VARIOUS POWERING METHODS FOR FTTX ARCHITECTURES

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ABSTRACT

While competitive and robust fiber optic communications networks evolve and grow, so does the requirement for reliable, uninterruptible powering methods. The ever-changing landscape of municipalities, utility companies, home developers, cable TV companies, and telephone companies deploying fiber to the home or business (FTTx) cannot be serviced with "one size fits all" products. Uninterruptible power systems (UPS), required to keep communications network running and protect vital 911 lifeline service to telephone subscribers, come in a variety of sizes, shapes, and topologies to meet the requirements of this diverse user base. As power supply manufacturing companies improve their ability to adapt quickly to this changing environment, innovative and unique powering solutions emerge.

1. INTRODUCTION

Fiber networks come in a variety of architectures, all of which require powering. Traditional fiber in the loop (FITL) and fiber to the curb (FTTC) architectures are now joined by a variety of passive optical network (PON) architectures. Although these optical networks are inherently different, each network requires powering at the optical line termination (OLT) points where electrical signals are converter to optical signals. They also require power at the transition points where optical signals are converted back to electrical signals, either at optical network units (ONUs) located at the curb or network interface devices (NIDs) located on the side of the home. Since these optical networks carry vital and critical data, such as online business transactions, battery backup systems with a minimum of six-hours of runtime during a power utility outage are typically used to support these networks.

Powering FITL and FTTC networks are well defined [1], but powering PON networks at the NID are just starting to evolve into another generation of products. Traditionally, PON NIDs have been powered with small UPSs mounted inside the home, typically in the garage, but new innovative strategies have emerged to overcome some of the disadvantages of this powering scheme. Environmentally hardened outdoor power supplies with batteries are now available. These power supplies get their power from the utility meter or from a dedicated circuit in the house. Another NID powering alternative is network powering. This is the practice of sizing one power supply with batteries to support 8 or more NIDs and locating it next to the final optical splitter. A hybrid fiber / copper drop cable is used to power 8 NIDs from a single power supply.

Similarly, multiple dwelling units (MDUs) and business complexes use similar types of power supplies, only with higher power capacity.

The headend OLT powering portion of the PON is very reminiscent of typical CATV headend power systems or traditional central office battery plants. CATV headends use AC UPS or DC power plants usually backed-up by a facility generator. Central office backup systems almost exclusively use DC power plants. Additional, remote headends or ONUs can be powered from hardened outdoor enclosures and power systems. These outdoor enclosures typically have enough internal room for additional optics and fiber management. Heat exchanger technology or air conditioner systems are incorporated in these outdoor enclosure systems to protect co-located sensitive optical equipment from harsh environmental conditions.

Each of these powering scenarios are presented in this paper. Premise powering, MDU powering, and business powering are discussed. This is followed by a brief discussion on network powering followed by a headend powering presentation.

2. Powering the Home

This powering method is where a co-located uninterruptible power supply (UPS) powers the subscriber's optical NID. Premise power at the home is currently the most common method of FTTH powering.

The popularity of this approach is supported by the concept where one customer gets one UPS/NID and there is one revenue stream to support the equipment. Power supplies only need to be placed where required. No power is needed for homes passed that do not subscribe. Capital outlay is required only where associated revenue is generated.

These subscriber located UPSs use the normal household current as a source and has a low "safe" voltage output to power the NID. The UPS typically also generates status alarms relating to the UPS operation and presents these alarms for the NID to read. Most of the UPSs use, at least in part, the predefined PacketCable™ suite of alarms. Currently these alarms are: AC Fail, No Battery, Replace Battery and Low Battery.

The UPSs providing power at the home serve NIDs with relatively low power requirements. During normal operation, and depending on the manufacturer, residential NIDs require between 12 to 30 Watts. During a power outage, some non-critical services are disabled at the NID reducing power requirements to maximize the backup time provided by the battery in the UPS. During a power outage, the typical power required by the NID is between 7 to 10 Watts. This particular power range is important as one of the most cost effective batteries is the 7.2AH AGM VRLA battery. This cost effective battery can provide roughly 8 hours of backup with this load, thereby making the FTTH equipment comply with industry standard backup time requirements [2].

