Customer Premises Optical Network Terminal
Equipment Installation Practices

Introduction:

When a new technology is deployed very often appropriate standards and installation practices are not in place to cover the change. Fibre to the Home (FTTH) is an example of this situation. The fibre cable connects to an Optical Network Terminal, ONT, at the dwelling, which processes the fibre cable signal into telephone, television, and data signals. The ONT is powered by customers mains supply.

To understand what was needed to deploy ONTs, ADTRAN allocated resource to visit installations to understand what was needed in terms of installation practice and equipment performance. The results of this study have been an ADTRAN installation guide, ONT designs that comprehend the field environment and technical contributions made to the IEC, IEEE, ATIS-STEP and ITU-T for standards development.

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An ADTRAN White Paper

ONT Installation Practices

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ONT Installation Practices:

Managing factors that can cause undesired lightning related transients on ONT customer ports and the ONT ground

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Background

Optical Network Terminals (ONTs) are broadband telecommunications terminating devices typically installed on the outer wall of a residential customer's home, apartment complex, or place of business. The most common deployment is on residential homes. There are internal ONTs that are deployed inside these locations as well. This guide does not contain information about these internal ONTs, but the concepts provided could be useful for those deployments as well.

The broadband input to the ONTs is fed by a fiber interface from the service provider. The customer ports are generally "Plain Old Telephone Service" (POTS), Ethernet, and in some cases coaxial cable. These interfaces connect to the customer premise wiring for telephones, Cat 5 cabling for Ethernet (data and/or video via modems, switches/routers, and computers), and to coaxial cable for connection to TVs, VCRs, and other set-top boxes. Each of the customer devices will typically have a 2 or 3 prong power supply that plugs into wall outlets throughout the home.

The ONT typically receives power from an un-interruptible power supply (UPS), which provides several hours of battery backup. The UPS is typically located indoors and plugs into the customers AC via a nearby 110/120 VAC outlet. The ONT and UPS are connected by small gauge stranded wiring that typically consists of low voltage DC power (i.e 12 VDC) and some alarm leads. The alarm leads transmit information about the status of the UPS battery and power to the ONT, which in turn can be transmitted back to the service provider. Some ONTs are fed by span power over existing copper, and thus the UPS is not needed. This guide does not include information about ONTs that receive power via OSP copper, but is focused on ONTs powered from a UPS.

Although the fiber feed to the ONT is made of glass and therefore is non-conductive and immune to affects of voltage and current, these fiber cables often have a metallic locate wire, strength member, or shield, which is no less susceptible to transients than old fashioned metallic OSP or drop cables.

Below are some pictures of typical ONT Installations and a pictorial diagram of elements that could be found in typical installations.

The following figures (Figure 1 and Figure 2) illustrate typical ONT installations. The diagram shown in Figure 3 shows the elements that could be found in typical installations.
Most ONT installations will be unique and provide their own set of challenges. Unless ONTs are being installed in a uniform fashion (such as with installations in newer subdivisions), there will be factors that require that precautions be taken to minimize potential transient damage to the ONT or the customer equipment.

The installation precautions in this guide are intended to mitigate (to the greatest extent possible) the effects of transients imposed on the metallic interfaces of the customer ports and voltage differentials that can occur between various grounds and the customer ports. The latter is referred to as Ground Potential Rise (GPR), but just as easily could be called the ground potential drop, when looking at the voltage polarity relative to some other point. The voltage rise or drop is relative to the points being viewed, and therefore polarity is also relative. In most cases involving ONTs, the polarity of the transient voltages is not critical.

It might not seem possible for an ONT to be damaged by transients or GPRs, because an ONT is a fiber-based device with no connections to devices that could get hit by lightning. In reality, however, there are many sources of transients and GPRs that can cause potential ONT damage. These sources, some of which are more obvious than others, are discussed in detail in this guide. If ONT installation precautions are not followed, the potential for transient damage, particularly from lightning storms, will increase significantly.

