Case Studies Supporting -48VDC as the Power Input of Choice for Computer Equipment Deployed in the Telecom Network

Dan McMenamin
Specialist - Energy Systems & Equipment Environments
Bell Atlantic Corporation
1050 Virginia Drive
Fort Washington, Pennsylvania 19034 USA
+215-830-0865
d.p.mcmenamin@bellatlantic.com

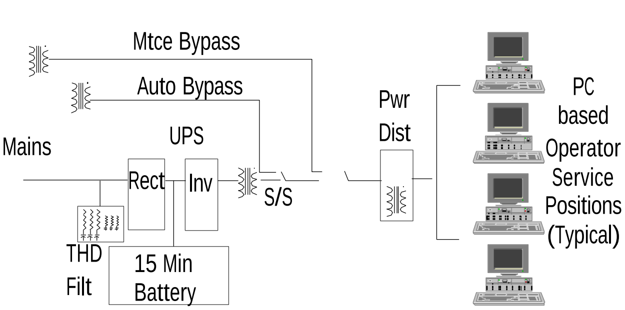
Abstract

This paper will present a number of case studies and technical arguments which support the concept that the -48 volt rail is the source of choice for computer equipment deployed in the telecommunications network.

Computer equipment purchases are an increasing percentage of the engineering budget as data, Internet transport and related systems grow exponentially throughout the word. Traditionally, such systems are equipped with ac power supplies, usually relatively inexpensive switchmode units with little or no power factor correction, or harmonic filtering. Using this topology means an engineer must compensate for this power source by providing a stand-alone Uninterruptible Power Supply (UPS) or provide an inverter and cabling from the 48 volt rail in the central office, equipment hut, or Controlled Environmental Vault (CEV).

This topology is suboptimal because UPS systems are expensive to install and maintain, and because they introduce another point of failure into the system. Energy use increases because power is converted from commercial power to dc, then inverted to ac in the UPS then converted to dc in the computing device. This is at least 3 power conversions and the UPS may have both input and output transformers, which also have approximately a 2% loss in each one.

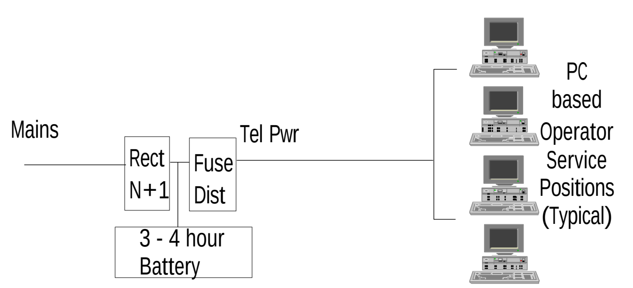
ac-fed topology for an Operator Service Center



In addition to these concerns, the UPS battery, typically, is a relatively short duration source of approximately fifteen (15) to thirty (30) minutes. UPS batteries are typically more fraught with trouble than stationary cells such as thermal runaway, early failure due to cyclic discharge and damage from high ripple currents. UPS batteries are more expensive to maintain and due to their inherently high string voltages, can be dangerous to service.

Inverters fed from dc plants offer some advantages in that the battery is the high capacity telephone source and the rectifiers are arranged for n+ redundancy. Inverters are not without their problems however. These include complicated circuitry, static switches and expensive cabling.

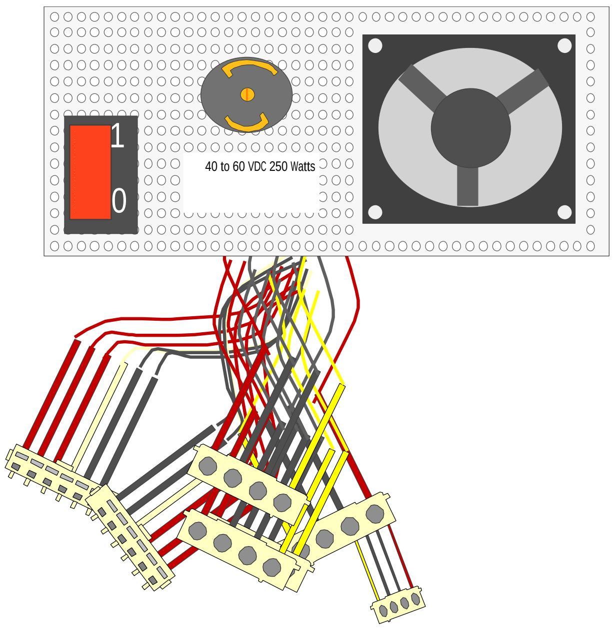
dc-fed topology for an Operator Service Center



