SMARTGRID APPLICATIONS USING NARROW BAND POWER LINE CARRIER IN UNDERGROUND POWER DISTRIBUTION SYSTEMS. PLC FAULT LOCATOR

José Antonio Moreno
Dimat (PLCoupling) – Spain
jam@dimat.es

Rafael Quintanilla
ZIV P+C - Spain
r.quintanilla@ziv.es

ABSTRACT

Within the scope of distribution automation, there is a wide range of applications that should work co-ordinately. As the devices supporting such applications are, in general, spread over a large part of the distribution network, one of the key issues to be considered is the communication, understood as: technology, equipment, protocols, standardization… Since equipment and functions are located at different hierarchical levels, they should be able to share information among them, no matter their relative position within the hierarchy. It is also important, in order to minimize restrictions, to have the possibility of using various technologies even to support the same application.

One of the most important targets of distribution automation is to detect any fault in the network and to report on it as soon as the failure occurs and, at the same time, to provide accurate information about the location of the fault. Any improvement in the time required to know where the fault occurred will directly minimize the time to isolate the faulty feeder section and restore the network and service to those customers not fed through it.

Fault location in a distribution network is much more difficult than in a transmission network; usually the protection functions and the fault location associated to them are at the substation where the distribution feeder has its origin. Due to the complex topology of downstream network, the calculated value is far from being as accurate as needed for a fast and reliable service restoration; so any method that helps to locate the faults, as soon as possible, is welcomed.

Fault indicators, based on various indication methods, have been a solution applied for long time, helping the Distribution System Operator to improve its response after the inception of a fault. This paper describes an application for the location of faults in underground urban distribution networks. It is build-in on a detection/communication device that, connected to the feeder at distribution centres, measures the current and, after the fault clearance by the feeder protection at the substation, triggers the communication system and sends a message indicating if it detected or not the fault. This information is addressed to a processing unit (may be the feeder protection or the substation central unit) that determine the real location of the failure.

The communication is supported by a narrow band PLC built in modem that couples the signal to the ground shield of the power cable to reach the substation, directly o through other communication technologies as: optical fibre, GPRS, Broad band PLC… Once at the substation, and after processing all messages received from the detector involved in the fault, the fault location is calculated and sent to the control centre or used to initiate an automatism that sends commands to the switches along the feeder to restore the path to the electrical power, keeping the line ready to be powered by the recloser at the feeder protection.

INTRODUCTION

Using the high voltage electric conductors to transmit high frequency signals (40 to 500 kHz) is not a new technology. Such technology, known as power line carrier, is in use by power utilities since the early 20th century to transmit teleprotection signals and other data.

The high voltage transmission system topology allows for point to point power line carrier connections between substations, covering distances up to few hundred kilometers. Blocking coils are used to isolate the high frequency transmission over the power line from the substation impedance. The signal transmission is achieved using capacitors and coupling units as line tuners.

In medium voltage distribution power systems, mainly in urban areas, the usage of blocking coils is not an economical option due to the system topology and impedances, with transformer and switching vaults located few hundred meters apart. Also, the characteristic low impedance of distribution underground cables doesn´t favor the adaptation of impedances to power line carrier frequencies.

This document proposes the usage of the shield in the medium voltage underground distribution cables as the transmission media for power line carrier signals.

The application included in this paper shows how to integrate and communicate intelligent elements to locate short-circuit faults in medium voltage underground distribution systems using a PLC Fault Locator.

UNDERGROUND CABLES AS PLC

TRANSMISSION MEDIA

The layered construction of some underground power distribution cables can be compared to the structure of coaxial cables.

The inner conductor is covered by an insulating layer, in turn covered by a shield. This shield is connected to ground in the medium to low voltage transformation centers.