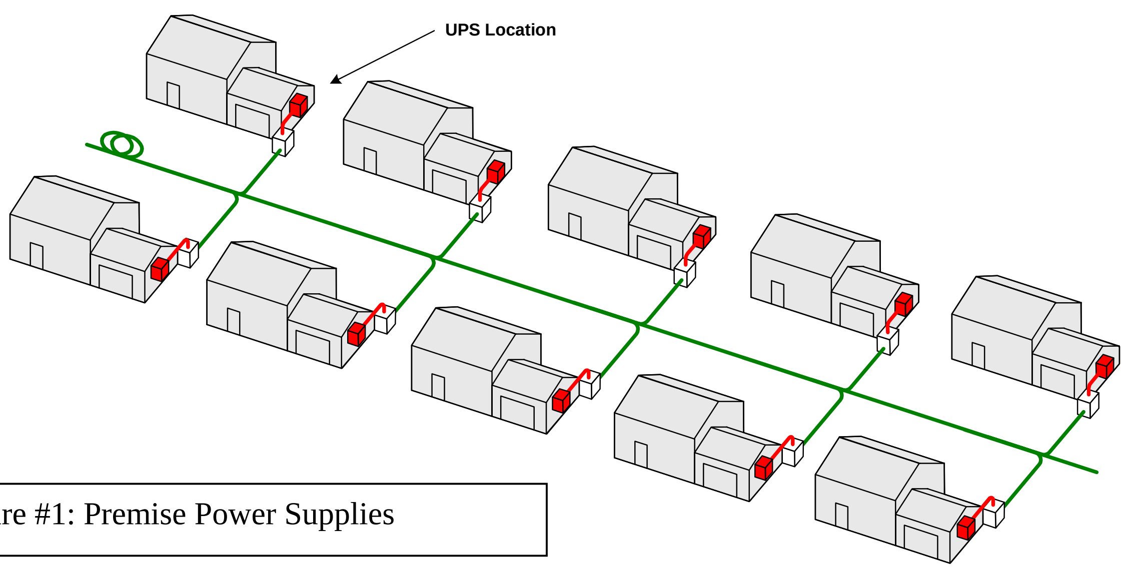

Figure #1: Premise Power Supplies

The two different basic locations for these UPS’s are indoor and outdoor. Both locations have particular advantages and disadvantages.

2.1. Indoor Located UPS

The indoor version of the UPS is typically located in the subscriber’s basement or garage. As the NID is typically mounted in the outdoors on the subscriber’s residence, an interconnecting wire carrying the supply voltages and alarms must be fed through a wall to the outdoors. Depending on the voltage required by the NID, the connection distance between the two devices must be minimized. Those NIDs that use 48VDC can typically run longer cable distances than those NIDs that use 12VDC.

The indoor UPS is typically the most capital cost effective powering solution. Being indoors, the UPS does not require the cost of being protected from the elements. Further, consumer grade electronics can get to be very inexpensive.

The largest issue of UPSs being located indoors is the FTTH operator getting access to the UPS and it’s location. Starting from installation to removal, coordinating service to the UPS with the subscriber can be problematic. Should a UPS fail, how does the FTTH service company contact the subscriber, particularly if the FTTH company is providing telephony service?

Other questions need to be examined. Who replaces the battery when it reaches the end of its service life? If the customer is primarily responsible then there are a number of logistical issues such as; customer notification, sending or delivering the replacement battery, getting the customer to return the old battery for recycling. Any of these issues being mishandled or otherwise compromised will result in a service call. Should the FTTH company be responsible for servicing the UPS, including battery replacement, then scheduling service with the customer to get access is required. All of these service issues require significant resource coordination.

If the NID is out of service for a time or the battery has expired and there is a power failure, there could be significant liability to the FTTH operator if the subscriber cannot access emergency services.

Another issue to be considered is nuisance alarms. Home owners have been know to unplug UPSs in the garage to plug in a shop-vac or power drill and forget to plug the power supply back in, the FTTH company will have to make a service call. Consequently, the service provider has lost direct control of a vital piece of the network -- adversely affect overall reliability.

In summary for the indoor UPS, the initial equipment cost to the FTTH operator can be low when compared to other solutions. However, the FTTH operator must be aware of the potentially hidden costs relating to getting access to the customer’s residence for installation and servicing issues.

2.2. Outdoor Located UPS

The outdoor version of the UPS is typically mounted on the side of the subscriber’s residence, preferably near the NID. Connection of the power and alarms from the UPS to the NID is simply a preferably short cable connecting the two and stapled to the wall. Getting AC power to the UPS safely is the largest installation challenge.

The outdoor UPS can be initially more expensive than the indoor UPS alternative. The electronics and enclosure must be hardened for outdoor use. In most cases, the battery will need some sort of heater mechanism to continue to provide reasonable backup energy in the wintertime. These cost adders can be balanced against the fact that the electronics of the UPS is available 24 hours a day, 7 days a week to the FTTH operator for servicing.

As mentioned previously, the largest non-financial issue of UPSs being located outdoors is getting AC power to the UPS. As the NID is typically placed at the service entrance location of the residence, an

AC outlet is not normally available. The FTTH operator must arrange an AC connection to be installed. Depending on appropriate electrical codes, a ground fault protector device may also need to be installed and the AC power line may need to be protected with conduit.

