# COMPATIBILITY OF A G3PLC TELECOM SOLUTION ON A THREE PHASE 230 V NETWORK

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## ABSTRACT

*ORES has made the choice to use G3-PLC communication for its smart metering infrastructure. As G3-PLC hardware has been designed for 4 wires 400 V grids one difficulty for ORES is the existing "3-phase 230V" grids.*
*The problem is that the Linky G3-PLC data concentrator hasn't been designed for this type of low voltage network.*
*The chosen strategy is to adapt existing Linky equipment without modifying the existing hardware design for smart metering infrastructure in order to have a robust G3-PLC communication solution on a three-phase network.*
*The objective of this research is to compare different solutions for the data concentrator connections, in order to identify the best communication performances scenario.*

## INTRODUCTION

ORES is a DSO operating electricity and gas distribution grids in Wallonia (Belgium). In the context of smart metering deployment, ORES has decided to use Linky G3-PLC meter. One challenge is to make G3-PLC compliant and performant for the part of three-phase 230 V networks.

This research is split in two phases of study. The first part is the comparison of two technical solutions on a real network with the goal to identify the best deterministic telecom solution. The second part is to improve the performance of the best identified solution.

## CONTEXT

Historically two types of three-phase networks coexist on the low voltage distribution network operated by ORES : 3 phases 400 V with neutral and 3 phases 230 V. 3 phases 400 V with neutral is a classic distribution case present in most of European countries. But in the case of the 3 phases 230 V, grids are very specific to Belgium. They are implemented with specific MV/LV transformer with seven terminals ( 3 terminals for 400 V and 3 terminals for 230 V and one common neutral).

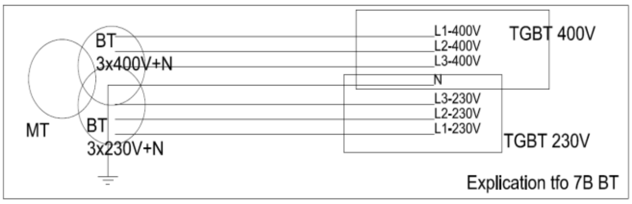


**Figure 1 : Three-phase network, 7 terminals transformer**

In the case of the 3 phases 230 V network, the neutral conductor is partially distributed but the neutral is never used by the client, so the neutral wire is not connected for the client installation. The client uses only the phase to phase voltage for their equipment connection.
The meter types used on this network can be three-phase or single-phase depending on the choice of the client.

In the context of smart metering deployment based on the G3 PLC Linky, ORES needs to make the Linky data concentrator compliant with a three phase network without neutral wire used for telecommunications. To address this difficulty ORES has searched for the best adapted solution.

## TECHNICAL SOLUTIONS

Two solutions have been identified as compatible. The first solution is based on a two-phase connection between the network and the data concentrator (fig2). Single phase Smart Meters are distributed between the 3 phases. With this solution some Smart Meters only relying on crosstalk between wires into the same cable to communicate with the data concentrator. The risk of this solution is that some smart meters communications are based on the cross talk phenomena. That is not a deterministic telecom solution.

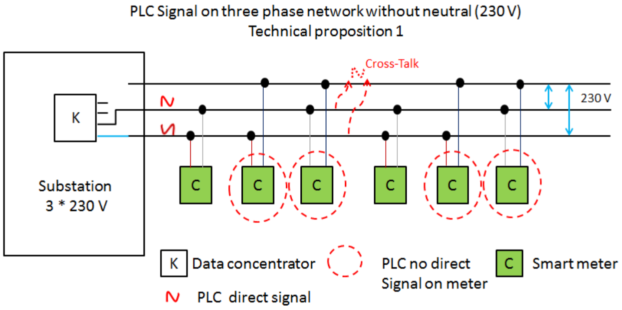


**Figure 2 : Technical proposition 1**

## Using an external coupler

Enedis and EDF R&D have developed a specific adaptation coupler for the three phase 230 V network. This coupler allows using a standard four wire data concentrator (fig3).
The laboratory measurements performed on the coupler show that the G3-PLC signal is homogeneously distributed between the three phases of the network. The coupler is based on a 50 Hz transformer for the power supply of the concentrator and a pulse transformer for the G3-PLC signal. A prototype was built at EDF R&D with the objective to carry out field tests on the ORES network.