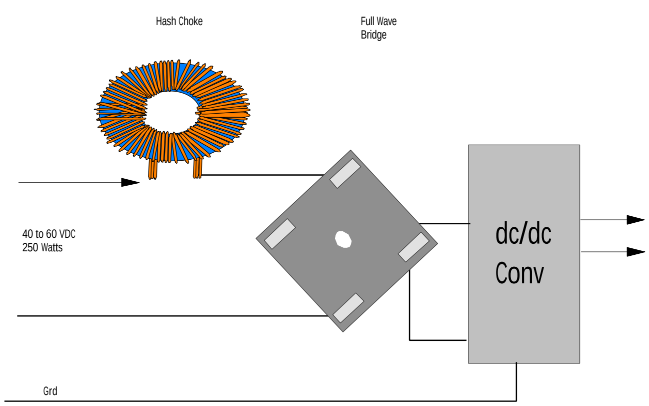
A dc fed system might look as simple as the above sketch. This very simple topology offers higher reliability, lower first cost, reduced energy consumption, and reduced maintenance cost. The key to it is using a dc to dc converter in place of an ac driven power supply in the PC or other computing device. In today's world, there is little reason why a 250 watt dc/dc converter can't be built as a similar ac switchmode power supply.

As a practical matter, the dc/dc supply could, likely, be even less expensive because the power factor correction circuitry would be replaced by a simple toroid "hash" choke, to protect the 48 volt rail from converter generated noise. From a size or weight perspective, there's no reason why a dc/dc converter would be significantly different. The electronics would be about the same. In fact, it's probably simpler to produce the dc unit because instead of a 100 to 240 volt (+ or - 10%) volts at 50 or 60 Hertz, the supply would source on, say, 40 to 60 volts dc.

Power cords might be a simple twist-lock design, offering standardization plus improved reliability because the plug won/t be as easily knocked out. With ac supplies, the plug can fall out easily, it can also be plugged-into an unprotected source by mistake, and different cords are needed for the variety of receptacle configurations around the world.

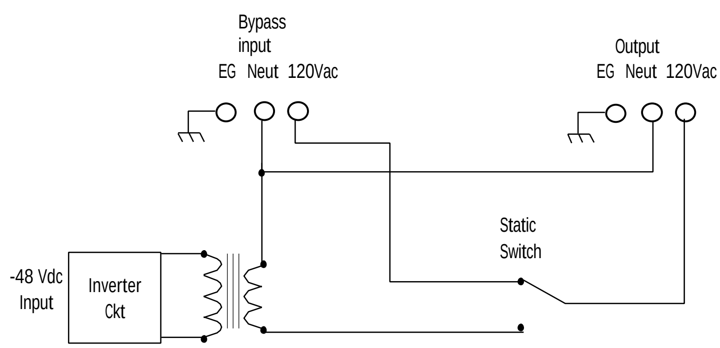


Protecting the input polarity could be as simple as a LED polarized to show reverse polarity. As an alternative, a back-biased diode could operate the overcurrent device or a diode full wave bridge could make the converter independent of battery polarity.