Recent efforts have involved modifying the electrical utility meter installation in some way to access AC power. This provides an advantage that the UPS/NID installation can be performed entirely outside the residence. Utility power can be accessed either before or after the electrical meter. If the UPS power is provided prior to the meter, the customer can still have communications, even if their electrical service has been disconnected. If UPS power is accessed after the meter, then the customer pays for the communications power required by the UPS and NID, however the utility company will likely need to limit AC power in some way rather than disconnect so the customer can still make telephone calls.

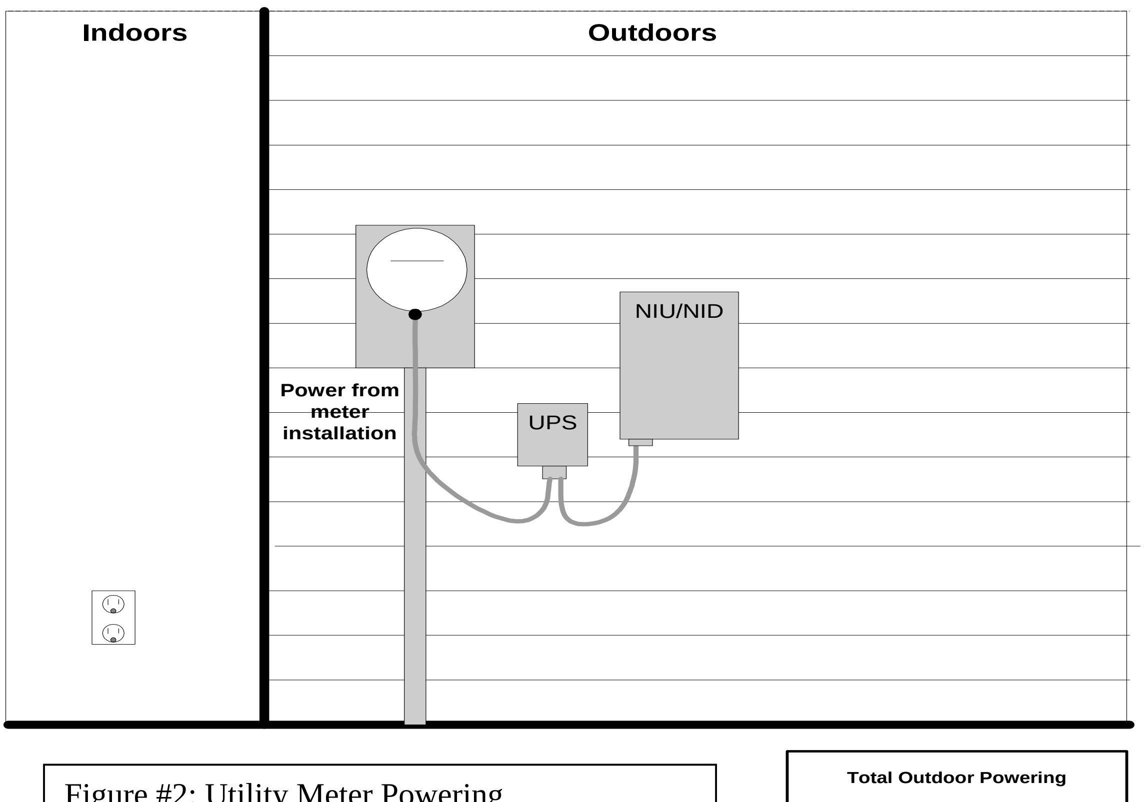

Figure #2: Utility Meter Powering

If the demarcation points of the internal wiring of the residence (coax cable for video, telephone and data wiring) are readily available from the outside (likely new homes only) the installation could be performed without any customer present. It may be possible for the FTTH operator to encourage potential subscribers to engage local contractors to prepare the residence wiring for NID connection.

Once the outdoor UPS and NID installation has been completed, servicing becomes relatively easy. As most if not all the electronics is now available outside, the FTTH technician can perform service as required. Should the battery need to be changed, it can be performed easily. As the input and output wiring to the UPS and NID are essentially permanent, there are minimal nuisance service calls for accidentally disconnected wiring.

In summary for the outdoor UPS, the initial equipment cost to the FTTH operator may be higher when compared to the indoor UPS alternative, as the electronics must be hardened against the outdoor environment. However, once this initial fixed cost has been expended, the FTTH operator should find that the servicing costs of the subscriber equipment are minimized. Thus, the overall cost of ownership is less for the outdoor power supply.

