ERDF G3-PLC LINKY SYSTEM: A ROBUST AND FUTURE PROOF SOLUTION FOR LARGE SCALE AMM PROJECTS

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ABSTRACT

The G3-PLC technology (ITU-99.03) is an open international standard which is both robust and future proof. G3-PLC is a solution optimized specifically for smart metering applications and future smart grids services. This technology has been selected by ERDF, the main French electricity distribution network operator, for the mass roll-out of his 35 million Linky meters. This article describes the main mechanisms, the benefits and the opportunities of the G3-PLC technology. Actual results are revealed about the key performances achieved in the first G3-PLC field tests in France as well as the ability to dynamically adapt to different network configurations. More information are also provided about ERDF Linky G3 roadmap, as well as some perspectives about the way in which data management can enhance the operations of electricity distribution systems (phase detection, GIS data reliability, …)

INTRODUCTION

According to the European regulations, 80% of electricity LV consumers will be equipped with a smart meter by 2020 [1], representing more than 200 million two-way communicating meters, and consequently a very huge amount of data relative to each node connected to the LV network. Beside the real-time visibility of energy consumption, a DSO needs better and more accurate information about the state of its LV assets, opening the scope of new smart grids.

For an electricity DSO, PLC technology is a simple and low-cost solution since it doesn't require any additional infrastructure investments on the local LV network. PLC technologies have been yet chosen by main European DSOs in Italy, Spain, Sweden,… and obviously in France.

G3-PLC was chosen by eRDF for its AMM system : the first specification of G3-PLC, published in August 2009, was developed by Maxim Integrated Products, Sagemcom and ERDF. G3-PLC was designed to meet all the needs of any DSO or any industrial operator. It enables a high-speed, reliable, and secure way to collect meters or any other devices data. It is an open-standard which is now recognized at an international level since G3-PLC specifications have been shared and published as the ITU-T G.9903 standard [2]. This is a key issue to ensure interoperability between devices from different manufacturers.

In this paper, we will first remind some technical features describing the main mechanisms, the benefits and the opportunities of the G3-PLC technology. Actual results will then be revealed about the key performances achieved in the first G3-PLC field tests in France as well as the ability to dynamically adapt to different network configurations. In a second part, we will highlight two examples of new network services than can be offered by G3-PLC such as the phase detection and DSO GIS.

G3-PLC MAIN BENEFITS

G3-PLC is an open standard solution supporting frequency bands worldwide (10-490 kHz), based on the last advanced solutions for telecom protocols:

- the OFDM modulation which is already used by a wide range of applications (broadband PLC technologies, Wi-Fi, Bluetooth, LTE...); for instance, with 36 carriers in the CENELEC-A bandwith (3-95 kHz), it perfectly exploits the frequency resource, enabling comfortable data rate (up to 30 kbytes/s),
- auto-adapted modulation rates to the environment , with a ROBO mode improving communication performances in case of harsh, noise environments,
- security mechanisms to protect grid assets,
- a dynamic and reactive routing algorithm defining the best path between two nodes regarding the quality of link,
- a native compatibility to IPv6 protocol, which widely opens the G3-PLC to range of the Internet of Objects applications.

For more information about G3-PLC technical features, see [3].

During the last few years, G3-PLC specifications have been enhanced thanks to the feedbacks of field tests in France or in foreign countries (see [4] and [5]). They have been discussed and shared among various international organizations such as ITU and IEEE, achieving to the publication of recognised standards (ITU-T G.9903, IEEE P1901.2).

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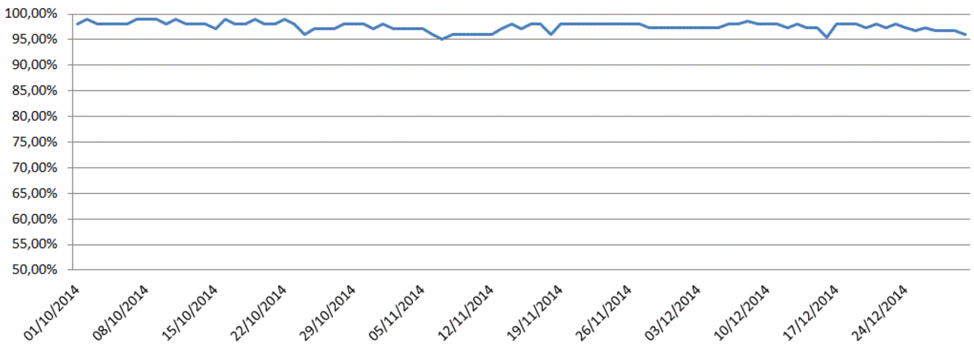