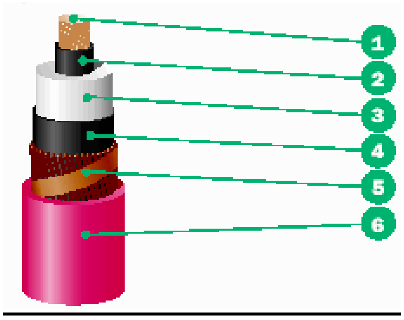

Figure 1 – Underground Distribution Cable

1. Conductor
2. Semiconducting layer
3. Isolating layer
4. Semiconducting layer
5. Metallic shield, outer layer

The shield in underground cables can perform different functions, such as:

- Confining the electrical field in the cable
- Symmetrical and radial distribution of the electrical energy
- Reduction of the mutual influence between adjacent cables
- Diminution of electrocution dangers

This list can be completed with a new function

- Transmission of PLC signals between transformer and switching vaults

The characteristic impedance of an underground distribution cable is determined by its construction and defined by the electrical parameters of inductance per meter (L), and capacitance per meter (C).

The typical values for these parameters provide an impedance range between 10 and 50 ohms, contrasting with the much higher values of overhead cables ranging between 200 and 600 ohms.

The blocking and tuning elements used in high voltage are not economically justifiable in medium voltage systems. Besides, in most cases, the space constraints in the underground vaults prevent the usage of such elements.

The transmission of high frequency signals via the cable shields makes the communication path independent of the electrical connections in the distribution system. This is an advantage in systems where loads are feed from multiple points and certain circuits can remain open.

The characteristic impedance of the shields is not as constant as the impedance of the medium voltage conductors, but the use of inductive couplers permits utilizing the path provided by the three phases providing a physical conductor between vaults.

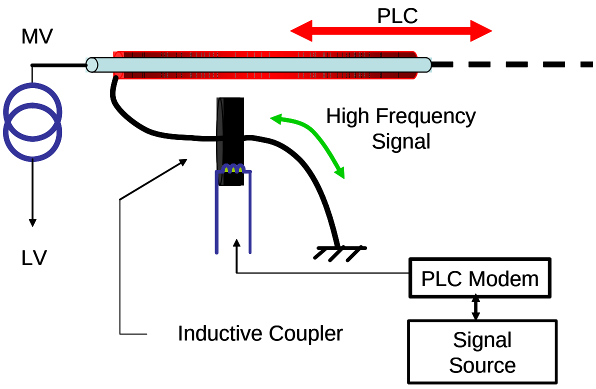

Figure 2 – Induction via the shield.

Example of the communication path for the high frequency signals via the inductive coupler and the medium voltage underground cable shield.

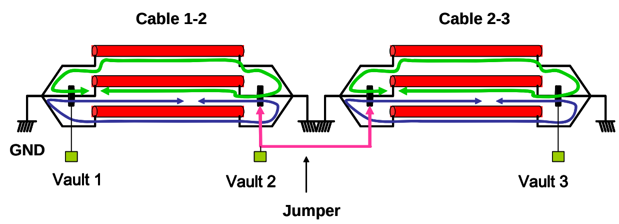

Figure 3 – Jumper between inductive couplers.

The high frequency signals travel from vault to vault via the current loops between the cable shields in each phase.
The signal advances between vaults creating links between the couplers.

Although there are not standards for this type of communications, the frequencies utilized in Europe are defined by the standard CENELEC EN50065 for Band A.

Note that this standard is not specific for communications in the medium voltage system but for data transmission in low voltage installations in the 3 to 148.5 kHz band.

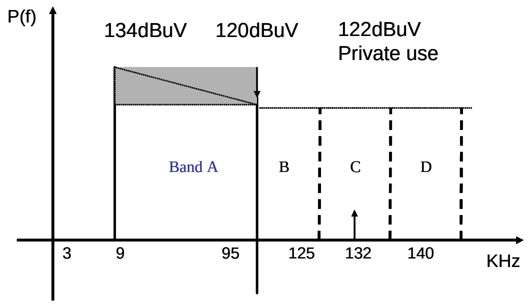

Figure 4 – Frequency bands for use by power utilities

The low frequency signal power is determined by the band used. Band A ranges from 9 to 95 kHz.

PLC FAULT LOCATOR: APPLICATION OF NARROW BAND POWER LINE CARRIER IN THE SHIELD OF UNDERGROUND POWER DISTRIBUTION CABLES.

The PLC Fault Locator is used to locate short-circuit faults in the distribution system. The integration of PLC modems in the transformer and switching vaults, communicates the fault detection to the control center in a short time.