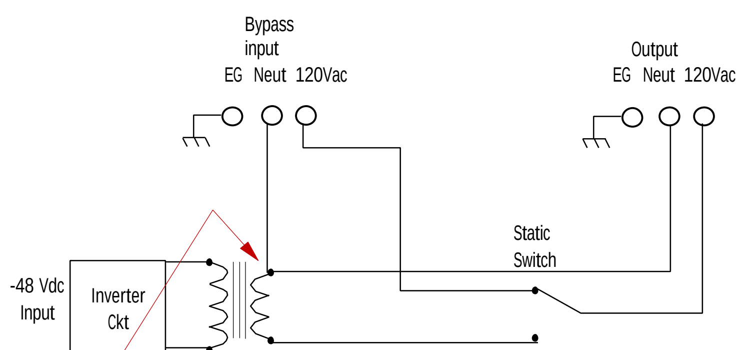


STP failure
An inverter problem contributed to the failure of a Signal Transfer Point switch with ac powered links (similar to modems). A 10 KVA inverter failed in service and went to bypass normally. During troubleshooting, the service technician thought there was a ground-fault internal to the inverter output transformer. According to the schematic in the inverter product manual, the transformer could be fully disconnected without disturbing the bypass path. The inverter, however, was wired slightly differently than the schematic showed.

The bypass Neutral lead and the inverter output Neutral leads actually connected together at a lug on the transformer. When the technician disconnected the transformer leads to perform ohmic tests of the windings, he inadvertently opened the bypass Neutral path, dropping the load. Although STP's are deployed as redundant pairs, a software glitch prevented the mate STP office from taking over and a major service interruption occurred. While the real weakness in the system was the STP software, the inverter problem was an event trigger. As soon as they became available, the ac powered links were replaced by dc powered units to prevent a repeat of this problem trigger.



What the wiring schematic showed...



How the inverter was actually wired...

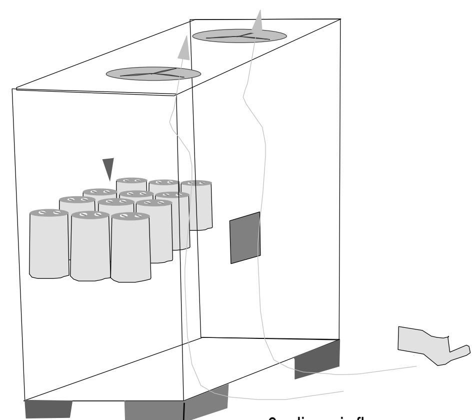
When the technician disconnected the transformer leads, he opened the bypass Neutral path to the output failing the load.

Standby engine system degraded reliability
A 4.5 Megawatt engine system in a Philadelphia central office was found to be dependent on ac powered programmable logic controllers for proper operation of the paralleling switchgear. For a measure of protection, three small 200 watt UPS units were installed in the switchgear cubicles. As designed, an UPS failure could have prevented the standby engine from operating. Given the legend unreliability of VRLA batteries and small UPS systems, this was deemed very undesirable. A pair of dc powered inverters were placed in the cubicles to provide logic controller power. Dc powered logic controllers would be even more desirable.