Figure 3. Diagram of Typical ONT Installation
Basics of Lightning and Electricity

It is important to have a basic understanding of lightning and electricity in order to understand why ONT damage occurs. In simplified terms, imagine the earth being one plate of a very large capacitor and the clouds being the other plate. As the clouds move during storms, the earth and the clouds become charged plates of opposite polarity. The air between the clouds and earth is the dielectric. Lightning is generated when the voltage between the clouds and earth exceeds the dielectric strength of the air. All the charge that is stored up for miles around is suddenly discharged through a small area that we see as a lightning bolt. The lightning bolt provides the path so that each plate becomes neutrally charged again, but in the process, a tremendous amount of electrons must flow from the point of the lightning strike out several miles across the outer surface of the earth (a similar process also happens in the clouds). From a practical perspective, the electron flow in the clouds is of little consequence, but the electron flow radiating outward in all directions from the point of the lightning strike on earth has a huge effect. Because the earth was acting as a huge capacitor plate, the charge is on the earth's surface; consequently, when lightning strikes the ground, it travels in all directions primarily across the outer surface of the earth. The earth has some level of resistance and, consequently, the currents flowing outward create a voltage potential between every unique point relative to all other points. That voltage differential can be hundreds or thousands of volts per meter and can last for several micro seconds (µS). If, for example, a person was standing hundreds of yards away from the lightning strike with one foot toward the lightning strike and the other facing away from the lightning strike, this person could have several thousand volts between their feet.

This basic overview of lightning and electricity demonstrates that lightning currents can flow outward for sometimes miles, generating voltages between points along the path called Ground Potential Rise (GPR), which is the result of the current and the ground impedance. (See Figure 6.)

Figure 4. Cows Struck by Lightning

Figure 5. Diagram of Lightning Current through Cow

Figure 6. Lightning Burn Marks on Ground

The first mechanism by which this affects us is that when lightning strikes the ground or an object, a transient voltage or GPR occurs. This can result in undesired currents that can flow in electronics, specifically ONTs (or people, animals, etc.). The currents from a GPR can be quite large in an ONT circuit (since the circuits are relatively short) resulting from a low impedance, large ground wires, and large ground paths. If a loop can be formed, the current will flow and likely cause damage. The loop can be capacitive or DC, since the transients or GPR will have a very high effective frequency (fast rise time). Even if a low impedance loop does not exist, however, very large voltages (tens of thousands of volts) can develop and will find the closest discharge point to complete the loop. This can result in significant damage and leave evidence of charring or arcing.

Ground currents can also induce currents into buried or aerial cables or cable shields. This is the most common lightning phenomena and affects long runs of OSP telephone or AC power lines. Buried cables lines can often be more susceptible than aerial cable due to the close coupling of the lines of magnetic flux. There can be direct lightning strikes to OSP aerial cable, but this is not as common. Direct lightning strikes can cause substantial damage, but the currents generally get shunted to ground by the OSP cable shields, unless it occurs very near a remote telecommunications cabinet/site or near the home.
It might seem logical to assume that ONTs are not affected by OSP cable lightning damage because ONTs do not have OSP cables. There are, however, at least three mechanisms involved in ONT installations that challenge this assumption. The first is lightning transients on the AC power that feed power to the UPS, and ultimately the ONT. The second is the metallic member of the fiber (if used) that may be intended for fiber locating, strength, or rodent control (shield). The last mechanism is the connections of the Ethernet or Telephone cables by the customer to separate structures (such as outbuildings, detached garages, barns, etc.). These connections to other structures can create significant susceptibility to GPR, induced lightning, and even power faults.

**ONT Construction**

ONTs consist of an outdoor box which is usually made of plastic and protects the electronics and connections from rain, sun and the environment. The outside of the ONT is constructed to be somewhat tamper proof to limit access to various compartments within the ONT to only personnel with authorized access. Figure 1 and Figure 2 show the area accessible to the customer to isolate problems to their premises wiring or the ONT. Figure 7 provides a hypothetical diagram of an ONT Fiber to the Home (FTTH) configuration.

The ONT might also have a fiber optic cable that has a locate wire attached, a metallic strength member, or a shielded fiber. Sometimes this metallic member is grounded to the ground lug in the ONT, left floating inside the ONT, or simply cut off and wrapped with electrical tape outside the ONT. Article 770.93 of the NEC (National Electric Code NFPA 70) dictates the treatment of this metallic member of the fiber.

