, the cutover could be accomplished with zero downtime in the system. It's critical that any embedded converter intended for telecommunications use have the high levels of input / output isolation (Typically 1,500 Volts) as is specified in existing telecommunications power system criteria. One reason this isolation is necessary is for a new power system to operate in harmony with the bonding and grounding systems presently used in

the telecommunications network as it exists today on 48 Volts. This especially is true if systems will migrate between the new 400 volt architecture and the legacy 48 Volt system. Between initial deployment and full rollover both power sources will be feeding network elements in the same community of network elements. This time period easily might be measured in years and therefore differences in potential that might influence the 'noise floor' of the power busses must be minimized in order to retain network reliability. The good news is that achieving such levels of input / output isolation is not all that expensive or difficult anymore.

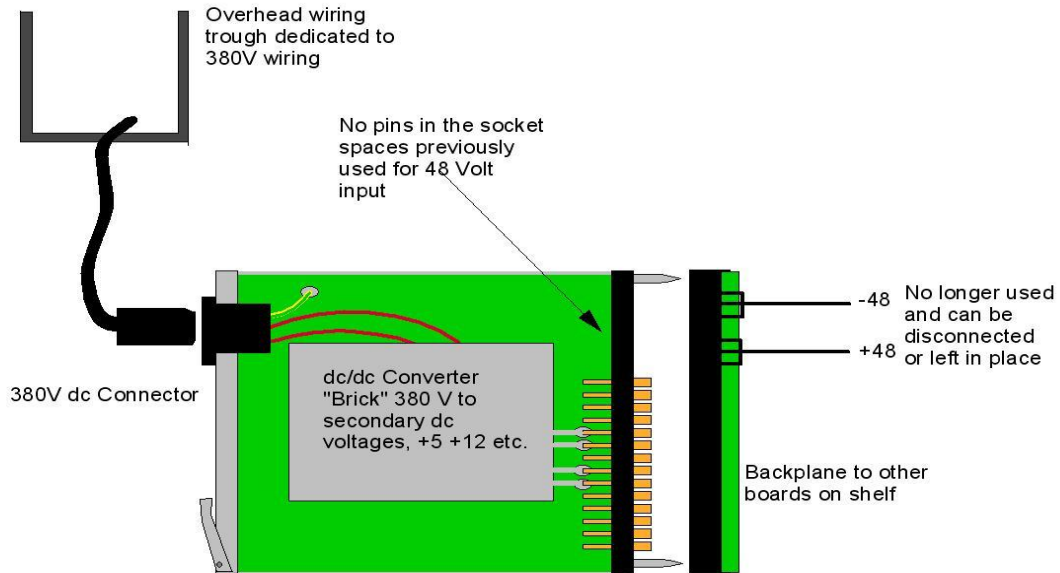


Figure 6 Using an OEM manufacturers 380V “Brick” a broad number of telephone equipment manufacturers could make a one board solution for their systems to operate either on 48Volts or 380 Volts.