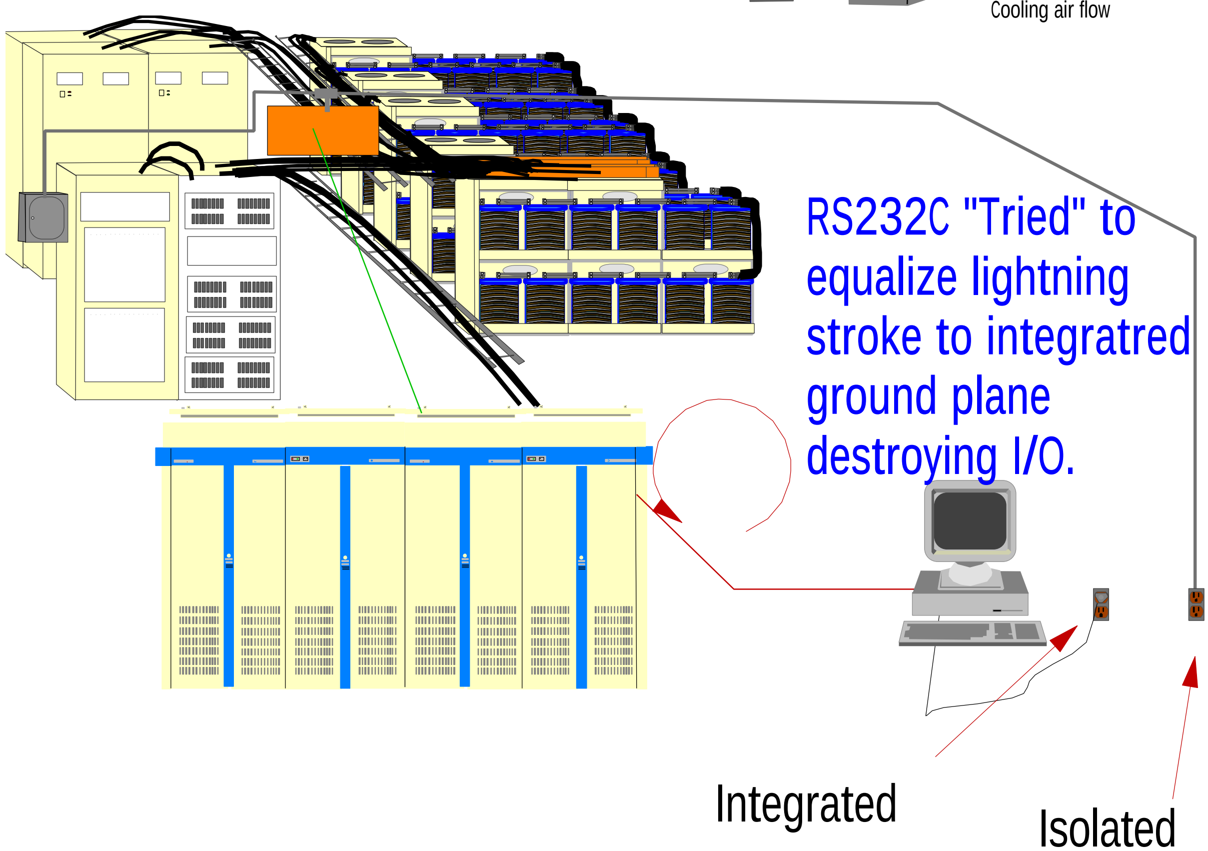
Switching failures during lightning
In two southern Delaware central offices, ac powered maintenance terminals were plugged into the wrong receptacles resulting in a violation of the single point ground system. Lightning strikes caused problems as a result. In both cases, the office maintenance terminals were plugged into the integrated ground plane. This resulted in an isolated ground plane single point-ground failure via pin 1 of the terminal serial ports to the input/output (I/O) port in the switch. In both cases the I/O frames sustained damage.

While a number of “fixes” would have prevented this problem, dc powered maintenance terminals would be desirable because the office would not need an expensive, maintenance-intensive inverter and the grounding architecture would be simpler.

Police 911 (enhanced) system failure
An aluminum foil chewing gum wrapper, sucked up by cooling fans and into the capacitor bank of an UPS system caused the failure of directory number look-up computers. The particular system, a 330 KVA UPS, had no provisions for grilles or filters in the airflow path. Essentially, the UPS was open at the bottom and the fans were at the top.



Cooling air flow



This failure underscores the overall vulnerability of UPS systems and of systems dependant on UPS for power.

Police 911 (enhanced) system failure

A loss of commercial power occurred during a scheduled preventative maintenance routine while an 80 KVA UPS was on maintenance bypass. This caused the loss of all 911 look-up information to a major metropolitan police department.

The particular Police building is served by dual 13KV mains from different sub stations. While their (non redundant) 80 KVA UPS was on hard-bypass being serviced, the feed connected to the load failed. By the time the switchgear tie-breaker operated, the computers were already in a shut down mode.

Lost in this failure was police dispatch lookup capability radio controllers, and computer-assisted dispatch for a city of 6 million people. Obviously, this was a very dangerous situation. Since this failure, a more modern 150 KVA parallel-redundant system has been installed, however, a dc system and flooded cell batteries would offer higher levels of reliability for this vital municipal service.

