Network Remote Powering using Packet Energy Transfer

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Abstract **- Network remote power feeding provides energy to telecommunications equipment over existing conductors normally used to transport data. Existing and emerging applications for remote powering are discussed along with the safety aspects, standards and limitations of using signal lines at elevated voltages. Finally the added capabilities of a new "digital" power distribution technology known as "Packet Energy Transfer" will be discussed.**

I. INTRODUCTION

Network remote power feeding provides energy to telecommunications equipment over existing conductors used to transport data; such as twisted pair or coaxial cable. A common implementation is the powering of Digital Subscriber Line Access Multiplexers (DSLAMs) over twisted pair signal lines from a telecom central office. More recently, a rapidly expanding Compact Base Transceiver Station (CBTS) market for 3G and 4G wireless networks is demanding innovative methods to minimize the capital equipment and maintenance costs for power conversion and energy storage components in small cabinets. Figure 1 exemplifies a pole mounted CBTS, sometimes referred to as

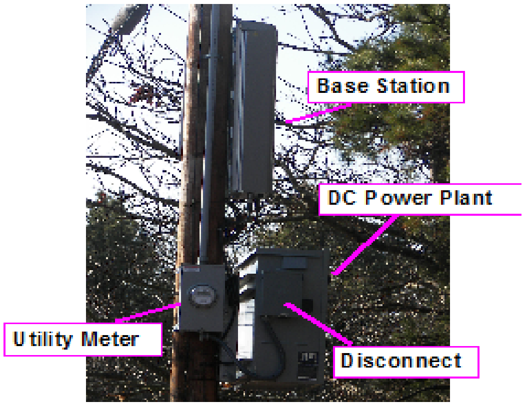

Figure 1: Pole Mounted Microcell

a "microcell", that would serve one or two city blocks. The unit draws approximately 300 Watts. Nearly a million CBTS installations are expected to be deployed over the next several years[i,ii].

Existing suppliers offer remote power feeding equipment designed to the specifications of IEC 60950-21[iii] and GR-1089[iv]. Approved devices are limited to a maximum steady-state power of 100 Watts per conductor pair; resulting in a maximum load current of 250mA. Multiple pairs can be combined to increase the power to the load device, provided that the pairs are individually monitored and protected. Most remote power feeding devices are applied to DSL installations. Their proliferation to newer applications has been hindered by safety concerns originating from the convention that data cables traditionally carry only low voltages and are segregated from power lines; meaning that technicians and the public may be caught unawares when these cables are used for hazardous voltages.

Packet Energy Transfer (PET) is a new technology that "digitizes" power by separating it into a series of discrete time domains referred to as energy packets. Each packet has a first component dedicated to energy transfer, and a second component dedicated to data; containing a digital and analog verification signature. Using this new approach, higher levels of safety for personnel and equipment can be achieved, opening the door for more widespread use of remote power feeding. The technology can distinguish between a person touching the power conductors and the regular current being drawn by the load equipment; something that has not been achieved using traditional methods.

II. ELECTRICAL SAFETY

The reaction of human muscle tissue to electrical current is dependent on the magnitude and duration of exposure. The magnitude of electric current through the body is determined by the contact voltage divided by the human body resistance, with the bulk of body resistance being dominated by skin resistance. For exposures of 10ms or more IEC 60479-1[v] provides a guide to the effect of various current-duration combinations on the human body; the worst case resulting in ventricular fibrillation. For shorter exposure periods IEC 60479-2[vi] is referenced. Traditional remote power feeding devices limit human body current to relatively safe levels

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when the fault is from a conductor line to earth using an approach similar to traditional ground fault interrupter (GFI) devices found in homes. However, when the fault occurs from one conductor to the other conductor (line-to-line) the exposure is undetectable by existing equipment and can fall into a dangerous region. At the 400Vdc maximum line-to-line voltage allowed by IEC 60950-21 for voltage limited circuits, the human body resistance from hand to hand is assumed to be 2,000 Ohms. This results in a body current of 200mA. Since conventional network powering devices are unable to distinguish between a person touching damaged or exposed line conductors and the normal load current, the

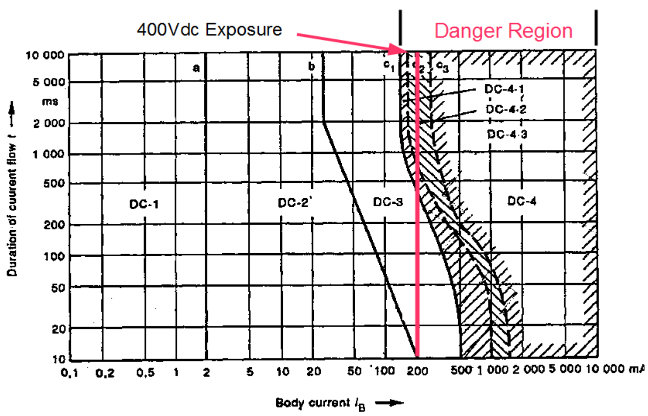

Figure 2: DC Current Effects (IEC-60947-1)

shock period will continue until the person manages to release contact.

