ASSESSMENT OF SMART METER COMMUNICATION OVER PLC PRIME IN A LABORATORY SIMULATING A REAL GRID

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ABSTRACT

The advent of smart grids has raised an increased development of disruptive technologies focusing distributed generation and renewable energy. Recent developments in smart metering has shown potential benefits for both customers and distribution systems operators allowing to improve quality in energy delivery, measurement of bi-directional power flows, remote readings, remote parametrizations, among others. Currently, smart meters are under massive rollout in Portugal, under the framework of InovGrid project. Since many of these meters require communication with a data concentrator over Power Line Communication (PLC) technology, attenuation and noise are relevant aspects for the successful exploitation of the implemented solution.

According to measurements from the field, PLC communication is strongly affected by noise from external sources, such as industrial machinery, electronic loads and switches. Therefore, communication between smart meters and data concentrators over PLC channels is affected. Since this problem is not fully characterized in bibliography, in this paper, a smart grid composed of a data concentrator and smart meters, in the presence of noise, is simulated in laboratory.

It is intended to answer the following research question: How to improve PLC communication between smart meters and data concentrators in networks affected by severe noise? In order to simulate communication problems detected in the field, a 1000 m power cable and a noise generator are employed to introduce perturbance in the frequency band (42 kHz to 89 kHz) used by PLC PRIME V1.3.6 belonging at the CENELEC-A band (3 kHz to 95 kHz). Communication between the data concentrator and smart meters have been tested under different scenarios, i.e. communication in the presence of noise in the smart meter location combined with distance over power cable (1000 m, 750 m, 500 m, 250 m, or 0 m) between the meters and the data concentrator.

A solution for communication enhancement, based on PLC repeaters, is tested in laboratory and discussed. With the proposed solution, the PLC communication between smart meters and data concentrator has been improved.

INTRODUCTION

The energy sector is rapidly changing due to the advent of smart grids. Therefore, to face the emergence of non-traditional equipment in electrical grids, such as distributed generation, energy storage and electric mobility, digitalization of the grid is mandatory. Thereby, smart meters and data concentrators are essential for an effective grid management [1]. Since these devices require remote communication, disturbances in the communication channels are an important topic. Many power electronic-based loads and/or sources, such as domestic appliances, distributed generators, electric vehicles and batteries, contribute to unwanted emission in the PLC PRIME band [2]–[4].

PLC communication is strongly affected by noise from external sources [5]. It is practically impossible to determine all sources of noise since the noise arising from a smart meter is transmitted to the rest of the smart meters nearby and vice-versa [6]. Therefore, in order to understand the influence of noise in smart meters and data concentrators, a controllable test grid is implemented in laboratory. This test grid simulates a low-voltage neighbourhood area network. A 1000 m-length power cable (split into 4 segments of 250 m) and a noise generator are used to simulate real field conditions. The test grid is galvanically separated from the real power grid by means of an isolation transformer.

BACKGROUND AND MOTIVATION

Since power lines have been originally designed to transmit power and not data, using the power line as physical layer for communication leads to several issues, mostly of them related to noise and electromagnetic interference [2].

In low-voltage networks, typical sources of noise are: lighting equipment, dimmers, televisions, receivers, antennas, computers, ventilation systems, water pumps, heat plants, washing machines, air- conditioners, inverters, among others [7]–[9].

In this work, it is intended to answer the following research question: *How to improve PLC PRIME communication between smart meters and data concentrators in networks affected by severe noise?* To answer this research question, a laboratory with a smart metering test infrastructure, denominated as SmartLab, depicted in Figure 1, is used. With this infrastructure, a smart grid with up to 400 smart meters and 4 data concentrators can be simulated in order to study several test cases.

Figure 1 – Smart metering test infrastructure at SmartLab.

RESULTS AND DISCUSSION

According to [2], noise play an important role in PLC communication. From some results gathered in the field, communication between smart meters and data concentrators tend to loss quality in peak hours (high demand of consumption and production by critical equipment). As hypothesis, distance between smart meters and data concentrators, combined with noise, are considered as determinant factors in PLC PRIME communication. The influence of these factors is considered in this study.