Operator Service support system failure

An electrician installing an additional branch circuit into a power distribution cabinet caused the lapse of Operator Service systems. An EG lead slipped from his hand and shorted to the line side of the main breaker for a 42-pole circuit breaker panel. This caused the upstream breaker (UPS output) to trip. Due to their relatively confined spaces, ac circuit breaker cabinets typically lack the space and protection commonly found in secondary dc distribution.

Operator Service failure

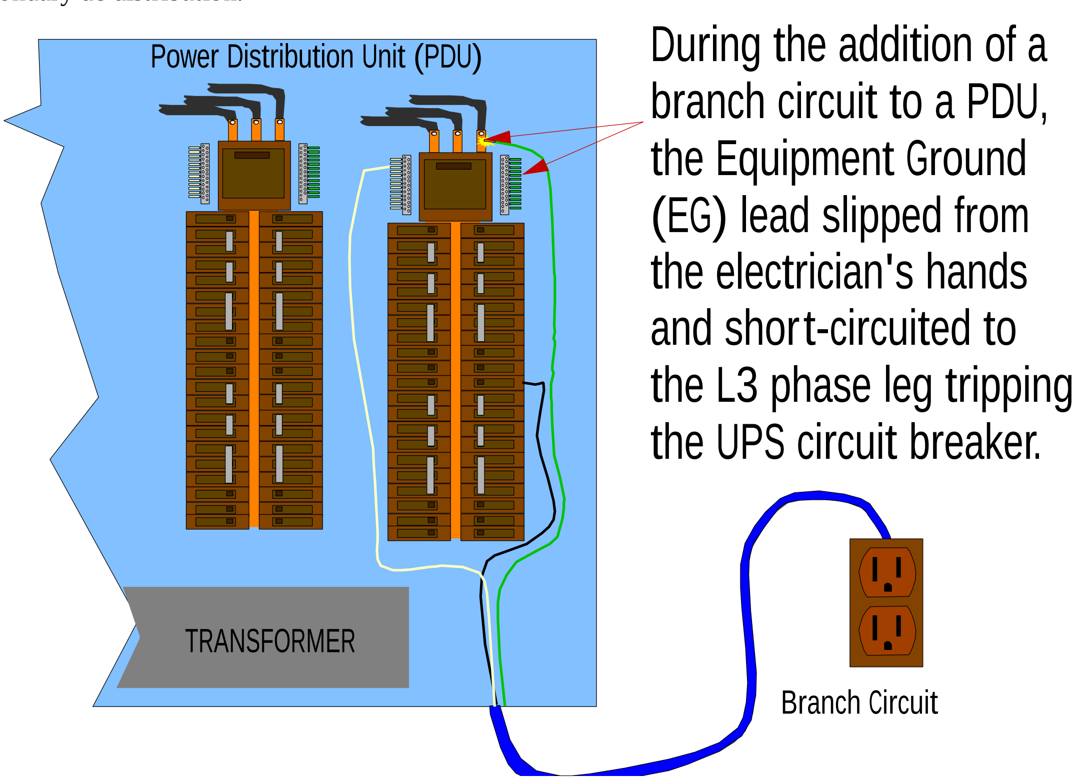
A failed UPS battery caused the service loss of an operator service center. A defective VRLA battery monoblock failed upon discharge causing the total failure of a 50 KVA UPS. This caused a major Operator service site to fail. Since most telephone power systems employ parallel battery strings, this failure would be unlikely had the load been fed by –48 volts.

SCC Support System failure

Harmonic distortion in a 45 KVA UPS caused a switching control center to run unreliably. The 5th and 7th order harmonic filter traps in the UPS were undersized for the degree of distortion in the load. Additionally, since much of the load was single phase, there was a large third-order harmonic component as well. This caused the failure of several minicomputers providing system surveillance for the telephone network of a large metropolitan city. Correcting the problem called for the addition of external traps and using a delta-wye transformer to “sink” the triplin harmonics in the delta winding and dissipate this energy as heat.

UPS fire

A 20 KVA UPS caught fire when it’s harmonic distortion filters began burning due to undersized chokes. Similar to the problem above, many UPS vendors underestimate the harmonic contribution of switchmode power supplies in the load. In this case, the manufacturer underestimated the size needed for the torroid coil and overestimated the required overcurrent protection. As a result, the windings caught fire. This caused the failure of Internet access equipment for a large customer base.