2.3. Hub Power to the Home

This powering method is where a small group of homes are supported from a common, reasonably centrally located UPS. Like spokes on a wheel connected to a central hub, power is fed from a hub via a copper twisted pair to the subscriber's NID. Typically, one UPS can power up to eight subscriber NID's. Each copper power pair can be up to 2000 feet long. To overcome the voltage drop across the cable, the UPS must source and the NID receive 48 Volts DC. Some of the other terms to describe this method of powering is cluster or curb power.

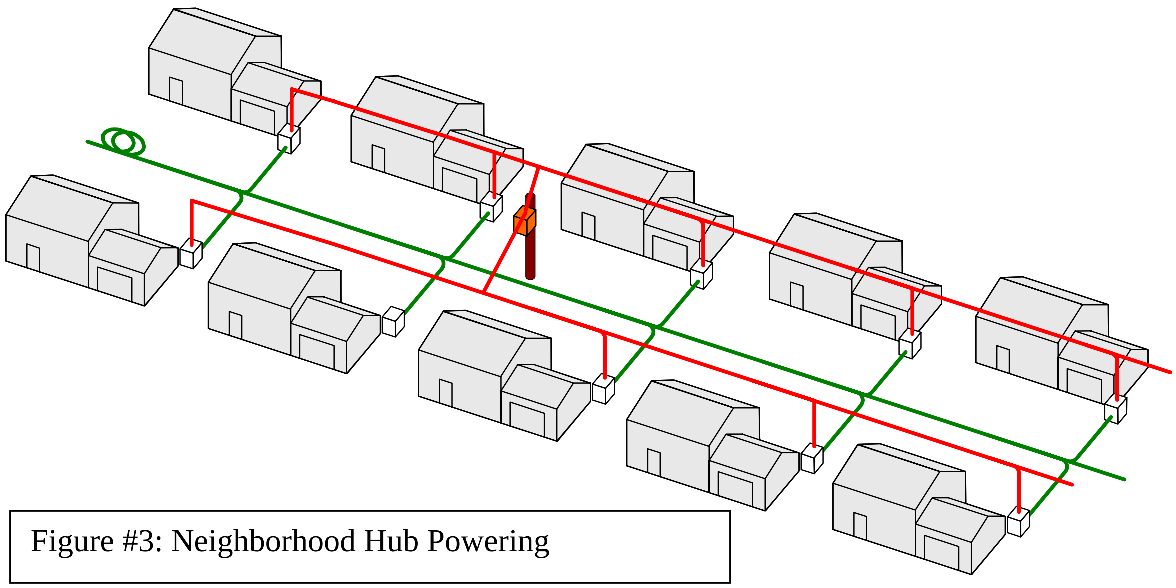

Figure #3: Neighborhood Hub Powering

This approach has the promise of being one of the most cost effective in both equipment expense as well as service labor in those systems with reasonable subscriber penetration rates. Another advantage is that this method, almost by necessity is an outdoor system and therefore has all the installation and servicing benefits of an outdoor system. However, as the power requirements for a particular service area must be substantially deployed prior to any customers being connected, this approach is initially more expensive on a per subscriber basis.

An example of how this hub powering approach might be used and deployed is as follows. The FTTH operator must make an initial estimate on the near-term penetration rate of the FTTH system. If the estimate is approximately 50% and one UPS can service eight connected NIDs, then the FTTH operator must place one UPS reasonably centrally for every 16 residences. This UPS location is likely to be the same as the location of the optical splitter that is also typically an 8-way splitter. As each subscriber is connected, a combination fiber/twisted pair cable would be fed from the UPS/optical tap location to the subscriber. The copper pair then furnishes the power, the optical fiber provides the FTTH services.

One large drawback to this approach is that most of the FTTH manufactured equipment uses 12VDC today. The 12VDC was selected as it was the most cost effective single residence UPS on the market at that time. Most FTTH manufacturers did not fully appreciate the cable length issues that would arise from using 12VDC until after the first NIDs were deployed. Some FTTH manufacturers are now starting to offer 48VDC NIDs to overcome the voltage issues. For those FTTH manufacturers that are still at 12VDC, a power converter is usually available to adapt a 12VDC NID to 48VDC power. The additional cost of the additional power converter removes some of the price advantage of the hub power solution.

Once the equipment is installed, all the advantages of an outdoor powering solution apply. Installation is as easy as connecting the hybrid copper/fiber cable from the NID to the UPS/tap location. Should service be required, the UPS is available outdoors. Compared to a subscriber based powering solution, there would be eight times fewer power supplies deployed in the field. There would also be eight times fewer batteries to be replaced and recycled. In critical service areas during extended power outages, discharged batteries can be feasibly exchanged for fully charged batteries to maintain service. The eventual labor savings of this approach, combined with the shared cost of the electronics, should be the one of most cost-effective powering solutions for FTTH systems with greater than 30% penetration.