Figure 1: Daily meter data rate for the 2000 PLC-G3 ERDF field test (from October to December 2014)

Thanks to the G3-PLC Alliance created in 2011[6], G3-PLC is promoted and supported all over the word. More than 60 members have joined the Alliance, among them many manufacturers or utilities from Europe, Asia, or US.

Since September 1st 2014, G3-PLC Alliance delivers a certification program, ensuring the interoperability of a large number of platforms (a solution implementing the G3-PLC stack), or product (end-user equipment such as meter, data Concentrator, ...). At the end of 2014, 14 G3-PLC platforms and 4 G3-PLC products have been fully certified.

G3-PLC ERDF FIRST RESULTS

ERDF is the main French DSO delivering electricity in more than 95% of French landscape. ERDF manages nearly 35 million domestic and professional customers and operates more than 600 000 km of LV networks and almost 700 000 MV/LV substations.
ERDF and EDF R&D have been engaged at the very first steps of G3-PLC. ERDF has launched a field test in 2012 with around 2000 meters and 40 Data Concentrators made by Sagemcom manufacturer. These meters have been deployed in the French region of city of Lyon (high-dense area with underground LV networks) and in “Touraine” (rural area with mainly overhead LV lines).
For this experiment, this is a lab-test Sagemcom IS (Information System) that has been used for the data collection, without any connection to the ERDF Linky IS. Main objectives were to validate the behavior of G3 meters on ERDF grid networks.

Only 40% of electricity meters connected to the MV/LV substation were removed by G3-PLC meters, meanwhile this low saturation ratio didn’t influence the overall performance. As a first step, G3 meters only included a single G3 chipset from Maxim Integrated manufacturer. In a second phase, 158 additional meters including an alternative Texas Instrument chipset have been developed and tested on the field. Results for both technologies have been completely fulfilled, with a daily data rate above 98% as well in urban as in rural areas, as seen in Figure 1.
For more information about the 2000 meter experiment field results, see [5].

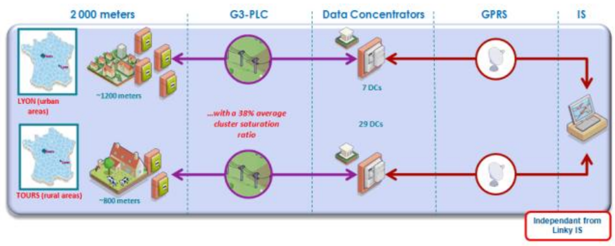

Figure 2: IT architecture for the 2000 G3-PLC ERDF field test

G3-PLC NETWORKS MONITORING

The 2000 meters experiment has also confirmed the suitability of G3-PLCfor large scale AMM systems, as powerful network management systems can be built on top of it thanks to the amount of available information about network state. Majority of this network management data come from the Routing mechanism used by G3 to provide end-to-end connectivity in the PLC network: it consists in choosing the optimal relay nodes (meter or data concentrator) to propagate data packets addressed to a specific destination node. As routing information can be retrieved from every node of the G3 network, it is possible to represent the network topology, as depicted in Figure 3. Moreover, thanks to the adaptative nature of G3-PLC, it is possible to follow the evolution in time of the network (quality of the links, number of hops along the routes…). Another indicator of interest for monitoring purposes is the *neighbour table*: for each node (meter or data concentrator), this dynamic table records every neighbouring node (meters or the data concentrator) within range of the node, which gives information about the density of the mesh-network and link quality between every node of the network. The statistical analysis of neighbour and *routing tables* leads to the definition of powerful indicators for monitoring and troubleshooting purposes.