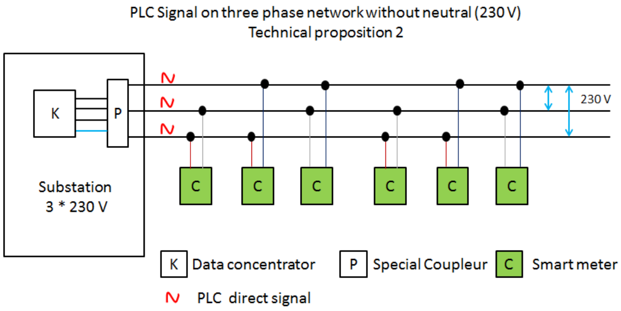


**Figure 3 : Technical proposition 2**

## FIELD TEST & MEASUREMENTS

With the support of Enedis and EDF R&D, field trials have been performed on a real distribution network. The objective was to challenge the performances of both solutions. One substation was selected in Blaugies (Area of Mons, Belgium).

## Materials and methods

Measurements have been carried out on a real network in a rural environment. 6 connection points were used on an aerial network (bundled isolated and bare copper overheadline).

Trials were organized with 2 types of measures, physical characteristics and telecommunications trial.

In a first time, measurements of the attenuation level were performed in the range between 10 kHz and 150 kHz. This range is based on the Cenelec A range defined by EN 50065-1[2].
The objective was to determine the level of crosstalk between different configurations. These measurements were performed by the injection of signal with a low frequency generator in sweeping mode (10 kHz -150 kHz). For the reception and measurement a Picoscope in spectral analyser mode was used with capacitive PLC couplers define in the range 35 kHz – 120 kHz (ratio 1:1). To compensate the non-linear response of the couplers, a first measurement take place at the injection point. The level of signal measured at this point is used as the reference signal. Injection was performed in various places of the network with various phase configurations, reception point was fixed and connected on RS phases.

In a second time, communication field trials were performed with a G3-PLC Linky data-concentrator and 6 G3-PLC Linky single-phase meters. The tests were performed with technical proposition 1 and technical proposition 2 (with three-phase coupler) with the objective to compare both solutions.
The communication results are based on the logs supplied by the data concentrator and the data from a G3-PLC sniffer (Neuron box).

For technical proposition 1 the data concentrator is connected to the RS phases of the network.
For the technical proposition 2 using an external coupler, a prototype previously tested in laboratory was connected between the data concentrator (4 wires) and the three phases 230 V of the network (RST).

## Network characteristics

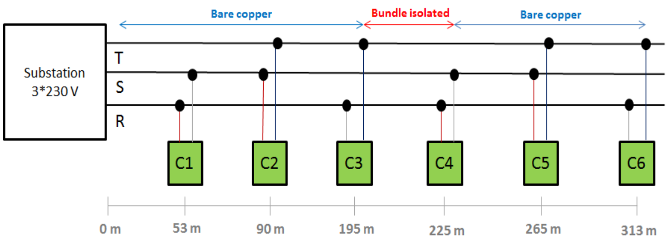


**Figure 4 : Network and connections characteristics**

The bundle isolated section was alternatively connected and disconnected to evaluate the influence of this section on the crosstalk (yellow on the figure 5).


**Figure 5 : View of the network with the 6 connections points (yellow stars)**

In the first report, after measurements is was noted that the crosstalk was very important on this network.
At the injection point (injection on RS) the attenuation level for the no direct phases is between 4.7 dB (measure on RT) and 7.4 dB (measure on ST) in the worst case. When the distance between the injection point and the measurement point increased, the attenuation level of direct path and indirect path were very similar. One indirect way configuration was less favourable than the 2 others. This gap can be explained probably by an impedance difference.