The ONT ground connection is intended to be connected to the MGN point at the AC entrance to the house per the NEC. The most recent version of the NEC, however, is somewhat vague and complex on this issue, as is the latest draft of the RUS ONT installation practices.

The NEC article 840, in simplified terms, specifies that the ONT be grounded per code-approved methods, if the safety Listing of the ONT requires a Listing. The current UL safety listing standard for ONTs is UL-60950-1, 2nd Edition, and suggests the requirement that the ONT be grounded. ONTs generally will be required to be grounded by the NEC.

The latest requirements from the RUS (RUS Bulletin 1753F-153 and RUS Form 515d draft April 12, 2011) are still in final draft form, but state that ONTs can either be floated or grounded, provided that the method complies with the NEC. The NEC typically requires grounding, as does the RUS requirements. Complying with the NEC or the RUS requirements is completely up to the service provider, but from the standpoint of liability, most service providers choose to take the most conservative route and comply with the codes by grounding the ONTs.

Failing to ground the ONT can result in less-obvious consequences, such as the FCC Part 15 radiated emissions levels deviating from specifications and resulting in customer complaints from RF interference. Because analog broadcasts are no longer allowed for TV, many of those complaints would be mitigated, but interference of radio signals (by HAM operators, cell phone users, etc.) can still cause complaints. Grounding the ONT at least pushes the onus of RF emissions and FCC Part 15 complaints back to the ONT manufacturer. Another form of liability can occur. If the ONT is required to be grounded by the Listing on the Equipment, and if a fire does occur and the ONT is not grounded, the service provider is consequently exposed to an even greater degree regarding litigation and settlements.

Although failing to ground an ONT eliminates a potential path for currents and voltages to damage the ONT or customer equipment, it is not a reasonable or feasible method to mitigate damage without exposing the service provider or manufacturer of the ONTs to more serious issues. Therefore it is assumed throughout this guide that ONTs are properly bonded and grounded through a short, direct, and low impedance path to the appropriate grounding electrode. Although not actually part of the ONT itself, the installation and connections of the ONT may also encounter the old NID and POTS drop, and it effects on the ONT must be considered!
Precautions to Minimize ONT Damage

This section provides a list of precautions that can be implemented to minimize potential lightning damage. This section also explains why these actions matter, and provides the legal/code requirements that could impact various mitigation techniques.

1.) The metallic fiber locate wire/strength member/shield (referred to as a locate wire in the remainder of this document), must not enter the ONT box. Allowing this to occur, whether grounded or floating, can create large voltage or current transients from nearby lightning that can destroy an ONT.

The best method to secure the locate wire is to cut off the excess and, using electrical tape, attach it a few inches or more below the ONT to the fiber. Per the National Electric Code (NEC), no exposure of metallic member is permitted, so several wraps should be made. This conforms to the “isolation” method for terminating a metallic member of an OSP fiber cable.

An alternate method is to cut the locate wire off, tape it, and bury it below ground. However, this method is not feasible if there are plans to use it for fiber locating.

A third and least desirable method is to cut off the locate wire or shield outside the ONT, bond it to a ground wire, and run the ground wire in a dedicated fashion to the ground rod. Although allowed by code and feasible, this will still drive large currents into the ground rod and potentially affect the ONT.

Do not connect the locate wire/shield to a grounding wire between the ONT and the ground rod, if at all possible.

Why is this important?

Visual evidence and analysis of ONTs that have been damaged has indicated that voltage in excess of 30,000 Volts have been generated between the ONT ground and the fiber locate wire, with very large surge current capacities. This can be seen after such an event in an area around the ground lug where a strong arc has occurred or there has been charring inside the ONT. The voltage required to cause the arcing in Figure 8 is calculated to be between 30 KV and 40 KV.

Note that the locate wire is actually tie-wrapped to the power and alarm wiring feeding the ONT. Not only was a significant transient generated on the ground lug inside the ONT, but the transient would also have been generated in the power and logic of the ONT due to induction and an electromagnetic pulse (EMP). Further exasperating this situation is the fact that the locate wire is wound like a crude inductor (imagine the ignition coil from a car). The following figures show the kind of damage that has been traced back to sites where things like this have been seen.