Lost telephone billing data

A small triport type UPS providing protected power for a billing data computer system caused a loss of revenue. The facility lost commercial power during a storm. Although the diesel engine ran normally, the ac sine wave was somewhat distorted due to the effects of harmonics on the line caused by the proliferation of switchmode equipment. Although adequate power was available, and the computers would have run OK on the mildly distorted waveform, the UPS software would not allow it to sync to the line or transfer to bypass. In this case the UPS ran on battery until it failed on discharge. Billing data for a large cluster of central offices was lost.

Dendrite growth causes UPS battery failure

Dendrite growth, in a flooded UPS battery, caused the battery to short circuit internally and fail. This caused the loss of a 135 KVA UPS system, interrupting power to many operations support systems. This would not have been an issue in a 48 volt plant because of battery string parallelling.

Loading errors

A large urban central office had a Switching Control Center, (SCC) surveillance operation and an Operator Service Center. To provide protected power to these two facilities, a 50 KVA UPS was installed in the basement and cabled to a circuit breaker panel feeding that space. Although the panel-board was clearly labeled "UPS Distribution," in the next few weeks there were three system failures related to improper system loading.

In the first failure, the UPS suddenly began going into bypass every few minutes. An electrician had fed an 8-ton air conditioner from the UPS Distribution cabinet.

The next failure was similar. An electrician fed a large photocopier from the UPS panel.

In the most recent of the improper load failures, someone in Operator services ordered desktop fluorescent lamps for each position, each with a dimmer. The additional load and the RFI/EMI "hash" from approximately 70 fluorescent dimmers severely distorted the load.

In another facility, a 10 KVA inverter was used to supply protected power to critical load. An electrician fed a condensate pump from the inverter distribution panel. The start-up inrush current from the pump caused the inverter to fail.

Similarly, at another facility, a five KVA inverter was used to provide protected power for several personal computers used for network support. Inadvertently, someone plugged a pair of large color laser printers into the system causing the inverter to fail as the inrush outstripped capacity.

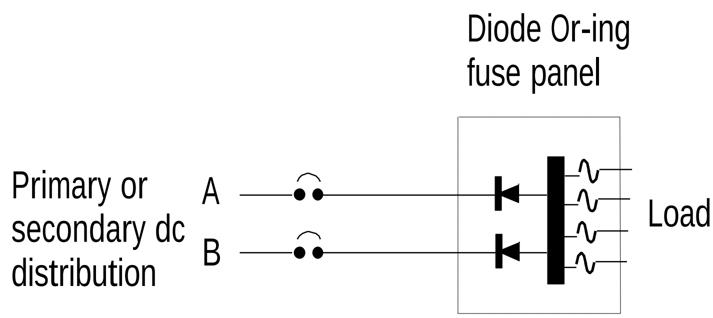
Load balancing

In a critical Operator Service computer center, frequent outages must be planned and tolerated, as load is phase-balanced on the Power Distribution Units (PDU). Otherwise, the PDU's overheat and cause alarms. This is a maintenance headache as it is an active facility with frequent system rearrangements.

Conclusions

While case studies and "war stories," could easily fill volumes, the common thread running through this collection is that the service failures, lost data and the resulting stress in various management organizations, all was needless. Had the systems reported herein been fed from the 48-volt rail the failures would never have occurred.

While it is true that even dc plants and distribution systems experience problems and human error, they do so with far less frequency than their ac counterparts. Also, many telephony based systems employ diode OR-ed inputs so that input power is redundant.



Collectively, the dc operation offers more reliability and in many cases less maintenance cost. This is because there are fewer precautions needed when working with 48 volts than 300 to 600 volt dc systems for UPS, and 100 to 480 volts on the ac side of the system. Harmonics are non-issues and the plant offers a very low characteristic impedance. The 48-volt dc rail remains the potential of choice for telephone systems and for computer elements migrating into the network.

###