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D2- 312

CIGRE 2014

Smart Communication System SCS

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SUMMARY

The current telecommunication infrastructure for Electrical Utilities is based in about 90% on TDM techniques deployed through fiber optic rings, linear radio or power line carrier links. The nature of the electrical grid is a Mesh, so why not to take advantage of the heterogeneous infrastructure deployed over such grid implementing automated traffic transit independently of the technology existing on each point to point link?

Smart Communication System (SCS) defines the operation philosophy for the interface of new generation power line carrier equipment PLC [1] with legacy fibber optic and radio communication systems converging all them in a homogeneous communication network allowing packet switching over the mesh grid using all existing point to point links even if they are TDM nature.

SCS allows the implementation of the SMART GRID over the power transmission lines establishing the bridge between the smart generation systems, the control center and the distribution grid.

Power line Carrier is evaluated as the key element to convert the transmission grid into a packet switching network taking advantage of existing TDM structure as well of modern packet switching devices.

Traditional scada protocols inside the Substation are TDM (DNP, MODBUS) transported to the control center by TDM protocols as well (IEC 60870-5-101 or DNP 3.0) by TDM network topologies as fiber optic ring or linear PLC or Radio links. The commutation on intermediate sites is performed by means of human intervention which will take minutes, hours or days in case of failed node difficult access.

New trend of Scada protocols are packet switched based (IEC 61850) inside substation and also on the pat to the control center (IEC 60870-5-104) are being deployed by the implementation of pure packet switched platforms (Layer 2 and layer 3 switches). On this technology, all traffic routing and switching is performed automatically without human intervention.

However, the challenge presented is how to take advantage of the existing TDM infrastructure in order to incorporate the packet switching technology of new nodes.

The Power Line Carrier equipment with routing capabilities merge as the key element that provides reliability of the communication channel (the power line itself) and the way to perform the commutation of the packetized Voice and data and providing as well the necessary interface to existing fiber optic or radio links, taking advantage of each of their point to point links in order to establish a smart communication system representing a hybrid platform capable of transport TDM and IP protocols.

KEYWORDS
Smart - Communication – System – Digital - Powerline – Carrier - Routing, Electrical - Substation

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1. COMMUNICATION SCHEMES

1.1 CRITICAL SERVICES

Critical services are those related to the critical communications functions of an electric system which are essential for the network operation, see Figure 1.

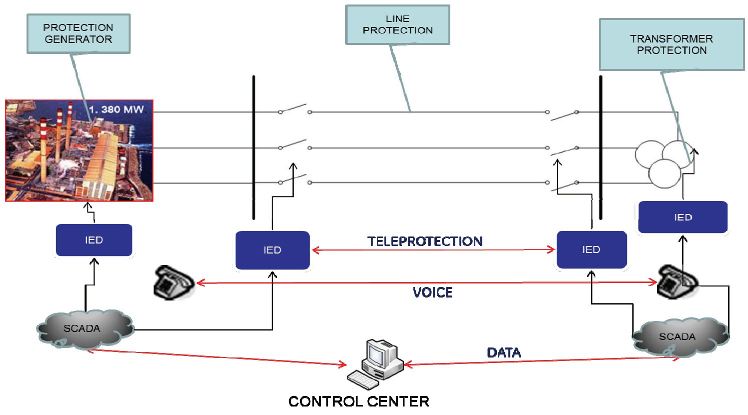

Fig. 1 Critical services in an electric energy transmission system

The services, in order of importance, are as follows:

1.1.1. Teleprotection [2]. The transfer of potential free contacts between two ends of a 115 kV^{+} power line in accordance with the transmission times as specified by IEC 60834 [3].
1.1.2. SCADA. Serial or IP data transmitted from a substation to the control center and vice versa which allows a central control system to analyze and make decisions based on the actual electrical system parameters.
1.1.3. Voice. Traditional voice communication or VoIP required for communication between the control center and the substations operators.

1.2 TRADITIONAL COMUNICATION SYSTEM

The majority of communication systems implemented today are of the origin-destination variety where the communication path is fixed or predefined with respect to the communication path for the voice and data.

A traditional scheme, see Figure 2, consists of a substation with the internal communication addressed via a protocol such as DNP or MODBUS via a serial data channel. This information is typically communicated via a data concentrator to the control center via a similar protocol such as DNP or IEC 60870-5-101.

The communication of information between the origin and the destination is addressed by linear or ring based fiber optic systems via point to point links of the same type (same system, such as series radio links) or of different types interconnected between them in a linear fashion (for example radio link in series with power line carrier link) maintaining a fixed route between the origin and destination.