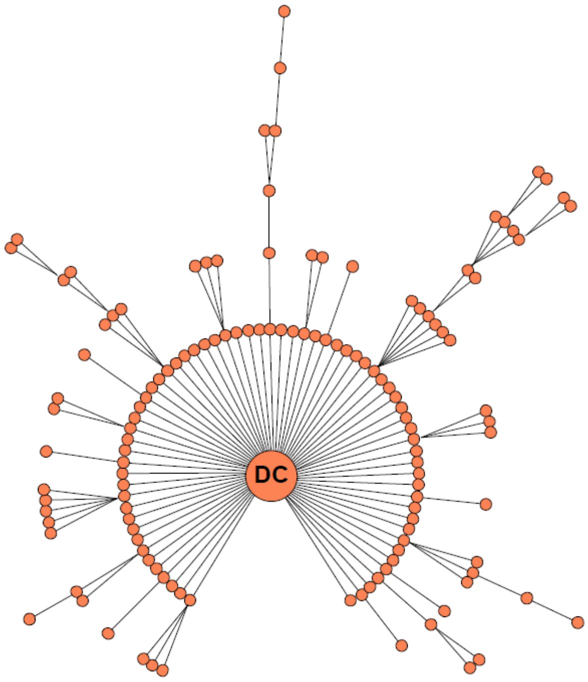

Figure 3: Example of G3 logical network topology (central node corresponds to the Data Concentrator)

G3-PLC NETWORK MANAGEMENT DATA: THE HIDDEN RICHNESS OF THE DSO

As PLC makes use of the distribution network as a telecommunication network, existing protocols can be differentiated by the intrinsic richness of the data they carry. To understand what the authors mean by "intrinsic richness", it is important to recall that in every telecommunication network, the exchanged information can always be classified into two data sets:

1. the first one contains end-user information (e.g.: index collected on a meter).
2. the second one contains network management data set, i.e. all data related to the control of communications in the network (these data are needed by the protocol to work properly).

While the first data set is obviously independent on the chosen protocol, the second one is purely dependent on it. Consequently, the intrinsic richness of the protocol can be defined as the value created when network management data are correctly exploited.

G3-PLC naturally offers a lot of network control information that can be collected by the central IS. Thanks to exploratory studies conducted by eRDF on the 2000 G3 meters experimentation, we were able to catch a first glimpse on the potential benefits G3-PLC data could bring to eRDF. In the following we give 2 examples of direct applications exclusively-based on the exploitation of two G3-PLC signaling information, the *routing tables* and the *neighbour tables.*

G3-PLC Phase Detection

Network balance is a key operation for the DSO: it consists in equitably balancing the electricity consumption between the three phases of the LV network. To perform this operation, the DSO needs to know accurately the phase connection of every meter distributed along the LV network: nowadays, the reliability of this information can be questioned as it is manually entered in the central IS.

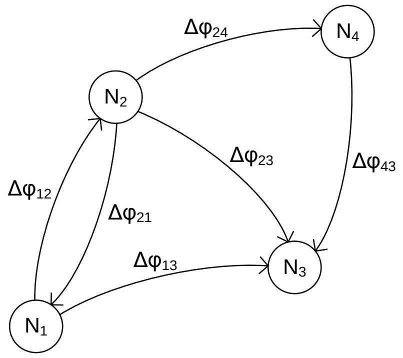

Figure 4: Phase shifting graph constructed with Neighbour Tables

G3-PLC offers the possibility to compute the phase connection of a meter by collecting the *neighbour tables* of the network. Each line in the table corresponds to a specific neighbouring device for which several indicators are recorded, most of them being related to the link quality. Among all available indicators, one corresponds to the estimated phase difference with the neighbour[1]: this is illustrated in Figure 4, in which $\Delta\varphi_{i,j}$ can be equal to 0°, 120° or -120°. In Figure 5, we present a data visualization of a G3 Network realized with *Gephi* [7]. This graph was constructed by collecting every neighbour table from the meters of a real G3 PLC Network: nodes correspond to meters and links represent neighbouring relationships between meters. Links are classified into three subsets, according to the carried phase information: 0°, 120° or -120°. Figure 5 shows that a simple filtering operation combined with a new spatialization of the graph bring to light three clusters of meters, each one representing one phase of the three-phase distribution network. It is interesting to notice the remaining links between two of the three clusters: these two links corresponds to wrong estimations of the phase difference between meters. Our studies have shown that the information redundancy in the network makes the identification of these errors straightforward. Therefore these links can be excluded before estimating the phase connection of a meter. Thanks to the 2000 meters experimentation, we are now confident enough to say that

1 As electrical wires are not shielded, PLC signal can be received on a different phase from the one the original transmitter was connected to.

the G3-PLC phase detection mecanism will ensure eRDF to know the phase connection of every G3-PLC meter.