The ONT damage includes arcing and charring on the ground lug and at the power/alarm connector. The locate wire has been moved in Figure 8, but was originally in close proximity to the ground lug and alarm wiring when the ONT was opened.

It is very important that voltages that can be generated in the locate wire not be placed anywhere in proximity to the electronics in the ONT. It is also important not to allow the surge currents to cause a ground bounce in the ONT by grounding the locate wire. If the locate wire must be grounded based on company practice, it should be done with a dedicated bond and wired directly to the ground wire so that the voltage on the ONT ground is minimized.

Figure 8. Fiber Locate Wire and Ground (Signs of Arching Likely >30,000V for this Distance)

Figure 9. Lightning Damage from Arcing Locate Wire
The NEC permits any of the three methods described above, however it does not allow the floating of the locate wire inside the ONT. Note that article 770.100 only dictates grounding methods if the "grounding option" of 770.93 is chosen.

NEC

**770.93 Grounding or Interruption of Non–Current–Carrying Metallic Members of Optical Fiber Cables.**

Optical fiber cables entering the building or terminating on the outside of the building shall comply with 770.93(A) or (B).

(A) Entering Buildings. In installations where an optical fiber cable is exposed to contact with electric light or power conductors and the cable enters the building, the non–current-carrying metallic members shall be either grounded as specified in 770.100, or interrupted by an insulating joint or equivalent device. The grounding or interruption shall be as close as practicable to the point of entrance.

(B) Terminating On the Outside of Buildings. In installations where an optical fiber cable is exposed to contact with electric light or power conductors and the cable is terminated on the outside of the building, the non–current-carrying metallic members shall be either grounded as specified in 770.100, or interrupted by an insulating joint or equivalent device. The grounding or interruption shall be as close as practicable to the point of termination of the cable.

IV Grounding Methods.

**770.100 Entrance Cable Grounding.** Where grounded, the non–current-carrying metallic members of optical fiber cables entering buildings shall be grounded as specified in 770.100(A) through (D).

2.) Although not part of the ONT itself, most ONT installations must somehow address the abandoned POTS drop that originally fed the home. Some service providers cut it off below ground and bury it, while others keep it in place for potential use later. In Greenfield installations, it may never have been installed. By itself, this old POTS drop and old NID are fairly benign. However, in many instances for sake of convenience, the old NID and POTS drop contained within it are used for cross-connecting the customer premise wiring and the ONT POTS wiring. Never do this if the abandoned POTS drop still terminates in the old NID. This is true even if the ONT POTS wiring is never connected to the old POTS drop.

Therefore, the recommended treatment of the abandoned drop is to cut it off and tape it below ground level such that code is met. If the drop must remain, cut it off outside the NID and tape or cap it, which also meets code. Neither of these methods violate the NEC or National Electric Safety Code (NESC). Article 800.93 of the NEC covers this and is essentially the same as article 770.93 that addresses optical cables.

If it is required by practice to bond the shield of the abandoned drop, bond it outside the NID with a dedicated ground wire terminated at the ground rod. Do not bond the NID and/or POTS drop ground wire to the ONT ground wire between the ONT and the ground wire.

**Why is this important?**

The threat of lightning damage to the ONT is similar to that of the locate wire. The abandoned POTS drop is a metallic
cable that can have large lightning voltage potentials generated or currents induced in it. In some cases, the cable drop shield is still terminated to the NID ground which is tied to the ONT ground. In other situations, that shield is blown open and causes arcing to the ground lug each time there is a lightning event. This is often evidenced by black charring inside the NID cover. The old POTS wiring is often disconnected from the old station protector and arc to ground as well.

In the case where the NID is being used as a cross-connect, the arcing of the old drop causes an EMP in the proximity of the POTS wiring from the ONT. This damages the ONT because it cannot handle events of this magnitude. If the ground is connected, the old POTS wiring can still arc to the NID ground. If the NID ground is defective, the old POTS wiring for drop cable shield could easily arc to the ONT POTS wiring, because the voltage can exceed the dielectric strength of the ONT POTS wiring or customer premises wiring. Any of these occurrences can damage the POTS interface of the ONT or cause a voltage spike on the ONT ground.