As presented in figure 5, the attenuation level of the direct way between the substation and C1 is very significant. The meters with an indirect way are highlighted in orange (crosstalk).

| | C1 RS | C2 ST | C3 RT | C4 RS | C5 ST | C6 RT |
|---|---|---|---|---|---|---|
| Average attenuation (dB) from the substation | -28,5 | -40,7 | -44,1 | -43,6 | -50,7 | -45,7 |
| Distance (m) | 53 | 90 | 195 | 225 | 265 | 313 |

**Figure 6: Avergage Attenuation (RS : Directway)**

It can be deduced that the three phases connection cables used for the connection points and the substation equipment generate high level of crosstalk between wires. The influence of the bundle isolated overheadline on the crosstalk was not demonstrated.

## Communication tests

Various scenarios of communication tests between one data concentrator and Linky meters took place in both configurations ( data concentrator on two wires and data concentrator on 3 wires with external coupler).
The performance indicators are defined as Ping, Link quality indicator, Round trip time, hop number, modulation type.

With configuration 1 and 2 , RTT (round trip time) and success rate ping (near 100%) are very similar. The crosstalk phenomena is so important that it is possible to establish a communication to all meters of the network without difficulty with both configurations.

| | | Sucess ping rate | | Minimun RTT | |
|---|---|---|---|---|---|
| | | Case 1 | Case 2 | Case 1 | Case 2 |
| C1 | RS | 98% | 100% | 162 | 157 |
| C2 | ST | 100% | 100% | 239 | 226 |
| C3 | RT | 100% | 100% | 185 | 190 |
| C4 | RS | 97% | 100% | 320 | 443 |
| C5 | ST | 100% | 80% | 336 | 319 |
| C6 | RT | 100% | 95% | 329 | 378 |

**Figure 7 : ping and RTT (ms) results**

The results of the LQI (link quality indicator) could not provide a real difference of performance between configuration 1 and configuration 2. The LQI (link quality indicator) value is derived from the average signal noise ratio. The LQI is an integer ranging from 0x00 to 0xFF. In comparison with the SNR, the LQI mapping is :

- SNR $\leq -10$ dB maps to LQI 0x00
- SNR $\geq 53.75$ dB maps to LQI 0xFF
- $-10 <$ SNR $< 53.75$dB is linearly interpolated between 0x00 and 0xFF (the nominal step size is 0.25 dB).

| | | Average LQI | |
|---|---|---|---|
| | | Case 1 | Case 2 |
| C1 | RS | 88 | 105 |
| C2 | ST | 41 | 49 |
| C3 | RT | 38 | 58 |
| C4 | RS | 40 | 30 |
| C5 | ST | NA* | NA* |
| C6 | RT | NA* | NA* |

**Figure 8: LQI (Meter to concentrator way)**

With these results, we can see that the choice of configuration 1 or configuration 2 does not impact neither the modulation type or the number of hops ( estimated with the RTT). There is no data available for C5 and C6 because these meters use more than 2 hops in order to communicate with data concentrator. There is no interest to look at the LQI of C5 and C6 (only the first hop could assess the impact of the coupler).

However, one scenario demonstrated the benefit of the external coupler (configuration 2).
This scenario consists to only connect the Linky meter C3 on the network (distance 195 meters) and to use the data-concentrator in the substation to establish a communication.

Firstly with the configuration 1 (Data-concentrator is connected on 2 wires RS and meter is connected on RT) based on crosstalk communication it is impossible to establish a communication between data-concentrator and the Linky meter.
Secondly, the same scenario is executed with configuration 2 (external coupler on 3 wires). In this case the meter C3 can be connected to the data-concentrator.
This last scenario confirms that a determinist solution is needed for the 3 phases 230 V network.