To simulate real field conditions, communication between a smart meter and a data concentrator is performed in the presence of noise. Besides that, communication is tested as a function of distance between smart meter and data concentrator. All tested combinations are schematically depicted in Figure 2 (please note that just one smart meter and noise generator are used at a time). To avoid external perturbances, an isolation transformer is used to feed the test grid.

The smart meter has been placed at 0 m, 250 m, 500 m, 750 m and 1000 m from the data concentrator. Similar noise to a real case is injected in the meter connection point by means of a signal generator [2]. The spectrum of noise introduced in the grid by the generator is presented in Figure 3.

A PLC PRIME v1.3.6 sniffer has been used to measure the frequency response of both communication signal and noise. The spectrum of PLC PRIME signal, from a smart meter, in the absence of generated noise, is depicted in Figure 4.

When the smart meter is close to the data concentrator, PLC PRIME communication can be performed between the smart meter and the data concentrator. This is the only scenario in which the smart meter can communicate with the data concentrator in the presence of noise. If the smart meter is placed at 250 m, 500 m, 750 m or 1000 m, in combination with noise, it does not communicate, per se, with the data concentrator.

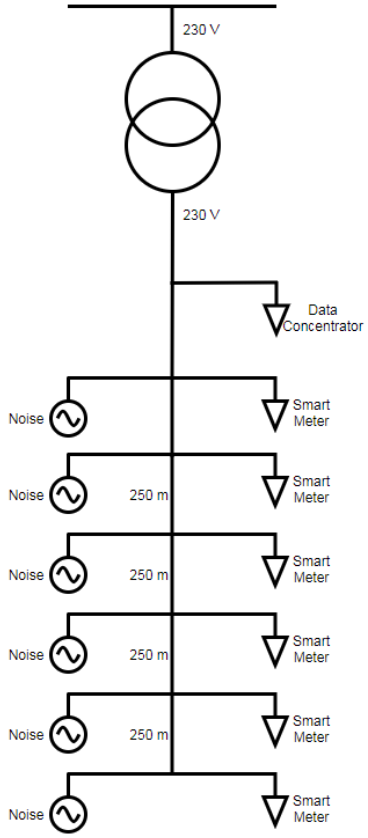

Figure 2 – Test grid diagram.

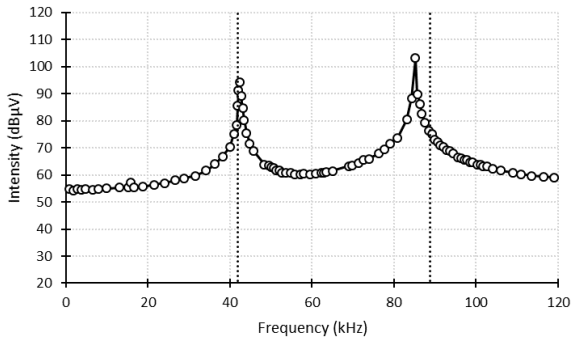

Figure 3 – Spectrum of generated noise signal.

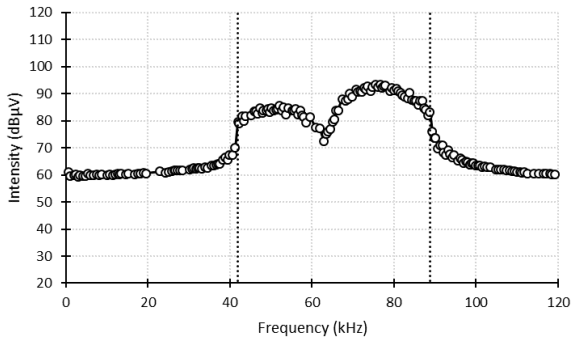

Figure 4 – Spectrum of PLC PRIME signal (in the absence of generated noise).