The following figures show arcing of the old POTS drop cable shield and POTS wiring. The figures also show a station protector being used as a cross-connect for premises and ONT POTS wires, which should never be done (this is described in further detail in a following section of the document). The figures show damage typical of sites where the NID was used as a cross-connect for the ONT POTS ports and the old cable drop was not removed from the NID.
3.) The ONT should have its own dedicated ground wire that terminates at the ground rod or within a few inches of the ground rod. DO NOT ground the ONT to other ground wires from items such as the AC meter or old NID, except at the ground rod.

Why is this important?

Typically ONTs are bonded to ground via a wire at the old NID or near the meter, which can be a significant problem if large surge currents occur in this ground wire.

When the AC power is hit by lightning, large currents flow in the ground wire from the meter to the ground rod. This causes a voltage spike to occur in the ground wire, because the ground wire is fairly high in impedance at lightning frequencies. Even a few hundred mOhms times a few thousand amps can be significant and damage the ONT with a sudden voltage rise on the ground.

Similarly, as previously discussed, large surge currents from the abandoned POTS drop or the fiber locate wire can cause this same phenomena.

Damage in this situation is usually far less noticeable since it typically damages the solid state electronics of the ONT and leaves little or no visual evidence. Damage to digital logic circuits, processors, power supplies, and POTS interface components are the most often expected type of damage from a large voltage spike on the ONT ground.

Having a dedicated ONT ground all the way to the ground rod minimizes the voltage potential to the greatest extent possible.

4.) Avoid cross-connecting the ONT POTS port(s) with the customer premise wiring in the old NID. If this cannot be avoided, ensure that the old POTS drop and shield are not in the NID and remove the ground connection completely from the old NID. At the very least, if the NID and old drop must be used, route the ONT POTS cabling away from the ground connection, and also away from the old station protector.

Why is this important?

Lightning-related GPRs can generate significant voltages, and it is possible that under certain circumstances the voltage between the ground lug in the NID and the ONT POTS interface could differ by thousands of volts. The breakdown voltage of the wiring might be as low as a few thousand volts, or even have nicks in the insulation, and the voltage could arc between the POTS interface and the NID ground. If the NID and ONT are both properly grounded, this should not occur; however, real-world situations are not perfect and it is safer not to risk potential damage.
5.) Never connect the ONT POTS port wiring (or Ethernet wiring) to a NID station protector or use the station protector as a cross-connect.

**Why is this important?**

The station protectors Tip and Ring connection points are only separated from the ground by a gas tube or carbon block that breaks down somewhere in the 350 V range (maybe a little higher from lightning). If a GPR from lightning does occur, the station protector will operate and connect the POTS ports directly to the ground that has a spiking voltage. The risk of damaging the POTS ports is substantially increased. Not only does this protector provide a path to complete a current loop if the voltage of the protector is exceeded, but it also can operate asymmetrically causing damage from a conversion of a longitudinal (common) mode to a metallic (differential) mode, which can cause damage.

6.) Never leave the abandoned OSP Drop cable connected to the house wiring and ONT port.

**Why is this important?**

This not only can cause a noisy connection, but brings the surges directly into the ONT POTS port.

7.) Avoid POTS or CAT 5 wiring running in parallel (within 4 inches/10.2 centimeters) or being in contact with the grounds from ONTs, NIDs, AC Meter, AC masts, old POTS drops, or the fiber locate wires.

**Why is this important?**

This can result in insulation breakdowns and arcing as a result of large voltage potentials between these points, or induction of large currents into these POTS or Ethernet ONT interfaces, which can cause damage.
8.) Avoid running POTS, CAT 5, or the power/alarm wiring in parallel and close proximity to AC mains or AC house wiring. (This is a NEC requirement.) Requirements suggest that there be at least 4 inches/10.2 centimeters between AC and these other cables.

**Why is this important?**

This helps prevent induction of lightning surges on the AC wiring from getting coupled or induced into the POTS, Ethernet, or power/alarm ports of the ONT.