2.4. Network "Cable" Power to the Home

This powering method could be the eventual end game for those cable networks that capitulate into a FTTH system. The vestigial coaxial cable network would be an ideal network to cost effectively provide power to a subscriber's NID. This approach is also being considered as a cost effective solution for some FTTH new builds today. One cable power supply location, appropriately placed, could provide power for over 100 subscribers. To avoid galvanic corrosion in long lengths of coaxial cable, the distributed power would remain as it is today, which is typically 60 to 90 VAC.

The amount of power required by a FTTH network is somewhat higher than the power required of today's cable networks, so additional power would likely have to be added. However, even by adding newer power supplies and reusing the older existing power supplies can provide a very inexpensive FTTH powering network.

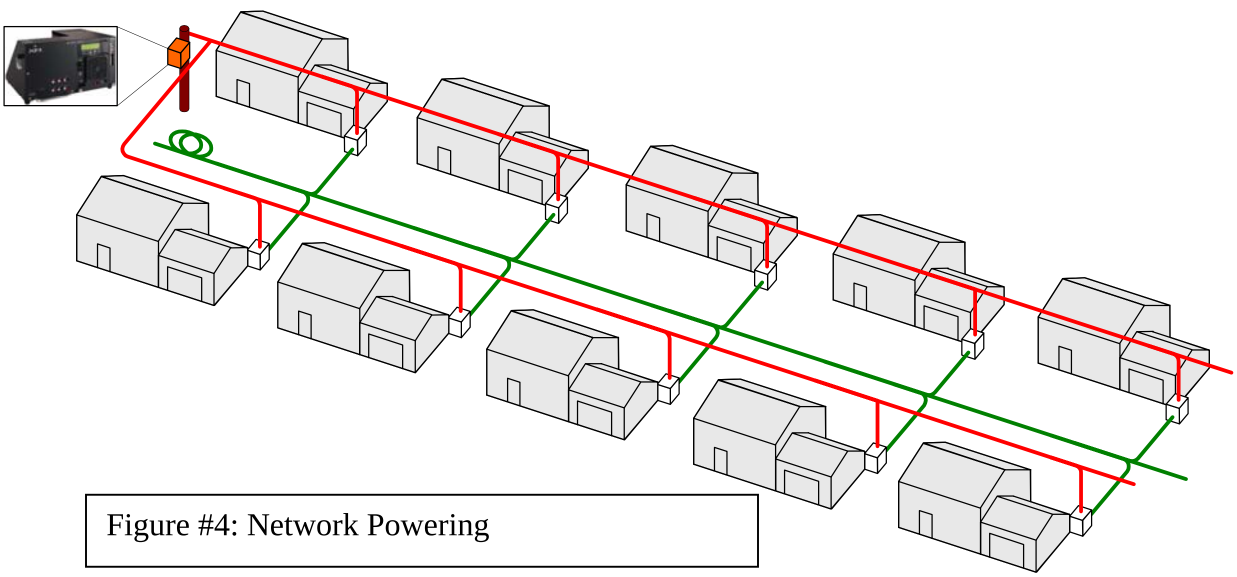

Figure #4: Network Powering

This approach has several advantages to it. As subscribers are removed from the "cable" network and added to the FTTH network, cable services can be maintained as most subscribers are switched over. Also, the coaxial cable now being fed to the home can serve as the power cable to the NID. Some cable systems power their telephony service subscriber NIUs today using this method. All the advantages relating to installation and service of an outdoor powering network are available here. Older technology would be used for new dramatically reducing the build cost of the FTTH network. Further, the high degree of possible power centralization would make standby generators feasible thereby providing a high degree of network reliability.

As previously mentioned, today's FTTH NIDs uses 12VDC. The 12VDC was selected because it was the most cost effective single residence UPS on the market at that time. However should the existing cable networks decide to convert to FTTH, there should be more than sufficient financial justification for the FTTH manufacturers to build a NID that accepts "cable" power. Should there be early adherents to this powering approach, power converters are available to convert "cable power" to 12VDC.

Again, once the equipment is installed, all the advantages of an outdoor powering solution apply. Should service be required, the UPS is available outdoors. Compared to a subscriber based powering solution, there would be many times less equipment deployed in the field. There would also be many times less batteries to be replaced and recycled. In critical service areas during extended power outages, discharged batteries can be feasibly exchanged for fully charged batteries to maintain service. These advantages would be somewhat offset by the cost of maintaining a separate coaxial power network as well as the fiber network. However, the "craft" needed to maintain the coaxial network is well known, costs should be at a minimum.

