HIGH VOLTAGE INTERFACE APPLICATION: PROTECTING CRITICAL COMMUNICATIONS NETWORKS WITHIN HIGH VOLTAGE CORRIDORS

By Pradip Sheth

Communications equipment (telephone lines, SCADA RTUs, transfer trip, metering circuits etc.), in power substations, often serving the critical operation of the power plant, are subjected to the proximity of high voltage environments. In North America, Europe and Asia, zoning laws are now increasingly mandating utilization of shared facilities; as an example, utilizing high voltage transmission towers for mounting cell site communications equipment. This requirement has resulted in cellular communications equipment being mounted in close proximity to high voltage environments; a situation that had not existed previously. The primary reasons for the changing zoning laws are to:

- Reduce the associated costs of constructing communication towers.
- Minimize the number of tall structures to preserve and protect the environment.
- Maintain rural ambience and minimize adverse visual impacts.
- Protect citizens, wildlife and property from the hazards posed by tower structure failures.

GROUND POTENTIAL RISE (GPR)

Power generating stations, substations and now these co-located cell sites are continuously being subjected to errant current flows causing Ground Potential Rise (GPR) during high voltage fault conditions; for example, when a high voltage power line falls or otherwise shorts to ground, or from lightning strikes energy. Other factors that create power surges and errant current flows are power switching operations and capacitor bank switching by the local utilities.

During a GPR event, the voltage potential of the substation ground grid or the co-located cell site/power transmission tower ground, can rise to several thousand volts, while the phone company's CO ground remains at near zero potential. A metallic link between the location of the GPR and the CO provides a conductive path for this high GPR voltage to propagate to the CO. The high voltage associated with GPRs can cause serious damage to telephones, copper communications facilities (e.g. POTS, SCADA equipment RTUs, T1 or HDSL circuits) and Central Office (CO) switching equipment. Communications equipment can be completely destroyed, line cables can be vaporized and anyone who is in contact with telephone equipment or lines could be in fatal danger. The hazards posed by high voltage fault conditions to personnel and communications equipment, are therefore, real.

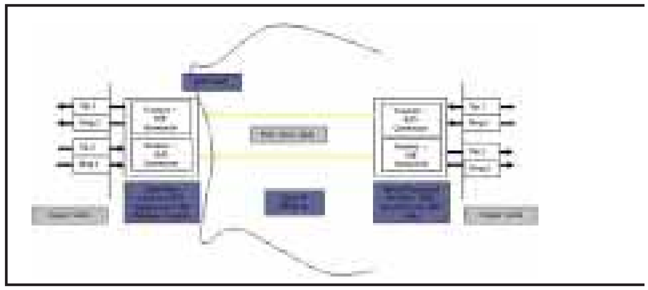

Figure 1: Fiber Isolation Equipment Topology

THE HIGH VOLTAGE INTERFACE (HVI)

In an environment subject to GPR of over 1000V, it is recommended that a high voltage interface (HVI) be deployed. In North America, IEEE 487-2000 standard recommends the practice for designing an HVI to protect sites, maintain proper operation of the wireline communications equipment and ensure the safety of personnel.

The primary function of the HVI equipment is, therefore, to isolate and protect the wireline telecommunications circuit from high-voltage surges resulting from a Ground Potential Rise (GPR). The isolation technique recommended for an HVI interface is analogous to the functionality of a river dam. A river dam at all times attempts to regulate the water surge on one side of the structure (even during heavy rains or spring snow melts), maintaining a controlled water flow through to the other side of the structure. This concept is similar to that proposed by the HVI, which keeps the sudden high voltage surge of a GPR (much like the sudden increase in water flow in a dam due to heavy rains or spring snow melts) to one side of the copper circuit and transparently lets through the telecommunications information flow (signaling and data) to the other side.

The HVI proposes that the metallic pair be cut with the insertion of isolation equipment(s), bridging the gap. The two ends of the break are identified through a common nomenclature:

- The Customer Premises Equipment (CPE) side or the station side, which is the end of the copper circuit routed to the power station or the cell site, connecting to the CPE equipment.
- The Central Office (CO) side, which is the end of the copper circuit routed to the telecommunications provider's CO equipment.

The CPE side generally experiences the GPR due to its proximity to high voltage fault conditions (power station or transmission tower ground). The CO side on the other hand, normally maintains the lower ground potential of the remote Central Office. At the moment in time when a GPR event is taking place, the function of the HVI equipment is to:

- Properly isolate the CPE and the CO sides from each other in order not to let damaging currents flow through the copper circuits by either utilizing magnetic coupling transformers or by fiber optic isolation.
- Keep the CPE side ground at the same high-voltage potential as the fault ground potential, creating little or no opportunity for damaging current flows to take place on the station side equipment.
- Keep the CO side of the circuit at or near the potential of the CO, limiting damaging current flows on the CO side of the HVI equipment.
- Reproduce the communications

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information (data and signaling) on either side of the HVI splice, allowing for full duplex information flow to be maintained.

ISOLATION/PROTECTION USING FIBER OPTIC TECHNOLOGY

Optical fiber is extensively utilized in telecommunications networks today and its properties are well understood by the telecommunications providers including the IT departments of power companies. An optical fiber is a non-conductive material that has the capability to break the conductive bridge of the copper circuit. When inserted in the telecommunications circuit, the fiber optic cable provides an ideal isolation/protection medium (it will carry no current and eliminates the hazards of short circuits seen in copper cables). The fiber optic medium provides a comprehensive means to isolate all types of telecommunications circuits whether their operation entails AC or DC currents. The fiber optic HVI equipment does this by encoding the communications information and performing Electrical/ Optical/ Electrical (EOE) conversion.