The results of PLC PRIME communication between smart meter and data concentrator, considering all tested scenarios, are presented in Table 1. This table shows the relative distance of the noise generator and smart meter with respect to the data concentrator position. It is considered that noise generator and smart meter are placed in the same connection location. In this case, when noise generator is injecting noise, the smart meter does not communicate successfully with the data concentrator (exception is when smart meter, noise generator and data concentrator are connected in the same point). To improve communication, PLC PRIME repeaters are introduced. To determine the influence of the PLC PRIME repeater, this is placed in each possible connection location and the communication status between data concentrator and smart meter is evaluated. Both smart meter and repeater can communicate with the data concentrator. Therefore, to answer the research question of this work, it is suggested to use PLC PRIME repeaters. These repeaters behave as service switches whose their objective is to increase the signal intensity in power line and, therefore, mitigate the effects of noise and attenuation in PLC PRIME communication.

From the different test scenarios, it has been found that the optimal positioning of the repeater is dependent on the noise location. When the smart meter and noise generator are far from the data concentrator (250 m, 500 m, 750 m or 1000 m), placing the repeater in the same location as the noise source does not improve communication. Either for repeater positions far than the position of smart meter and noise generator. From the obtained results:

- When the noise generator and smart meter connection point is close to the data concentrator (approximately 0 m), communication with data concentrator is successful.
- When the noise generator and smart meter are placed at 250 m from the data concentrator, it is observed that the smart meter does not communicate with the data concentrator whatever the position of the repeater is. In this scenario, the repeater can only communicate with the data concentrator if placed close to it (approximately 0 m).
- With the noise generator and smart meter far 500 m from the data concentrator, communication can only be established when the repeater is placed at 250 m from the data concentrator. In any other position, the repeater does not improve communication.
- At 750 m, the smart meter does not communicate with data concentrator if noise generation is at same position. By introducing the repeater at 250 m or 500 m far from the data concentrator, communication is re-established. Placing the repeater at 0 m, 750 m or 1000 m far from the data concentrator, communication between smart meter and data concentrator is not established.
- When the noise generator and smart meter are at 1000 m far from data concentrator, communication is successful when the repeater is placed at 250 m, 500 m and 750 m from the data concentrator. Placing the repeater at 0 m or 1000 m does not improve communication.

Table 1 – Result of test scenarios.

Distance to Data Concentrator (m)		**Communication with Data Concentrator**	
Smart Meter and Noise Generator	**PLC Repeater**	**Smart Meter**	**PLC Repeater**
0	0	Yes	Yes
	250	Yes	No
	500	Yes	No
	750	Yes	No
	1000	Yes	No
250	0	No	Yes
	250	No	No
	500	No	No
	750	No	No
	1000	No	No
500	0	No	Yes
	250	Yes	Yes
	500	No	No
	750	No	No
	1000	No	No
750	0	No	Yes
	250	Yes	Yes
	500	Yes	Yes
	750	No	No
	1000	No	No
1000	0	No	Yes
	250	Yes	Yes
	500	Yes	Yes
	750	Yes	Yes
	1000	No	No

CONCLUSIONS AND FUTURE WORK

In this paper, the influence of noise and distance in PLC PRIME communication in a smart grid composed of a smart meter and a data concentrator has been studied. Several scenarios with unsuccessful PLC PRIME communication have been reproduced and a solution based on a PLC PRIME repeater has been presented. From the obtained results, the main conclusions are as follows:

- For each scenario, in the absence of noise, PLC PRIME communication can be established whatever the distance from the data concentrator is (up to 1000 m). Therefore, distance, per se, does not influence communication.
- Placing the repeater in the same location as noise source or data concentrator, does not constitutes a good option since any improvement in communication is observed. Also, placing the repeater far than the noise source and smart meter location (with respect to location of data concentrator) does not improve communication.
- When the smart meter is between 500 m and 1000 m from the data concentrator, the ideal location of the repeater is, in general, in the middle distance between data concentrator and smart meter.

As future work, it is suggested to study the behaviour of the simulated grid against different noise profiles (reproducing typical profiles of critical equipment), as well as multiple noise sources and multiple consumption/production points (grid with several smart meters). The presence of signal attenuation, due to e.g. power line distance and power cable aging, should also be considered in further studies. It is also envisaged field tests to assess the performance and robustness of the proposed solution against real field conditions as well as the determination of the optimal locations of PLC PRIME repeaters in the grid.

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