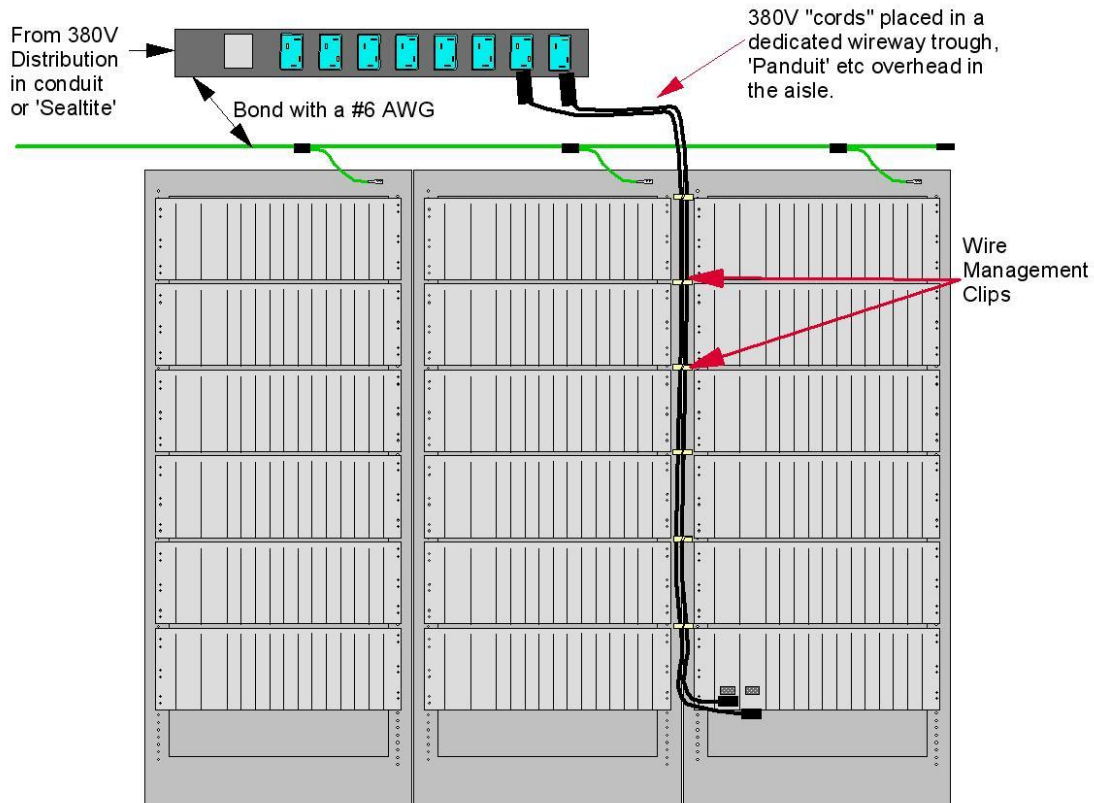


Figure 7 A 380V plug distribution module could be placed overhead and cords of appropriate length placed in a wiring trough and then down to feed the front of a bay. (not to scale)

A system friendly, low drama rollover strategy would make the 400V architecture a shoe-in technology for central offices that had major growth imminent. One could power the new equipment with 400 Volt technology and then rewire ancillary equipment that previously was served by 48 Volts. Or, one could power the new network elements and any growth from the 400 Volt plant and allow the 48 volt load to reduce through attrition.

Another hybrid 48V 400 V topology is that of the A and B power plant. A number of companies feed systems that have diode ORed embedded converters with dual dc power plants. Sometimes these plants are called 'Red and Blue plants' because the two are color coded with output cabling to help avoid A/B loading mistakes. There is an added level of reliability (at some cost) to feeding systems this way. Figure 8 is a block schematic of that topology.

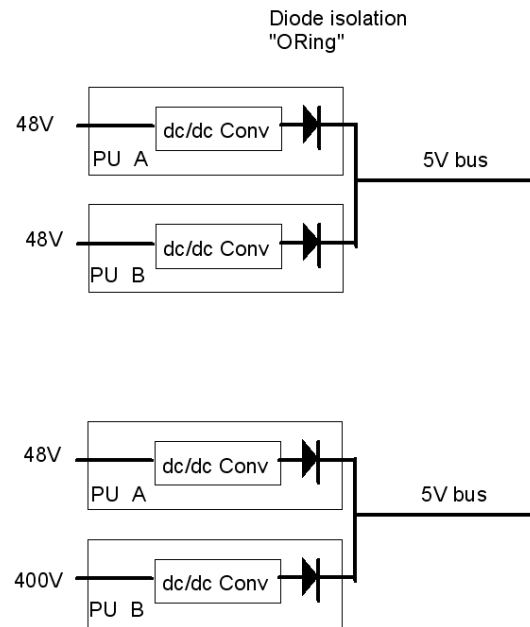


Figure 8 If separate 48V power plants can feed diode ORed switching equipment, why can't 400 V and 48V dc plants operate in the same manner?

Using a 400V / 48V topology for A Plant B Plant (or Red plant Blue Plant) operation would reduce the space, cost and complexity needed for such an operation. An existing switch could inexpensively be upgraded to 400 / 48 Volt operation, freeing 48 Volt capacity thereby adding growth potential and at the same time improving network reliability. Because there were dual plants, one could afford to reduce battery capacity without affecting reserve time and also, with the 48V plant perhaps using vented battery strings, less expensive and space intensive VRLA cells could be considered for the 400V plant further reducing cost and battery ‘footprint.’ The topology might look like Figure 9.

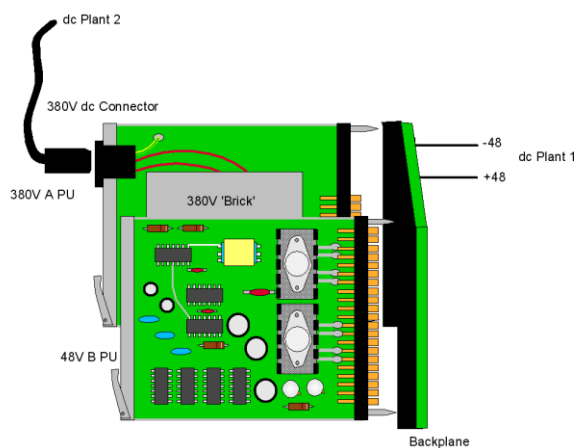


Figure 9 parallel diode-ORed power units, one fed by 48V and one by 400V would achieve a dual plant operation at less cost and cabling complexity than two 48V plants.

