EVALUATION OF COMMUNICATION COMPONENTS FOR MONITORING SMALL HYDROELECTRIC PLANTS

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ABSTRACT

In Brazil, SHP (Small Hydroelectric Plant) has been used as alternative to generate cleaner and renewable energy. These small power plants are between 1 and 30 MW and are located in rural areas. The SHP should be supervised from an OCC (Operational Control Centre) located, usually, at one substation. For that, several data communication technologies can be used as: Leased Line, Private Line, GPRS (General Packet Radio Service), among others. This paper presents the study how the PLC can be used as alternative service for monitoring and control of SHP, describing the functional and non-functional requirements to be met to the PLC specification. In addition, the paper focuses attention on the new strategies required for controlling and monitoring at Smart Grids and shows how PLC could have a key role among the technologies that can be applied.

INTRODUCTION

This paper describes the requirements needed for monitoring and controlling (supervisory) of SHP (Small Hydroelectric Plant) through the PLC technology as communication with the OCC (Operational Control Centre). The communication between SHP and OCC is very important to assure the integrity of the transmission of electric energy, so the Smart Grid concepts should be considered in the requirements for controlling and monitoring of SHP.

The Smart Grid is based on intensive use of information and communication technology (ICT) to monitor and control the power electric network, which will allow the network management with more efficiency. The Smart Grid allows the convergence between generation, transmission and distribution infrastructure with data communication and processing infrastructure.

The smart grid is composed of generation, transmission, distribution and consumer, as shown on figure 1:

- Centralized and Distributed Generation: The centralized generation is the conventional way of electric power generation. It consists on medium or large generating plants. Nowadays, a distributed generation, composed of small power generation plants closed to the load is used. The main issue of Smart Grid derives from the introduction of energy sources with different characteristics on the same electrical network infrastructure. These new situation requires the development of intelligent techniques in order to accommodate their features seasonal and intermittent chain energy optimization of the system.
- Transmission: The transmission system is responsible for connecting the various power generators to consumers through the distribution system. Systematic failures in the transmission system may result in dismissal of part or all of the electrical system. Transmission systems are supervised and controlled through the SCADA system, which measures processing scans analogy quantities (voltage, power flow, etc.), and states of switches and circuit breakers (open / closed), with sampling rates with range of 2-10 seconds. [1] [7] [8]. The technological advances in the areas of sensors, measurement devices and digital communications are allowing a volume of high quality information on the conditions of operation from electric system;
- Distribution Systems: In the distribution systems is being used the electronic measurement equipment, which enables real time reading of consumer demand, detection and isolation of faults or restoration and reconfiguration of services.
- Consumer: The Smart Grid allows monitoring of consumer demand by sending data on how to use the grid for it, besides the possibility of small generation capable of producing energy for own consumption and even selling to the utility.

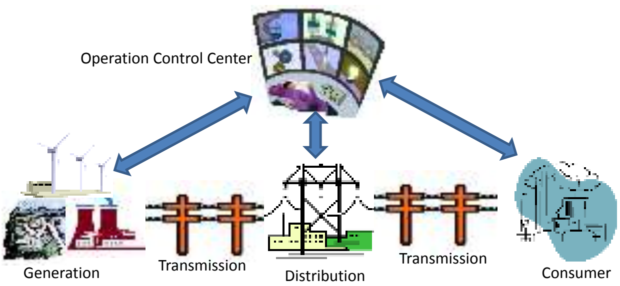

Figure 1. Overview of smart grid components

SMALL HYDROELETRIC PLANTS

According to Resolution No. 394 of 1998, April 4th of ANEEL (Brazilian National Agency of Electrical Energy) [3], the SHP is a hydroelectric power plant whose capacity is from 1 through 30 MW, and the reservoir area must be less than 3 km2. A typical SHP operates with water falls, so in the seasons of reduction of the flow rate available, the generation capacity of the turbines is less than the optimum, causing idleness. Therefore, the cost of electricity generated by SHP is larger than that of a large hydroelectric power plant. An advantage of SHP is that causes lower environmental impacts and lend themselves to decentralized generation; however it is necessary to have an effective smart grid, so the monitoring is an important matter to be considered.