This is depicted by the vertical red line at 200mA in Figure 2 where as exposure time increases (symbolized by traveling upwards on the vertical red line), it enters the DC-4 danger region where ventricular fibrillation is probable. The danger region is reached in under 1/2 second. It is also important to note that injury may occur not only from ventricular fibrillation but from a secondary injury if the shock is intensive enough to cause a "panic reaction" where a person could fall off a ladder or bump his head.

III. PACKET ENERGY TRANSFER OPERATION

PET has the unique ability to distinguish the difference between a person touching power conductors and the normal power drawn by the load. As described above, traditional remote powering devices or GFI devices do not have this ability. Similarly, PET can distinguish between the energy going to the normal load device and energy lost to a short circuit, high resistance connection or insulation breakdown.

As shown in Figure 3, PET separates electric power into a series of low energy packets with a period of approximately 1.5ms. A single packet does not contain enough energy to harm a person or do damage to equipment. However, by transferring hundreds of packets per second, high power levels are achieved. Each packet contains an energy component and a data component.

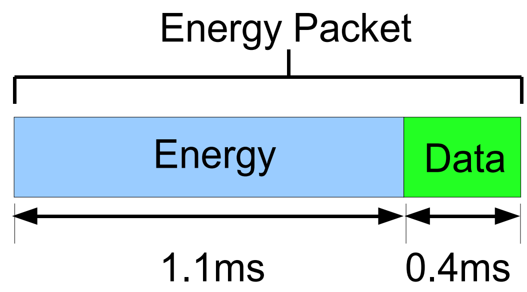

Figure 4: Packet Format

The energy component is approximately 1.1ms in duration. During this time, the source is electrically connected to the load; allowing electrical current to flow. During the 0.4ms data component, the power lines are isolated from both the source and load by the PET electronics. If a person or other conducting object comes in contact with the conductors, or if the conducting path resistance is out of the expected range, high speed voltage and current measurement made by the PET transmitting device do not concur with the receiving device; indicating an improper transfer of energy from the source to the load. If the transmitter cannot verify that a proper transfer is made, power is typically discontinued in two packet periods, or 3ms. The data component may also contain a unique verification code that must be corroborated between the transmitter and receiver.

Figure 3 depicts that in a PET protected circuit, the body current at the same 400Vdc falls well into the safe region where ventricular fibrillation in improbable. Moreover, the energy is low enough where an individual coming in contact will have much less probability of a panic reaction where he might fall off a ladder or suffer from some other secondary injury.

IV. MICROCELL APPLICATION

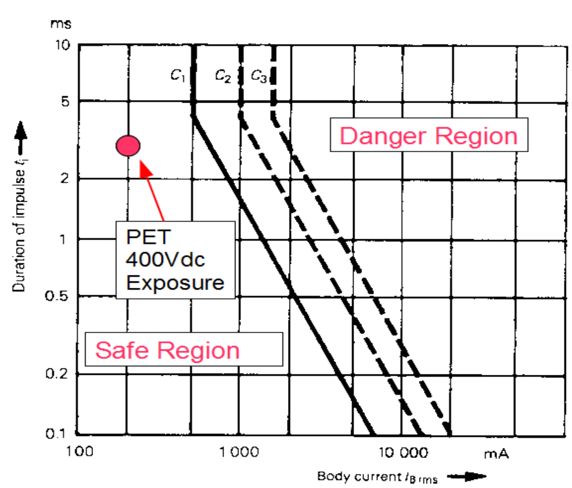

Figure 3: DC Current Effects (IEC-60947-2)

In one proposed remote power feeding application, a central hub or aggregation node processes data from a

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number of remote CBTS units (microcells) located on telephone poles, street lamps or buildings. Communication to the microcells may be accomplished over optical fiber, coax or CAT5 (ethernet) cable. When power for the microcell cabinet is derived locally, a number of provisions must be employed to safely distribute and convert AC power from the utility to the DC power used by the microcell. Figure 1 depicts a typical installation with conduit run, utility meter, disconnect junction box and DC power plant with batteries supplying a 300W CBTS.