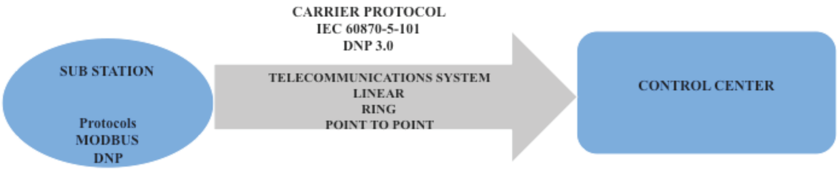

Fig. 2. Traditional communication system

The interface between each link regardless of technology (radio, power line carrier, fiber) is achieved via direct hard wiring, see Figure 3, between universal serial interfaces (V.24/RS-232) for data or 2/4 wires (FXS/FXO/4W E & M) for voice.

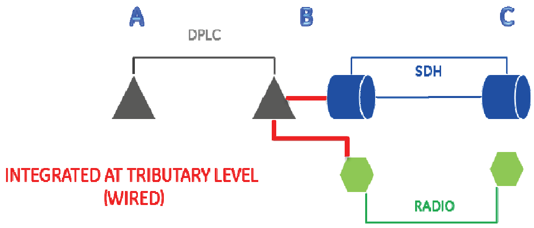

Fig. 3. Link interface between conventional linear or sequential

In Figure 3, the switching between and A and B must be made manually should a failure occur causing a temporary interruption between A/B and C which could last minutes, hours or days depending on the location of the substations in question.

1.3 TREND IN MODERN COMMUNICATION SYSTEMS

The dawn of packet switching platforms has impacted the trend in coding formats for voice and data to the point that voice compression algorithms and IP based SCADA protocols are being widely implemented in electrical substations. SIP (voice) and IEC 61850 protocols represent the latest trends and both are supported by Layer 2 packet switching platforms on LAN. For WAN networks, the IEC 60870-5-104 over Layer 3 switching establishes communication paths to the control center. This represents the most advanced stage of the old SCADA networks which consisted of voluminous quantities of copper wires carrying the signals, measurements and controls of the equipment located in the substation yard to a field interface cabinet located in the substation, which had a number of transducers that made appropriate electrical conversions for the Remote Terminal Unit (RTU). RTUs typically ran a proprietary protocol and were centralized units.

This configuration evolved into a system composed of Data Acquisition Units (DAU - climate controlled cabinets located next to the substation bays), interfacing with IEDs (intelligent electronic devices) and distributed multifunctional devices (protection, measurement, signaling) converting the information transport media from copper cables to optical fibers for transport to the Human Machine Interface located in the control house.

Today, there is a proposal to replace the DAU with a compact, environmentally harden product known as a "brick" located in the frames of the high-voltage equipment that converts the information from copper cables to optical signals. The other trend is the use of PMU (Phasor Measurement Unit) or Synchrophasors; these units give us a tool to see the energy system as a whole or to compare different points in real time.

Teleprotection has not escaped this trend. Signal transport has evolved from external equipment between the relay and the telecommunications equipment (power line carrier, PDH, SDH) with interfaces ranging from 4 Wire to 64 kb/s to 2 Mb/s, to being an integrated as part of the telecommunications equipment in the form of specialized cards interfacing directly to the relays, to becoming an integral function of the actual relays using electrical or optical ports connected to telecommunications equipment.

It is important to note the high reliability and improved response times that have been achieved by interconnecting protection relays (distance, current differential) via a dedicated DWDM or CWDM multiplexer, a configuration very close to the benefits of a dedicated fiber optic pair, but more cost-effective. As a result to the sustained development of teleprotection, the IEC 61850-8-1 protocol considers that the relays possess a "GOOSE" interface and IEC 61850-90-1 defines the communications between substation relays via an Ethernet LAN, not only for configuration purposes but for the actual communication of the protection commands (trips) via IP.

A modern scheme, see Figure 4, consists of the substation communication addressed by an IEC 61850 IP ETHERNET Network communicating with a control center using a similar type IP protocol such as IEC 60870-5-104.

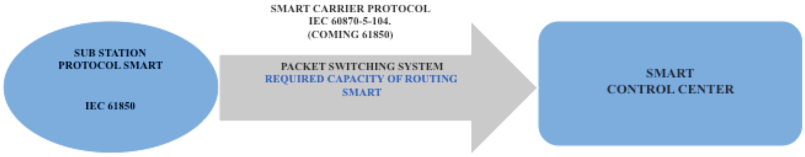

Fig. 4. Modern communication system

Under this topology, the communication between sites B and C, see Figure 5, have a redundant link allowing the implementation of a routing protocol permitting automatic switching between links when one of them is not available.