The network topology most suited to fiber optic HVI is a dual assembly design as depicted in Figure 1. The CO side assembly is deployed at the 300V point (mid-span) also termed the Cable Fiber Junction (CFJ) and performs the O/E (transmit direction) and E/O (receive direction) conversion. The station side assembly deployed inside the 'zone of influence' at the Optical Equipment Interface (OEI) or the CPE side, performs the E/O (transmit direction) and O/E (receive direction) conversion. Both assemblies are interconnected using a non-conductive fiber optic cable.

Use of a fiber cable at the mid-span is totally transparent to the copper circuits at the CO and the CPE: all copper connected network equipment at the CO and the CPE continues to operate, without the knowledge that a fiber cable has been inserted in the span. The fiber optic HVI equipment reproduces all signaling and data information completely.

Depending upon the requirement of the site, the fiber span used can be as short as several feet or as long as several thousand feet using Multi-Mode or Single-Mode fibers. Figures 2 and 3 show the topology of a fiber optic HVI deployed to protect telecommunications circuits at a co-located cell site and at a power station respectively.

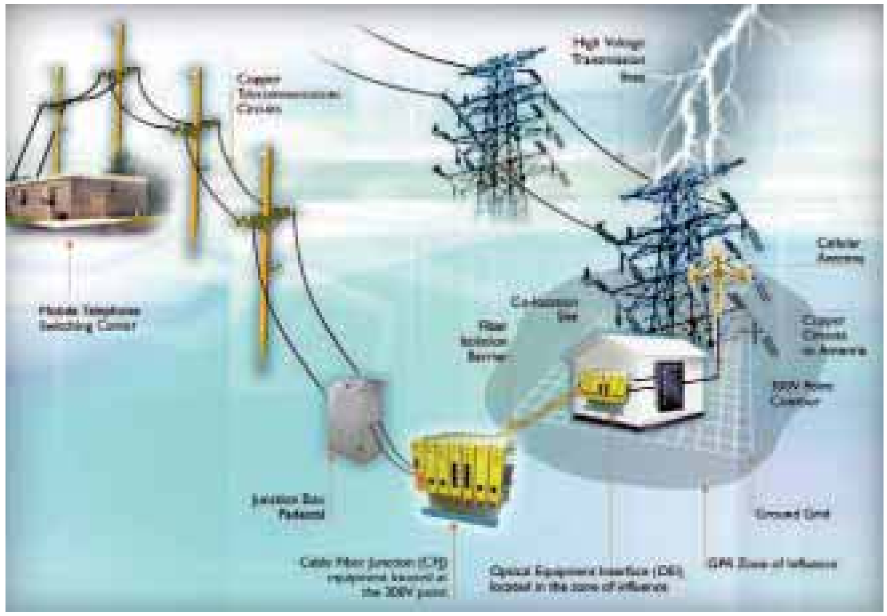

Figure 2: Fiber Isolation at a co-location site

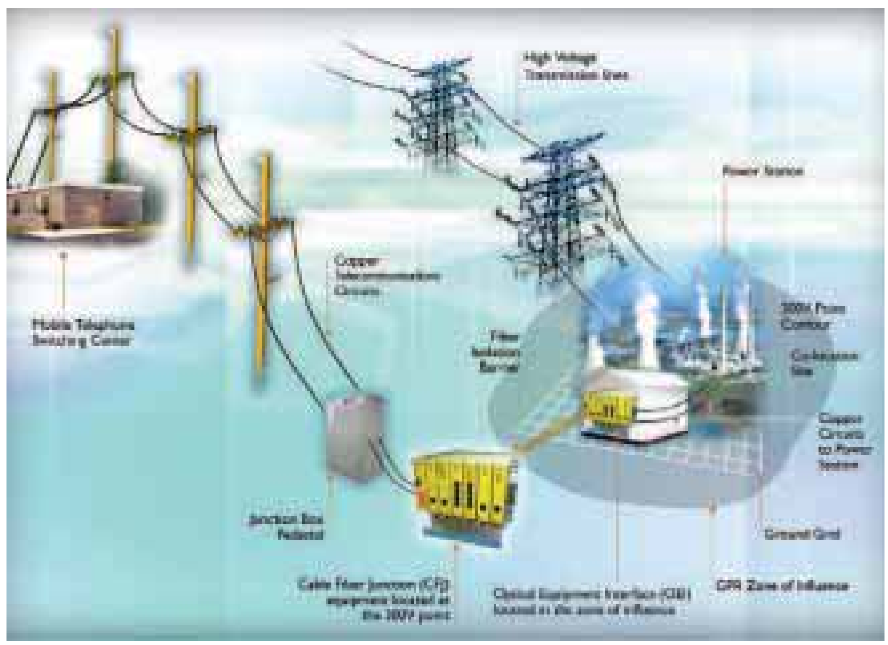

Figure 3: Fiber Isolation at a power station

CONCLUSION

Design of a robust and maintenance-free communications network in high voltage environments is possible by using state-of-the-art fiber optic HVI technology. The advantages of creating such a communications network, critical to the operation of the power plant and for the survival of the telecommunications and transmission network infrastructure, far outweigh the costs associated with:

- The replacement of damaged or destroyed communications equipment.
- Lost revenue from the loss of real-time communication equipment.
- The cost associated with dissatisfied customers.
- Indirect costs associated with injury to personnel.

Proper architecting of the communications facilities in high voltage environments will require close co-ordination between the power company, the cellular service provider and the local wireline communications provider (ILEC or CLEC).

This investment in time, effort and cost is well justified to preserve a high availability telecommunications network infrastructure, in close proximity to high voltage corridors.

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