Many service providers target at least four hours of battery back-up for the base station to support emergency services (911) during a utility outage. The service providers plan for the deployment of portable generators during extended outages where the batteries would be fully drained. In reality, limitations on cabinet weight and volume often reduce the installed battery capacity, and the logistics of deploying generators to hundreds or thousands of pole locations in severe weather results in wide spread service loss. Maintenance of the thousands of batteries in a CBTS network is intensive, particularly when the units are installed in metropolitan areas where the technician deployment cost alone (truck-roll) can reach $1,000 per visit.

The alternative of remote power feeding places the DC power plant and batteries at the aggregation node. The -48V DC plant voltage at the node is stepped up to +/-190V by the remote power feeding source and distributed to the microcell units over CAT3, CAT5 or other copper cable. A power converter at the microcell down-converts the +/-190V back to -48V to power the base station. In the “digitized” convention of Packet Energy Transfer, the source converter is referred to as a “transmitter” and the destination converter is referred to as the “receiver”. A single channel, 300W PET transmitter/receiver pair is depicted in Figure 5. The PET receiver unit can be placed inside the microcell enclosure or mounted externally adjacent to it.

Figure 5 - PET Transmitter and Receiver

A depiction of remote powering over existing aerial CAT3 (phone) lines is shown in Figure 6. It is proposed that the meter, disconnect and DC plant cabinet be removed. The DC power plant and storage batteries for all the microcells would be centralized at the node cabinet. Since a DC power plant is already required at the node, much of the equipment costs have already been incurred or can be expanded by adding modular components, such as additional rectifier modules. The AC utility meter at each CBTS would also be eliminated in exchange for a single meter at the node; eliminating the cost of the meter and meter reading labor. Some CBTS installations do not include a meter, but these are often penalized by a utility bill pegged at a single peak power consumption rate.

The cost of larger batteries and DC power plant components can be 30-40% less in the larger format of the centralized configuration, off-setting the cost of the remote power feeding equipment. Moreover, the larger format batteries often come in “telecom grade” versions that have a longer service life at lower cost.

Service visits for battery maintenance are greatly reduced in a centralized system. Assuming a system of ten CBTS remote cabinets (microcells) per node, and a battery replacement interval of 3 years, there is an avoided cost of $1,500 to $3,000 per year in truck-rolls alone at $500-$1000 per truck-roll. Finally and perhaps more importantly, battery capacity is no longer governed by the weight and volume limitations of the remote cabinets, and generator back-up is greatly simplified when delivered to a single aggregation node. Overall, customers can experience the availability during a utility outage previously known only with Plain Old Telephone Service (POTS) where reserve power originates at the central office.

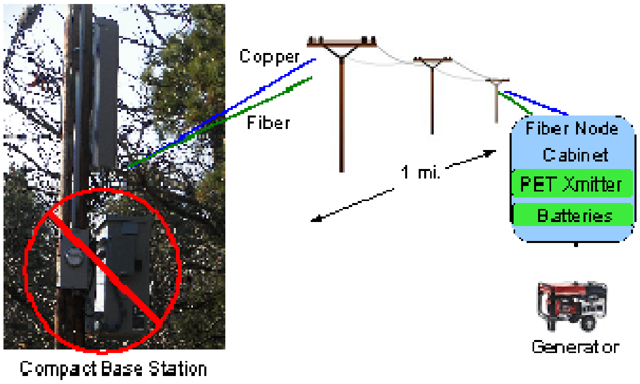

Figure 6 - Remote Powering of a Microcell using CAT 3 (telephone) Lines

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V. CONCLUSION

A remote power feeding architecture can significantly reduce capital equipment and maintenance costs in CBTS networks or other systems involving a central node that interfaces with multiple remote installations. The DC plant equipment and batteries are typically less expensive to acquire and install, and often more reliable in a centralized architecture. Additional benefits include reduced battery maintenance and POTS-like availability during utility outages.

Remote powering using Packet Energy Transfer, offers an unprecedented level of safety for both personnel and equipment, making it an attractive alternative to local powering approaches.

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[i] "The Future of Infrastructure: Compact Base Stations", In-Stat, June 2010,http://www.in-stat.com/

[ii] "Small Cell Economics and the Future of Mobile Broadband Services", Wireless Week, June 2012

[iii] "IEC 60950-21, Information technology equipment –. Safety –. Part 21: Remote power feeding", International Electrotechnical Commission, Voltage Limited Equipment, Sect. 6.2, http://www.iec.ch/

[iv] "GR-1089, Electromagnetic Compatibility and Electrical Safety - Generic Criteria for Network Telecommunications Equipment", Telcordia Technologies, http://telecom-info.telcordia.com

[v] "IEC 60479-1, Effects of current on human beings and livestock - Part 1: General aspects", International Electrotechnical Commission, http://www.iec.ch

[vi] "IEC 60479-2, Effects of current on human beings and livestock - Part 2: Special aspects", International Electrotechnical Commission, http://www.iec.ch

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