Fig. 5. Automatic Switching in modern systems.

This switching is performed automatically requiring no human intervention. In general terms, this provides isolation, differentiation, quality of service and recovery mechanism.

2. SMART COMUNICATION SYSTEM (SCS)

Is defined as a generic platform capable of directly interfacing with traditional TDM based substation protocols or modern IP protocols for the transport of voice and data in a hybrid mode (TDM/IP), see Figure 6. This system takes advantage of the meshed structure of the electrical grid without discriminating between the technological nature of the existing communication platform in each transmission line (Radio, power line carrier fiber).

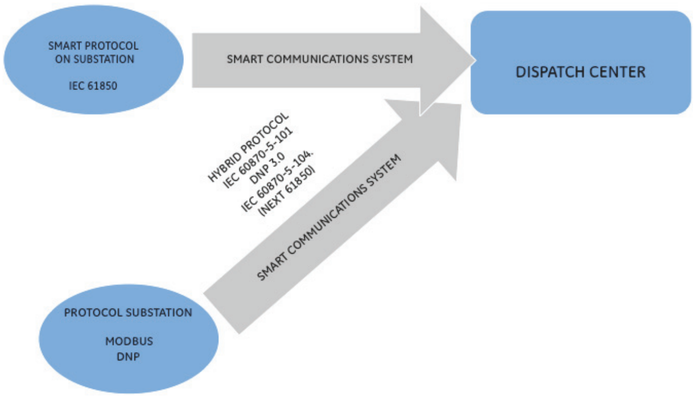

Fig 6. Smart Communications System Scheme

The switching between the different links of the network is implemented automatically by routing algorithms including OSPF (Open Shortest Path First). OSPF has emerged as a simple and effective alternative for the size of the grid in which each substation acts as a switching node or decision making node with respect to which path is more convenient for the transmission of the packets of information.

3. DIGITAL POWER LINE CARRIER AS THE INTEGRATION BRIDGE BETWEEN TRADITIONAL AND MODERN COMMUNICATION SCHEMES

The implementation of routing systems arises from the need for communication in electrical systems. Typically, routing systems cannot be completely implemented because a high percentage of the existing communications infrastructure is based on linear TDM based technologies. Due to this limitation, there is a need for communications equipment that can make the link between TDM and IP technologies while permitting the coexistence of both technologies and the gradual migration to an “All-IP” system.Additionally, the need for the coexistence of TDM protocols (IEC 60870-5-101 or DNP) and IP protocols (IEC 60870-5-104) also arises.

The reliability of the communication link is an important consideration in the integration of the link. Since optical fiber systems are susceptible to breakage and wireless communications are susceptible to weather conditions ("Fading") and losses due to antenna misalignment, power line carrier equipment reappears as a fundamental technology under the premise that while there is a power line to protect, there is a communication channel for that protection - the same power line itself.

The basic incentive to use power line carrier is that the grid provides an infrastructure that is much more extensive and widespread than any alternative wired or wireless one. This will allow all the equipment powered by electric lines to potentially become the target of value-added services.

Electric utilities prefer to have their own communications infrastructure then power line carrier offers this opportunity. Power lines are everywhere. Even rural areas can be covered by power line carrier as the power lines are there and can be used to provide these areas another technology where others which may be more costly and time consuming to implement.

A digital power line carrier (DPLC) terminal with the capability to provide both direct asynchronous data and IP data as well as voice compression is an ideal alternative to implement TDM/IP communications in a power system. The DPLC equipment with intelligent routing capability can automatically and in real time reconfigure the path of the information without the source or destinations nodes noticing these intermediate changes.

Additionally, a good reason to use power line carrier is the recent push to modernize the aging power grid through an information highway dedicated to the management of generation, transmission and distribution of energy, the so-called Smart Grid.