The principle of operation is that the fault current will only be detected by those devices located in the path to the fault. Knowing the system topology and the location of the detectors, it is possible to pinpoint the faulted cable section. In the example shown in figure 5, the fault is between the vaults 6 and 7.

The effective usage of the medium voltage lines as communication paths is limited by the existing noise and interference. The PLC Locator using the cable shields takes advantage of the application. In most cases, when the devices communicate the fault detection, the distribution feeder is dead after the operation of the protection relays. Therefore the noise generated by the AC power of 50 or 60 Hz or by the loads and apparatus connected to the grid is minimized or nonexistent. In the field trials for this application, the communication signal in the shield presents a high efficiency.

Existing Fault Locators activate an optical indication or radio signal. Using power line carrier, the information can be sent to a secure location from where to relay it to the control system via the Scada system, cellular GPRS modems, or other medium.

as a consequence.

A PLC Fault Location system also integrates functions such as remote setting programming for the different fault detectors, or remote access to the system sequence of

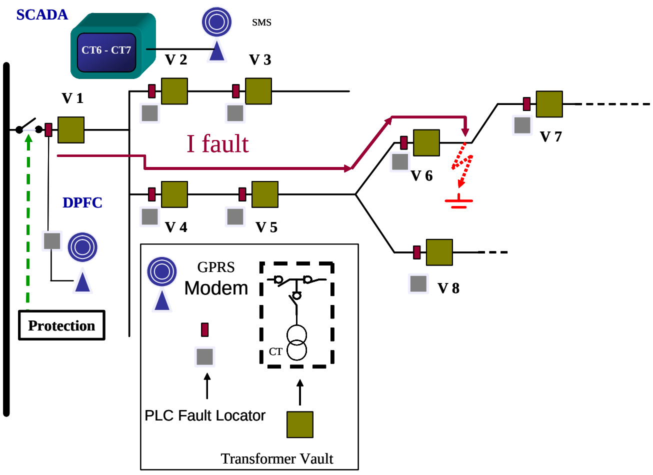

Figure 5 – Detector operation

The PLC modems used in this application do not require high complexity, since they do not have high levels of noise.

The Fault Locator system of detectors with PLC communications still requires a robust and efficient system.

There are multiple ways to configure the communication system. In a system where the fault detectors communicate with the control center via cellular GPRS modems, as show in figure 6, it is possible to minimize the usage of cellular modems.

By using PLC, some of the PLC modems act as a concentrator for other detectors using PLC communications.

With a master-slave configuration, the masters have a polling system to update the status of the slaves. The efficiency of the PLC communication system determines the maximum number of slaves that a master can handle.

Creating PLC islands is possible to monitor the complete distribution system.

In the example on figure 6, the whole system is monitored by 3 masters or concentrators that relay the information to the control center.

In case of a short-circuit and trip by the protective relays, the master detectors can send the status of each detector in the system via GPRS, SMS, LAN, BPL, fiber optics or any other Scada communications available. This system enables a fast location of the faulted section with a fast restoration events, alarms, and load profile records.

In those locations where the cable shields are not accessible, it is possible to communicate via the conductor itself using power line carrier with capacitive or inductive coupling devices.

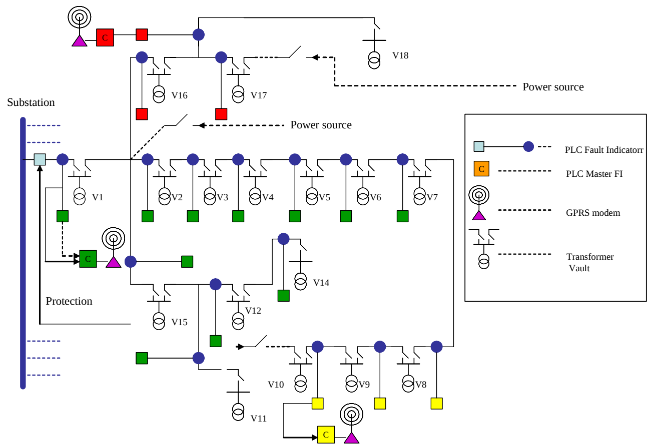

Figure 6 – PLC Fault Locator system