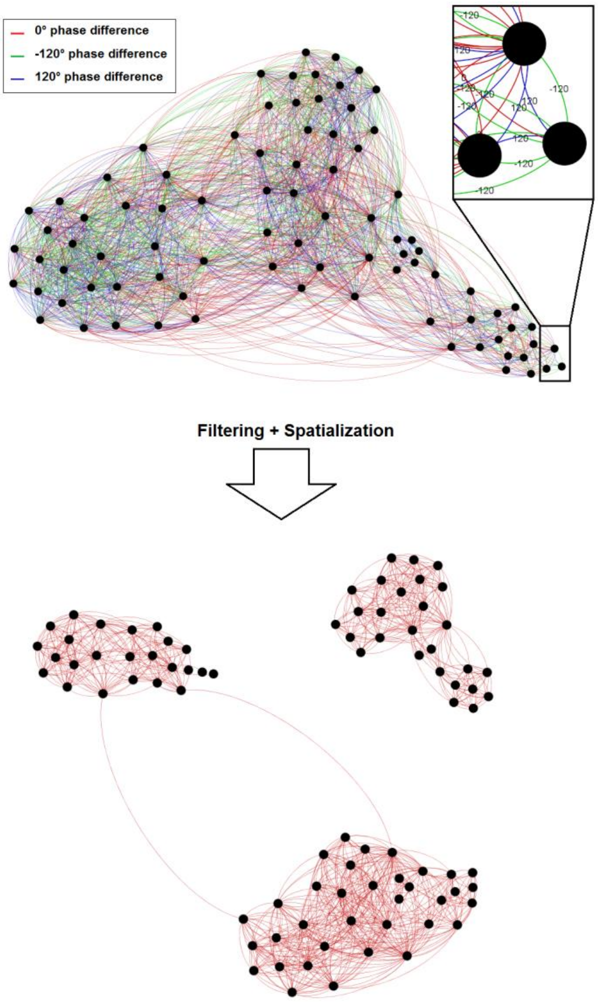

Figure 5: Phase detection in a G3 network (field results from eRDF's 2000 G3 meters experiment)

DSO GIS

eRDF is in charge of 35 millions customers distributed along a 600 000 kilometers Low-Voltage grid. Until now customers localizations are still entered manually in eRDF GIS, which naturally leads to referencing errors (we estimate that bout 5 % of the customers are badly referenced in eRDF GIS). These errors have multiple consequences on network operations: flawed network balancing operations, under-optimized network investments... Using PLC for last-mile connectivity is a unique opportunity to enhance the reliability of DSO GIS. Indeed, as PLC basically transforms the electrical grid into a communication network, information about the topology of the electrical grid can be inferred by analyzing network management data. Considering G3-PLC, The information contained in this data makes its exploitation pretty interesting for DSOs.

The first results shown in this section were derived from a simple and pretty-intuitive observation: the information flow in a G3 networks tends to follow the topology of the electrical grid. Consequently, from a statistical analysis of the routes in the G3 network, it is possible to partially reconstruct the topology of the LV grid. In Figure 6, we present a data visualization where the electrical (black links) and G3-PLC (red links) networks are overlapped: black nodes represent G3 smart meters and DC, while white nodes represent historical meters. This LV grid is constituted of 6 feeders, but only five of them are equipped with smart meters. A statistical analysis of the G3-PLC network topology can highlight some obvious GIS errors: looking at the box at the bottom of the figure, we can see that two meters located at the end of one feeder were identified as belonging to another feeder (they are coloured in red when they should be coloured in yellow) because they share few logical connections with meters that, according to GIS, are closely located. These two errors were confirmed on the field. At this point of our studies, we are pretty confident to say that in a near future, G3 PLC management data will help eRDF to detect the feeder on which a customer is connected to. Moreover, as this work is just starting, we can hope for increased precision in meters localization in the future.

CONCLUSION

In this analysis we confirm that the G3-PLC protocol is a very good solution for a DSO smart metering purposes. It provides investment and operating low-costs, highly and reliable performances in terms of meter data collection, or energy services, in many various kinds of electricity distribution configurations.