Some potential FTTH operators who have advanced this approach are considering leasing out the available bandwidth of the coaxial cable. Entities such as municipalities would be interested in using the bandwidth as a pathway for local origination, school systems or video security. Using low frequencies such as 20 to 50 MHz, little to no RF amplifiers would need to be used. The labor savings of this approach, combined with the shared cost of the electronics, as well as the potential to make money on the powering network, should be the most cost-effective powering solutions for the home for FTTH systems.

3. Powering the MDU

MDU NID's require power from 30Watts on up, depending on the number of subscribers served. Outside of certain predefined applications, like the "quad", most MDU applications have too many variables and will require that the UPS solution be individually engineered. Battery capacity will have to be scaled to the load served to achieve the desired backup run time, usually eight hours.

These powering methods attempt to distribute power from one power node to the subscriber located NID. This powering method is where a co-located uninterruptible power supply (UPS) powers the MDU's NID that in turn, provides services to the buildings subscribers. Premise power at the MDU is currently the most common method of FTTH powering for the MDU.

This approach is similar to the premise power for the home. Both indoor and outdoor solutions are available. In large MDU, UPS, and NID locations are typically located in the "service closet". Larger UPSs are typically used to support the variety of equipment needed. Depending on the type and manufacturer of the FTTH and other telco equipment used, the UPS may provide 48VDC or 120VAC. Installation and servicing the larger MDU installation is relatively straightforward as service closet access is readily available to the FTTH technician.

In smaller MDU's, the issues that are associated with home premise powering are virtually identical to MDU powering. There is no guarantee that there is a service closet in a small apartment building. Some FTTH manufacturers have NIDs that can service a four-unit MDU or "quad". The "quad" NID almost demands an outdoor power solution. If an indoor UPS were used, then one subscriber would bear the cost of power for the shared NID. Again, with an indoor UPS, the same indoor service access issues apply.

An outdoor UPS resolves the power issues, if power is taken off the prior to the meter. The utility then charges the UPS/NID power to the FTTH operator; the subscribers all share the power bill equally in their subscription fees.

4. Powering the Business

For small businesses, powering the business can be similar to powering the residence. A small business might have four telephony lines which is within the capability of most "subscriber grade" FTTH NIDs. The same indoor/outdoor options and issues are available. The only additional item that may be of interest is to add additional battery capability for additional run-time during a power outage. Depending on the UPS manufacturer, either larger batteries or additional battery modules can be added to the base UPS for additional run time.

For larger businesses, the FTTH operator and business owner may elect to have one UPS power the FTTx equipment as well as the balance of the business telecommunications equipment. If this is the selected configuration, the UPS requirements can be relatively large, i.e. greater than 500 watts. If the loads are powered by 120VAC, an AC UPS can be rack mounted or installed on the floor next to the equipment (similar to a computer tower case). AC UPSs in this format can typically handle 1000VA to 3000VA equipment loads and external battery packs are available for extended battery runtimes. AC outlets are built into the back of the UPS so the loads will plug directly into the unit. If the loads are powered by DC power, then a small DC kit can be rack mounted with the FTTx loads. Most DC plants of this type are based on 10 amp rectifier modules with 3-5 module slots available (depending on the equipment rack size). The batteries are installed on trays in the bottom of the rack and the kit has circuit breakers or fuses to feed the individual loads.

Some FTTx operators prefer to have a firm demarcation/service line between the FTTx equipment and the balance of the telecommunications equipment. Each equipment operator, business, and FTTx operator, is then responsible for their own equipment, services and level of maintenance. Should this be the case, the UPS requirements can be relatively modest, usually less than 200 Watts of power. The FTTx operator may elect to place their equipment package in the outdoors for easy non-restricted service access. There are a variety of UPS indoor and outdoor packages available.

5. Powering the Headend

All FTTx networks begin in one place- the Central Office or Headend facility. This is typically where the video headend equipment, high-speed data equipment and telephony equipment are located. In some architectures this equipment is spread out to multiple, smaller facilities located throughout the network (hubsites) but the critical nature of the facility is the same- unreliable power at the headend or hubsites will lead to service outages to some or all of the system's subscribers.

Headends and hubsites, therefore, should be built around headend power systems that can protect and backup the sensitive electronic equipment installed in these facilities. Headend power systems generally consist of an AC UPS and/or a DC power plant and a generator.

5.1 AC UPS Systems

Many of the sensitive electronic loads will be powered by 120VAC (just like the power coming out of a wall outlet). For these loads an AC UPS (uninterruptible power supply) should be installed to protect them from poor power quality or power outages during the transfer to and from the generator system. AC UPS' are available in a wide range of topologies with a myriad of system options but they all have a three common components- the UPS or electronics module, the battery and the distribution system.