Smart Communication System doesn’t represent the alternative or replacement to existing communication platform. It represents the smart way to provide intelligence and reliability improvement to the existing communication platform of Electric Power Networks

4. RELIABILITY OF SYSTEMS SUPPORTED BY DPLC WITH INTELLIGENT ROUTING

A graphical analysis of linear systems typically implemented in electrical transmission systems shows the dramatic decrease in the probability of losing the voice and data communications when such systems use Line Carrier that provides intelligent routing as backup

For a three substation communication system, we have the following representation, figure 7:

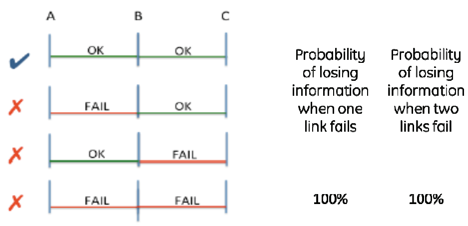

Figure 7. Three node linear communication link

Performing the same analysis on systems with additional links and in case of a single point of failure, the percentage of loss in communication from the source to the destination will be always 100%, If the same link in figure 7 is supported by Digital Power Line Carrier with smart routing capability, the percentage of losing communication is reduced to 0%, see Figure 8.

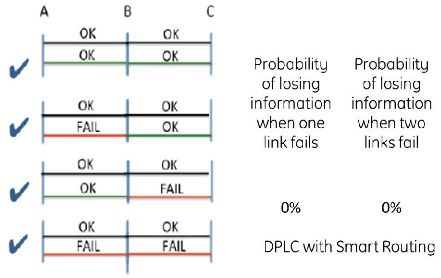

Figure 8. Three node linear communication system backed up by DPLC with smart routing. Single or double fault on main route

If we consider a more common and repetitive case in electrical systems such as the simultaneous failure of two different media of communication, fiber and power line carrier for example, the probability of loss of communication with a DPLC backed system would be reduced to 50%, see Figure 9.

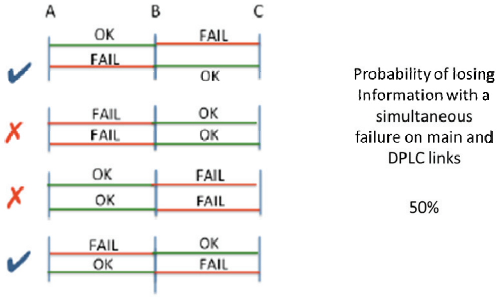

Fig 9. Simultaneous failure on main and DPLC links with smart routing

Performing the same analysis on systems with additional links with DPLC backup, considering simultaneous failures, we have a dramatic decrease in the probability of loss of communications, see Fig. 10.

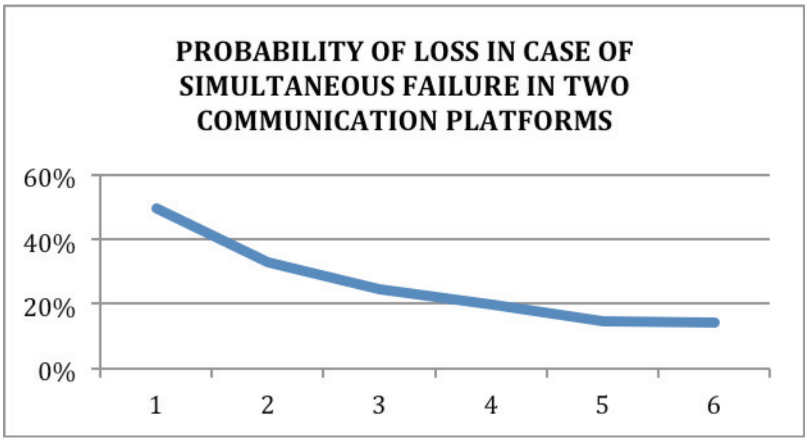

Figure 10. Reliability improved with DPLC Backup

The previous analysis corresponds to linear links. We can infer that in a real meshed network with multiple switching routes, communication loss probability is lower and therefore more reliable communication path for critical services.

5. CONCLUSIONS

Implementing a Smart Communications Systems using digital power line carrier with intelligent routing capability is preferred over the existing traditional TDM communications platform in electric transmission networks.

The reliability of power transmission is the most important factor and the reliability of these networks is significantly enhanced with the implementation of a smart communications system. These systems can be implemented with existing optical or radio communications platforms regardless of the make and model of these systems.

The smart communications system allows for the efficient use of naturally meshed electrical networks implementing packet switching, integrating TDM and/or IP. The SCS use each of them as alternate transportation media for an intelligent, self-configurable network.

BIBLIOGRAPHY

[1] IEC 495. Single sideband power-line carrier terminals, second edition 1993-09. CEI 1993. SWITZERLAND.

[2] GE PROTECTION & CONTROL. Relaying Communication Channels. GET-8034. USA.

[3] IEC 60834-1. Teleprotection equipment of power systems. Second edition 1999-10. CEI 1999. SWITZERLAND.