Furthermore, we find that the huge amount of statistics provided by a G3-PLC network can be easily managed in order to improve the knowledge of electrical assets such as phase detection or GIS database.

In the next steps, the 5k Linky G3-PLC pilot in 2015 will help ERDF to better analyse and optimize the G3-PLC network features in interoperability conditions and in relation with the electricity distribution network. Therefore, G3-PLC ERDF's Linky mass roll-out will carry on since beginning 2016 for more than 32 million smart meters.

Finally, ERDF will be ready to manage all this G3-PLC smart information and to become a new smart grid operator.

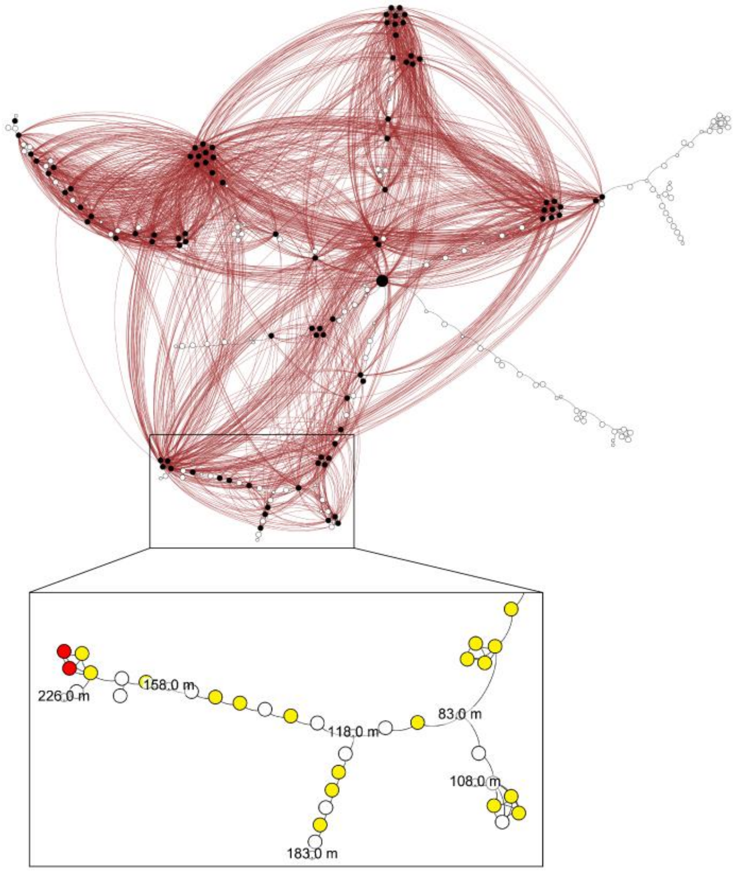

Figure 6: Feeder detection in a G3 network (field results from eRDF's 2000 G3 meters experiment)

REFERENCES

[1] Benchmarking smart metering deployment in the EU-27 with a focus on electricity, *available at* http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union

[2] Recommendation ITU-T G.9903, February 2014, Narrowband orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks, *available at http://www.itu.int/rec/T-REC-G.9903/fr*

[3] Razazian, K.; Umari, M.; Kamalizad, A.; Loginov, V.; Navid, M., "G3-PLC specification for powerline communication: Overview, system simulation and field trial results," *Power Line Communications and Its Applications (ISPLC), 2010 IEEE International Symposium on* , vol., no., pp.313,318, 28-31 March 2010

[4] Razazian, K.; Kamalizad, A.; Umari, M.; Qi Qu; Loginov, V.; Navid, M., "G3-PLC field trials in U.S. distribution grid: Initial results and requirements," *Power Line Communications and Its Applications (ISPLC), 2011 IEEE International Symposium on* , vol., no., pp.153,158, 3-6 April 2011

[5] Razazian, K.; Niktash, A.; Loginov, V.; LeClare, J.; Lys, T.; Lavenu, C., "Experimental and field trial results of enhanced routing based on LOAD for G3-PLC," *Power Line Communications and Its Applications (ISPLC), 2013 17th IEEE International Symposium on* , vol., no., pp.149,154, 24-27 March 2013

[6] G3-PLC Alliance website, http://www.g3-plc.com/alliance-members

[7] Gephi website, http://gephi.github.io/