The UPS or electronics module takes power from the utility and provides clean, reliable power to the loads and charge the batteries. The battery bank provides power to the electronics module when the main power to the UPS fails. Battery runtimes will vary from one system and project to another but a typical UPS runtime for a system in a site with a generator is 15-30 minutes. This provides ample time for the generator to start, come online and take over the load before the battery is depleted. The battery bank will be recharged automatically when the generator or utility is providing power to the electronics module. Finally the distribution system delivers the clean, protected power from the UPS to the critical loads. UPS' are often installed with one large circuit breaker feeding typically electrical distribution circuit breaker panels but the UPS can also be provided with built-in circuit breaker panels or individual multiple main output breakers.

Like a generator a UPS is sized according the to the size of the load placed on it's output. Unlike a generator however the UPS will not provide power to lights, air conditioning, heat, etc. Only the critical electronic equipment required to provide service to the subscribers should be connected to the UPS' output so the UPS is usually at least half the size of the generator system. It is important to consider future growth when sizing a UPS- replacing an undersized two-year old system is much more expensive than purchasing and oversized system at the time of construction.

The size, weight and heat output of a UPS should be considered when determine the UPS' location in the building. Large three-phase UPS' can be 10 or more feet long and weight thousands of pounds (due to the battery bank). The BTU's of heat exhausted by the UPS should be considered when sizing the air conditioning system for the facility.

UPS' are available in single phase sizes from 100VA to approximately 18kVA and in three phase sizes from 10kVA to 800kVA and beyond.

5.2 DC Power Systems

While UPS systems are great for AC powered loads there will inevitably be critical loads that require DC power. This is especially true of a system that is providing telephony service. Video-on-demand servers, data routers and newer cable TV video delivery equipment are other loads that typically operate on DC power. The DC power standard for communications equipment like this is typically –48VDC (positive ground).

Basically a DC power system is a UPS that provides DC power at it's output instead of AC power. While available in a wide variety of configurations all DC power systems consist of the following- recitifers, batteries and distributions components.

The rectifiers are the heart of any DC power plant. They take unprotected AC power from the utility or the generator and convert into DC power to power the electronic loads and charge the batteries. Most DC power systems use modular banks of rectifiers mounted in bays or equipment racks. The rectifiers have 10-200 amp rated outputs and the output of all the rectifier modules is summed together to provide a single DC power source. A small DC kit used to power a single router or server might have three 10 amp rectifier modules and fit in 3 or 4 rack units. A large power system powering a telephone switch and several other headend loads may have 10 or more 200 amp rectifiers and occupy several equipment bays.

Battery runtimes are typically longer with DC power plants than they are with AC UPS' but the theory of operation is the same. The battery keeps the power going to the load during a power outage or during the transfer of the load to and from the generator. The battery bank is connected directly to the output of the rectifiers. During normal operation the rectifiers power the load and float charge the batteries. During a power outage the recitifers shut down and the batteries are discharged to power the load.

Like a UPS a DC power system should be sized to power the current load with appropriate growth potential for future equipment.

5.3 Generators

The final consideration in a headend power system should be given to an AC generator. This is the machine that will take the place of the utility during any utility outages lasing longer than a few minutes and must be able carry the load of the entire facility for prolonged periods of time. A generator consists of an engine turning an AC generator that feeds an automatic transfer switch installed in the building before the main service distribution panel. When the power fails the automatic transfer switch sees the power failure, tells the generator to start and then transfers the load of the facility off the utility connection and onto the generator output. When the utility power is restored, the transfer switch transfers the load back to the utility and shuts down the generator.

Like all power supplies the size of the generator is determined by the size of the load. Of all the components of the headend power system the generator will be the largest because it must carry the entire building load- air conditioning, heat, lights, convenience outlets and of course the critical headend electronics. The voltage and phasing of the generator must also match the utility because it is taking the place of the utility during an outage. If the site is powered by a single phase 240V service then the generator must have a single phase 240V output.

Other factors affecting the generator are location and fuel supply. Typically generators are installed outside in a weatherproof housing. Some locations however (like a hubsite in a largely residential neighborhood) may require the generator to be installed indoors. This will reduce the noise and improve the appearance of the building but will increase the cost and complexity of the generator system. Generators installed indoors could require special cooling, exhaust, air intake and fuel systems that are not required for systems installed in a housing outside the building.

Generators up to approximately 50kW are usually powered by natural gas. In sites where natural gas is not available these systems can operate on liquid propane (LP). Larger generators are typically powered by diesel engines with the fuel stored in a separate tank or in a "sub-base" fuel tank where the tank is provided as part of the generator housing.