Monitoring

The SHP must be constantly monitored so that actions are taken according to the usage of that moment, and for this, SHP must have devices to collect the information needed for decision making. The main information to be collected are: [4]

- Status from the generator;
- Signaling data from the generator;
- Control commands to the generator;
- Alarms;
- Events;
- Counters;
- Timers;
- Data Structures; and
- Files.

The OCC is responsible for receiving the information and take the decision of which procedure should be performed at each SHP. For that, it is necessary for both side the communication channel is reliable, with adequate capacity and cheap. Moreover, the communication channel must support multiple data types.

DATA TRANSMISSION TECHNOLOGIES

This chapter presents a short description of communication technologies that can be used for monitoring SHP.

Dedicated Line

Dedicated or Private wired data network can be designed to comply all requirements, however the implementation costs depends on the distance between locations.

Radio Frequency (RF)

The RF technology is based on the transmission of data over radio waves, in which the frequencies used worldwide are controlled by the ITU (International Telecommunication Union) and ANATEL (National Agency of Telecommunication) in Brazil. The scope of an RF communication may vary depending on the signal strength of the transmitter module and has a low cost compared to other technologies. However, the issue of accreditation and certification of the radio frequencies by the regulatory agency may be a problem.

GSM (Global System for Mobile Communications) or GPRS (General Packet Radio Service)

The cellular network, i.e.: GSM or GPRS, is an alternative due to low installation cost and wide coverage area, however the service has strong operator dependency. The GSM is a mobile technology that has been used in over 200 countries and more than one billion of people. The bit rate on GSM is around 9.6 Kbit/s, so there is a limited bandwidth. The GPRS is a technology that increases the rate of data transfer in GSM infrastructure. This allows the transport of packet data, so it provides a higher transfer rate (56 to 114 Kbit/s) than previous technologies, because the use of circuit switching. The GPRS has as main advantage the huge infrastructure of the telephone operator network, but has disadvantages such as cost and small and inconsistent coverage in rural areas. [4]

PLC (Power Line Communication)

PLC is a communication system that uses the power line cable to transport telecommunications services, so it allows data communication over the grid at low, medium and high voltage, with the advantage of use of existing physical resources. In PLC communication, each user must have a PLC modem. Due to the power line transformers, some signal are blocked, so it is necessary a bridge to over pass it. Some applications use PLC on frequencies below 60Hz, allowing the signals to pass through transformers, but these signals transmit data at low speeds. The factors responsible for low capacity of data transmission are changes in impedance, high levels of noise caused by switching devices and inductors. This degradation in the transmission rate caused by noises often restricts the applicability of the technology. Other issues still require better solutions, such as electromagnetic compatibility, lack of standardization and better regulatory policies.

The broadband PLC is a communication system that provides broadband services (voice, data, multimedia, video, etc.) using high voltage electric system that belongs to the existing electric utilities. The scope of the PLC is the provision of broadband services using one or more power cables in the distribution network, while providing electricity simultaneously. The PLC RF signal is modulated at the first point with the data signal and inserted into the distribution network, which serves as a transmission channel. At second point, the RF signal is recovered from the power grid with a signal demodulator for recovering the original data signal. The data is sent from the second to the first point in a similar way, only changing the frequency band. The broadband service is full-duplex, simultaneous two-way communication, between two locations.

The narrow bandwidth PLC does not require changes in the distribution network and any additional equipment for crossing distribution transformer. The communication is not affected by any power line equipment or abnormal conditions that may occur in the electric distribution network, such as capacitor banks, transactions for underground electric lines, voltage dips and harmonics. There are no blind spots for the system, which could be caused by phenomena of standing waves generated by the extension of electric power supply or on its configuration.