9.) Avoid sharp bends in the ground wires and separate the ONT ground wire from other ground wires by at least 4 inches/10.2 centimeters when ground wires are in parallel.

**Why is this important?**

This helps prevent induction of lightning surges traveling in the AC ground or other grounds (i.e. NID ground) from getting coupled or induced into the ONT ground.

10.) Instruct customers not to install surge protectors on the POTS or Ethernet inside the house. These can be found on surge strips purchased from retailers or online. Surge strips for just the AC power ports of computers, modems, cordless phones, answering machines, etc., are acceptable and can be used.

**Why is this important?**

These POTS and Ethernet port protectors are not necessary. If installed, the port protectors can provide a path for GPR currents between the ONT ground and the local AC wall outlet ground (which may be at a different reference point due to various grounds in the home), thus causing damage to these ONT ports. Port protectors can convert longitudinal surges into metallic (differential) surges which stress the ONT ports and Ethernet ports more than longitudinal surges.

11.) Avoid stapling premise wiring (POTS or CAT 5 or power/alarm) to the outside of metallic structures such as mobile homes. Recommend that customers fix or replace POTS or CAT 5 premise wiring if it is stapled to metallic structures. If it must be attached to the outside of a metal structure, use insulators and make sure the wiring is outdoor UV rated and does not have cracks or nicks.
Why is this important?

The outer surface of the metal structure can be a different potential from the ONT ground from a GPR and cause arcing if the voltage is sufficient enough to break down the insulation.

![Example of visible arcing after staples were removed from the side of a mobile home. The premise wiring is dry, cracked, and rotten.]

Figure 24. Visible Arcing to POTS Wiring

12.) Ensure the power company and customer have the AC meter bonded to a ground rod as required by the NEC.

Why is this important?

Large GPRs can develop between the ONT ground and the AC power if this is not done, which can damage the ONTs. Figure 25 is from a site that had chronic lightning damage; the meter ground had been cut some time in the past. The closest AC ground was a pole about 100 feet away. The customer lost several ONTs from lightning, but is lucky they have not had a house fire or someone electrocuted.

![Figure 25. Dangling Ground Wire]

Figure 25. Dangling Ground Wire

13.) Although actual data is limited, a 3 prong surge suppressor for the 2 prong UPS’s is recommended. This is not needed for 3 prong UPS’s as the protection to ground is built in.

Anecdotal information, data, and theory indicate that there is a potential for 3-prong UPS to be more robust and provide better protection. CyberPower® 3-prong UPSs, when tested for lightning, are in fact better at protecting the UPS and possibly the ONTs from AC surges.

Summary

Understanding the basics of how lightning can be induced and how GPRs can create very large voltage gradients in "fiber to the home" ONT metallic ports (such as POTS, Ethernet, or power/alarm) helps design installations and institute common precautions to make ONTs as immune as possible to the effects of the lightning surges. Although ONTs were once thought to be relatively protected (or inherently immune) from lightning, field data from around the world indicates the opposite conclusion. Following the precautions recommended in this guide might not entirely eliminate all causes of ONT damage; however, it will improve the chances of the ONT surviving the effects of lightning transients.

In addition, manufacturers such as ADTRAN have recognized the threats from lightning that are present on the customer interfaces of the ONTs and have been working with standards bodies such as Telcordia, ATIS (Alliance of Telecommunications Industry Standards), and the ITU (International Telecommunications Union), to identify these issues and develop industry tests to demonstrate increased levels of robustness. In response, ADTRAN is completing the process of increasing the robustness to meet these new test standards, and is one of the first to do so. A coordinated effort of addressing the threats in the installation and increased robustness in industry standards is aimed at bringing the reliability of ONTs to the levels expected by service providers and customers. Feedback and follow-up will be a continuing effort at ADTRAN to improve reliability of ONTs with regard to lightning reliability to the greatest extent possible.

Finally, the two diagrams below illustrate a “Better” and “Best” installation respectively from a conceptual perspective.
Figure 27. “Better” ONT Installation Configuration
Figure 28. “Best” ONT Installation Configuration
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