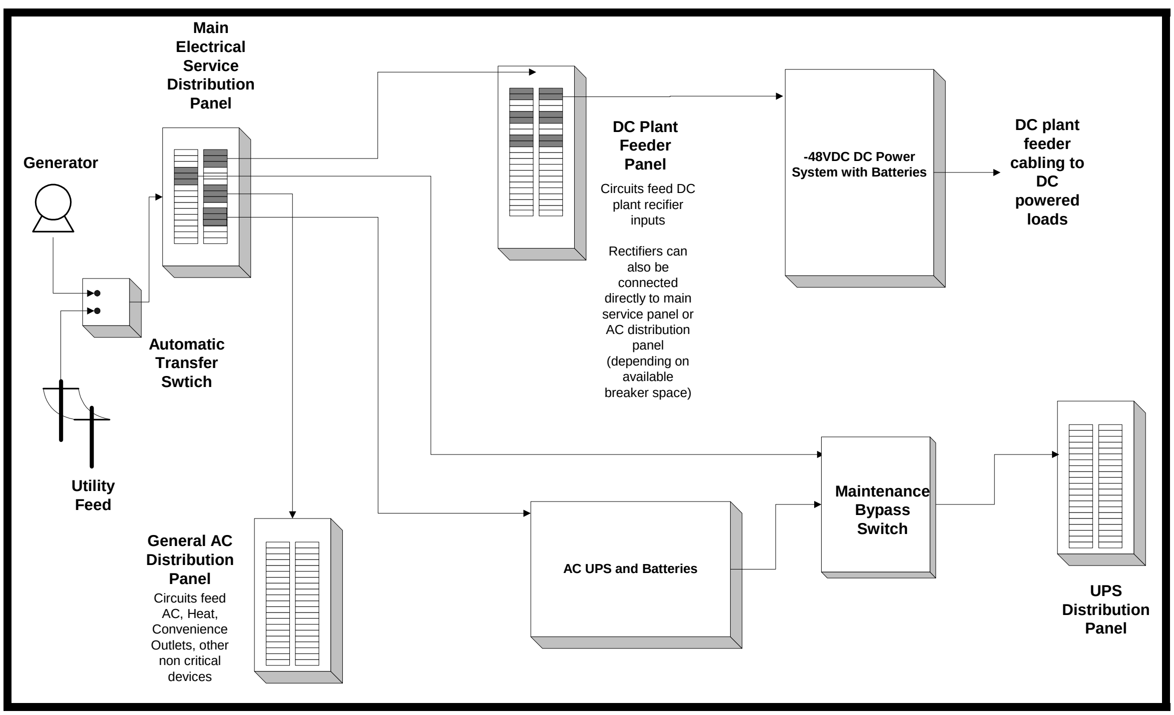

Figure #4: Typical Headend General One-Line Diagram

In new construction or remodels generators are typically specified for the project by the electrical engineer or designer. If a headend or hubsite is being installed in an existing facility it is advisable to contact an engineer or work directly with a qualified generator distributor/installation company to assemble a system that will be all the requirements of the project.

One important note- when a generator's automatic transfer switch transfers the between the generator and the utility there is a loss of power to the load. Critical electronic equipment providing service to the subscribers cannot typically tolerate this power loss (particularly telephony, high-speed data and video-on-demand equipment). This power loss is eliminated by the AC UPS and DC power system.

5.4 Remote Electronic Cabinets

In many plant designs it becomes desirable to locate sensitive critical electronics out in the field but the amount of space required cannot justify building a full hubsite facility. Outdoor electronic cabinets are now available to meet this need. While they are available in a wide range of choices all outdoor electronic cabinets consist of the following basic components- the cabinet shell, the equipment rack space, the power system and the climate control system.

The cabinet shell is just that- the housing to hold all the equipment. They are usually made of aluminum to prevent rust and corrosion and coated with paint or powder coating. The housings can be completely sealed from the outside environment (NEMA 4X) or they can have fans and filters that exchange air with the outside (NEMA 3R). NEMA 3R cabinets are typically less expensive but the electronics installed must be able to tolerate a wider temperature range and the possibility of dust and humidity entering the enclosure. The equipment rack(s) installed in the cabinet are generally standard 19" or 23" equipment rack rails for installing the critical electronic equipment.

Like the customer premise-business application (Section 4) the power system can be an AC UPS or a DC power kit. If the cabinet is NEMA 3R rated and is exchanging air with the environment then the batteries can be installed in the enclosure with the electronics. If an NEMA 4X cabinet is chosen however the batteries must be installed in a separate ventilated compartment.

Like the NEMA rating the climate control system should be chosen based on the nature of the installed electronic equipment. The cabinet can be cooled by fans and filters (NEMA 3R), heat exchangers (NEMA 4X) or air conditioners (NEMA 4X). Consult the manufacturers of the critical electronic loads being installed to verify the temperature and operating environment they were designed for.

6. References

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