Due to the characteristic of each system, the present paper analyses de performance of narrow bandwidth PLC to monitoring services of SHP. A major problem for the consolidation of the PLC in the world is the lack of standardization for narrowband, so without a standard, there is no interoperability between different manufacturers. Some discussion forums, particularly in Europe, USA and Japan, were created by manufacturers and electric utilities to try to resolve this problem.

Summary of communications technologies

The table 1 presents a summary of each communications technologies, presented at this chapter.

Technology	Advantage	Disadvantage
Dedicated Line	• Independent; • Permanent connection; • Large bandwidth.	• High implementation Cost
GSM	• Easy to handle; • Low modem cost; • 9,6 Kbps.	• Operator dependent services; • No influence in case of problems; • Reachability; • No permanent connection; • Limited bandwidth.
GPRS	• Easy to handle • Low modem costs • Permanent connection • Cost effective tariffs • 56-114 Kbps	• Operator dependent services; • No influence in case of problems; • Reachability; • No permanent connection; • Limited bandwidth
Broadband PLC	• Independent; • High reachability • Permanent Conection • High frequency • High bit rate	• Higher technical effort • Noise; • Bridge; • Interference.
Narrowband PLC	• Independent; • High reachability • Permanent Conection • Low frequency • Low bit rate	• Higher technical effort • Noise; • Interference.

Table 1. Transmission technologies comparison

USE OF NARROW BAND PLC TO MONITORING SHP

This paper presents the activities of the research work for evaluating the possibility of using the narrowband PLC as a communication channel between the SHP and the OCC, considering the topology shown in Figure 2. [8, 9, 10, 11, 12, 13]

To evaluate the scenario, the present paper considers the following initiatives:

- PRIME (Power line Intelligent Metering Evolution) is focused on the development of a new open, public and non-proprietary telecommunications solution which will support not only smart metering functionalities, but also the progress towards the smart grid. The PRIME has specified a PLC that uses a OFDM (orthogonal frequency-division multiplexing), open and non-proprietary with focus on interoperability among equipment and systems from different manufacturers.
- G3 PLC is focused on the definition of an open standard for smart grid implementation. The G3 PLC is a standards-based power line communication specification promoting interoperability in smart grid implementations.

Both projects are using the OFDM to modulate the signal in narrowband PLC frequency. The OFDM signal is characterized by the sum of several sub-orthogonal carriers, with the data of each sub-carrier being independently modulated using some form of QAM (quadrature amplitude modulation) or PSK (phase-shift keying). A signal baseband is used to modulate the main carrier, used for transmission via radio frequency. The advantages of using OFDM are many, including high efficiency spectral immunity against multipath and noise filtering.

Combining OFDM with error correction techniques, adaptive equalization and reconfigurable modulation, it delivers the following properties: [12]

- Resistance to optical dispersion;
- Resistance slowly changing phase distortion and fading;
- Resistance against multipath using guard interval;
- Resistance against frequency response null and frequency interference constant;
- Resistance against burst noise.

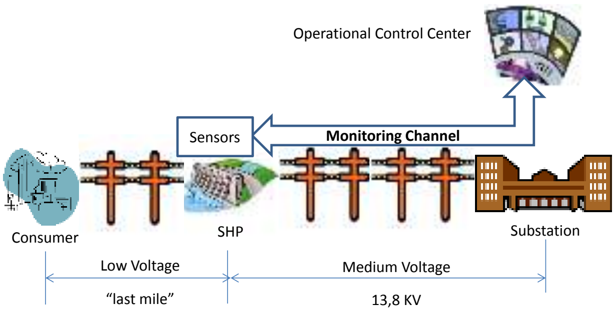

Figure 2. Evaluated scenario

The parameters of each project is presented on table 2, the structures and choices of coding parameters used in G3 PLC and PRIME have unique features and merits can be synthesized and optimized to produce a single coding structure that can yield high performance with low complexity in a variety of noise conditions. PRIME provides high data transmission rate through the use of uncoded mode, since the G3 PLC privileges the issue of robustness by supplementation of the convolutional code with a RS (Reed Solomon) outer code defined and repetition code rate of 1/4 convolutional end code in the output.