After this first trial, ORES wanted to continue the research to improve the coupler. One of the most important parameter that influences the performance of the G3-PLC coupler is the access impedance in its connection point. So in the second phase of the study, we need to estimate the average impedance of the network.

## IDEAL IMPEDANCE

For this second phase, we need to have a panel of impedance values from the network.
Seven substations with various network configurations were selected. The impedance of each circuit was measured. These measurements was realized with a network analyzer and a specific coupler. Further steps will consist in analyzing and aggregating the collected data. At the time of writing this paper, we are busy to finalize the results of this study. The results can be presented during CIRED 2017.

## ADAPTATION OF THE COUPLER

High frequency characteristics of the coupler are an input impedance (4 wires side) above 50 Ω after 37 kHz ( minimal value from EN 50065-7 [3]). And the output impedance (3 wires side) is above 50 Ω (fig 10).

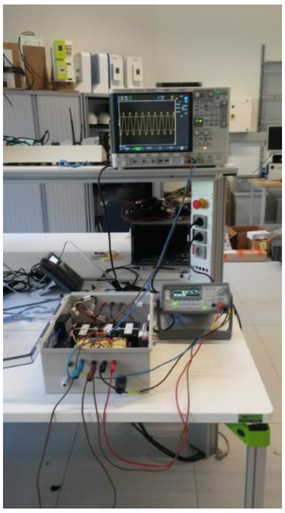

**Figure 9 : laboratory validation of the coupler**

What can be observed is that the impedance of the coupler on the 3 wires side (network) is not recommended for an ideal propagation of the signal. The real impedance observed by measuring on the distribution network is lower than 50 Ω for the Cenelec frequency band.

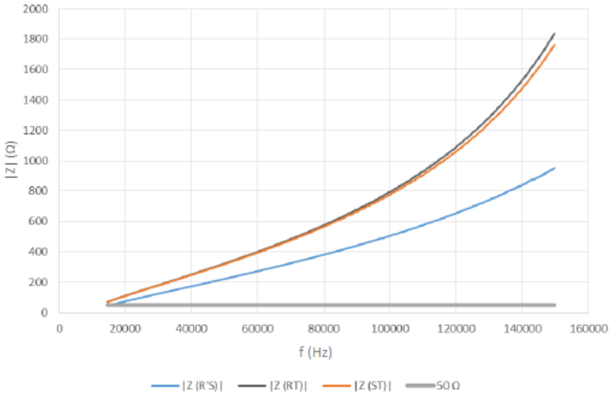


**Figure 10 : impedance of the coupler on the 3 way side (network)**

The results of the impedance measurements will be used in the next months to adapt the output impedance near the true impedance of the network distribution.

## CONCLUSION

This article describes the research of a G3PLC Telecom Solution on a three phases 230 v network.

The current results of the field trial show that using a 3 wires coupler between G3-PLC concentrator and 3 wires network does not improve significantly at the communication between G3-PLC data concentrator and G3-PLC meter when the network shows a high density of G3-plc meters or repeaters. But when the distance between meter and data concentrator increases, the configuration with the coupler can establish a connection between a distant meter and the data concentrator.

Compared with a 2 wires connection of the data concentrator, the coupler appears to be more deterministic telecommunication solution.
The interest is that the coupler is crosstalk independent.

But it needs to improve the performance of the coupler and to adapt the output impedance with the average impedance of the network.

The next steps are to calibrate a new prototype for an average impedance based on a panel of impedance measured on the network. Further tests on the field have to be performed with the new version of the coupler.

## REFERENCES

[1] Recommendation ITU-T G.9901 (2014): *Narrowband Orthogonal Frequency Division Multiplexing Power Line Communication Transceivers – Power Spectral Density Specification*

[2] EN50065-1:2011 , *Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz. General requirements, frequency bands and electromagnetic disturbances.*

[3] EN 50065-7:2001 , *Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - part 7: equipment impedance.*