It’s likely that there will be ancillary equipment for which no 400 Volt embedded power supply is available. Additionally, as a central office migrates to 400 Volt dc power, and load decreases on the 48 Volt battery plant, central office engineers will be faced with operating an underutilized battery plant, or replacing a large 48 Volt plant with a smaller one or perhaps using a bulk converter plant.

This author believes that a niche market will evolve for a reliable 5 to 10 KW 380 to 48 Volt converter. This parallels what happened in central offices

through the 1990’s as fiber optic cable replaced copper T-1 lines and the number of repeatered span lines dwindled to where it wasn’t cost effective to maintain 130 Volt battery plants. A market was born for 48 to 130Volt converter plants and tens of thousands of such plants were sold. History will repeat itself as 380 Volts deploys around the country.

Figure 10 offers a sketch of such a converter plant. In all likelihood, 5 or 10 KW is a practical size for such a bulk converter plant with individual plug-in modules of perhaps 1 KW each and arranged for N+1 redundancy. A desirable unit would employ a commonly used fuse such as the ubiquitous GMT series for output distribution. Because paper fuse assignment records often get lost in the field, it would be useful if the control and alarm function included memory space to assign fuse records within the board’s memory for display on a small LCD panel and/or a USB connection to an external laptop computer or similar user interface.

From a codes, standards and agency certifications viewpoint, in addition to the usual UL and CSA approvals for US deployments and the ETSI standards for EU deployment, most major US telecommunications carriers will insist upon certification for Telcordia NEBS Level 3 per GR-63-CORE and GR-1089-CORE and also the requirements covered in TR-TSY-001003, Embedded DC-to-DC Converters. Generally speaking, Telcordia’s GR-78-CORE is a well known ‘Cookbook’ for how to design equipment that will pass the NEBS tests.

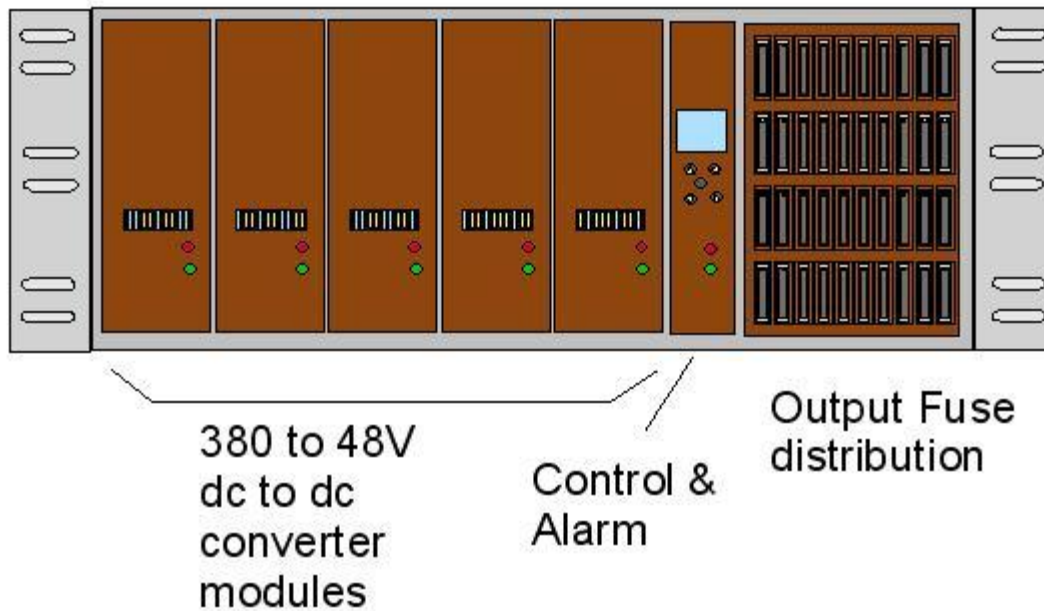


Figure 10 depicts a small, bulk converter plant to convert 400 VDC to -48 VDC for applications where there is only a few minor network elements for which a 400 Volt option is not available.

Conclusions

From the earliest days of the Ford Model T automobile, economies of scale drive mass production innovations that produce direct cause and effect relationships with production cost. Developing a line of 400 volt embedded bricks is key to increasing the demand for the new higher voltage dc architectures and thus reducing the overall energy usage in the network and the carbon footprint. At the risk of sounding like an erstwhile Wilford Brimley commercial, "It's the right thing to do."

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