Parameter	PRIME	G3
Nominal sample Frequency	250 KHz	400 KHz
FFT Length	512	256
Modulation	Frequency-Differential	Time-Differential
Type of Modulation	DBPSK DQPSK D8PSK	DBPSK DQPSK
Channel Interleaving	One symbol (2,048 ms)	Across symbols over the whole packet up to 256 symbols, each with 640 ms.

Table 2. Project comparison [5]

Moreover PRIME supports interleaving on the entire package of physical layer in only one symbol in 2.048 ms. The G3 PLC does the intercalation of the whole package of physical layer, up to 252 taking symbols in each 640 micro seconds. Although, the activities for exclusive monitoring of

SHP do not require high bandwidth transmission capacity, but it is necessary that quality of services of data transmission and / or allow the network performance meet the requirements of real time. The narrowband interference occurs mainly in low voltage distribution due to narrowband communications systems and television receivers screen refresh rate. This paper considers the use of narrowband PLC at medium voltage as presented on figure 2.

At PRIME and G3 PLC the different noise levels and impedances on the same network can create a good transmission level in one direction and a worst transmission level in opposite direction, so it is necessary to evaluate each direction separately. The magnitude of transfer function could be verified through the transmission of block with constant magnitude on neighbouring frequency bands, so the receiver detects these like OFDM symbols and performs a FFT (fast Fourier transform), as presented in figure 3. [6]

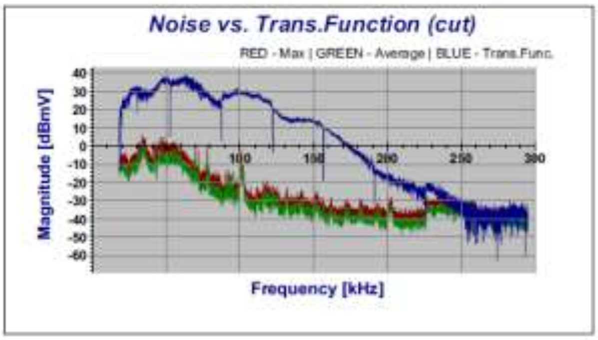

Figure 3. Noise vs. Transfer function [6]

The SNR (signal-noise relation) is an important criterion for evaluation of communication transmission, so it is necessary to analyses the signal in frequency and time domain in intensive communications tests on different frequencies, considering several bandwidths and types of modulation performed in each situation. The results lead to comparison of PRIME and G3 PLC, considering: [6]

- Number of received synchronization;
- Number of correct packets;
- Maximum and average value of the gain selected by AGC (Automatic Gain Control) during the synchronization.

The power energy distribution environment is extremely complex because it depends on several elements that are meeting the network as resistance wiring, transformers, repeaters, among others. So it is difficult to predict the behaviour of data transmission through PLC, which can be worsened with the amount of nodes that exist in the distribution line.

CONCLUSION

In this paper was evaluated the possibility of using the PLC narrowband as means of transmitting data between the SHP and the OCC on medium voltage lines (13.8 kV), which concludes that the transmission is feasible because the medium voltage lines interference and the noise is low, moreover, as the application of monitoring does not require high sustained transfer rate, this allows the PLC to operate with greater simplicity.

For that, this work considered the evaluation of PRIME and G3 PLC, which have similar physical layer, and the PRIME privileges the high data rates during favourable conditions and G3 PLC provides better performance on unfavourable conditions. Both projects can be used as a transmission data channel for communication between SHP and OCC, due to the low bit rate required.

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