POWER LINE COMMUNICATIONS USING LOW AND MEDIUM VOLTAGE NETWORKS

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Abstract - In this paper, we propose a complete framework dealing with power line communication (PLC) technique over power distribution networks including both medium and low voltage networks. We focus on both physical and application layers in order to show that fast backhauls can be used. The enhancement of the performances is also discussed.

I. INTRODUCTION

Distribution networks, including both medium voltage (MV) (see e.g [1] [2]) and low voltage (LV) networks (see e.g [3]), are new candidates for providing an access to high speed communications. Transmitting high data rates communications in the [1-30 MHz] band of the order of several Mbits/s is possible using power line communications (PLC). PLC technology offers great service potential with applications such as internet access, in-home services and energy management.

In this paper, we propose a complete analysis of an in-situ real network according to the physical and application layers. After describing the topology of this experimental network, we carry out a complete characterization of the physical layer. We reach this goal using experimental data only including path loss and impedance measurements. Then, we estimate the capacity of the PLC channel in order to evaluate the obtained data rates. The obtained data throughput results show that considering fast backhaul links. We also recommend the development of wideband impedance matching algorithms (see e.g [4] [5] [6]) for the reduction of power losses likewise the radiated emissions (see e.g [7] [8]).

II. PLC IN DISTRIBUTION NETWORKS

The general principle of a PLC network using both the MV and the LV networks is explained on figure 1. We can see that two PLC modems are needed in the MV/LV transformer substation, the connexion between them is assured through an ethernet cable. The ethernet bridge is necessary to bypass the MV/LV transformer since the attenuation associated with this block can be greater than 40dB. A first communication link can then be defined on the LV side between the LV PLC modem (see blue modems) in the substation and the LV PLC modem located further in the network (see green modems). A final communication link is necessary to reach the final customers (see red modems). We can therefore note that green modems are useful to achieve a repetition between the LV modems in the substation and the LV modems in the customer premices.

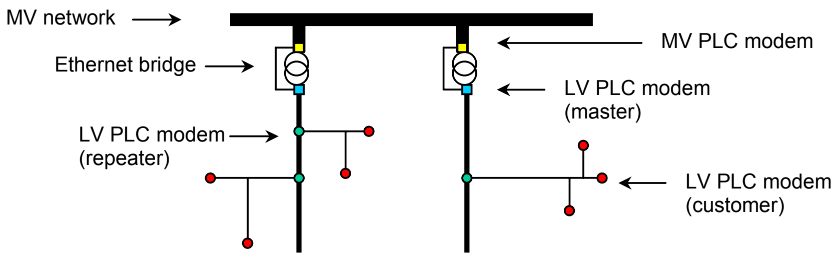

Fig. 1. PLC network using LV and MV networks

III. TOPOLOGY OF THE EXPERIMENTAL NETWORK

We have depicted on figure 2 the complete topology of the experimental network. We can see that we have five MV to LV transformer substations (see Nouvelle Gare, Helene, Sophie, Barie and Jacqueline). Inside each substation, two phase conductors have been equipped with inductive couplers mounted around the MV cables thus allowing some data transmissions with high data rates. Besides, some capacitive couplers have been installed in each substation on the LV side, it is therefore possible to transmit some data to the final customers connected to the power network.

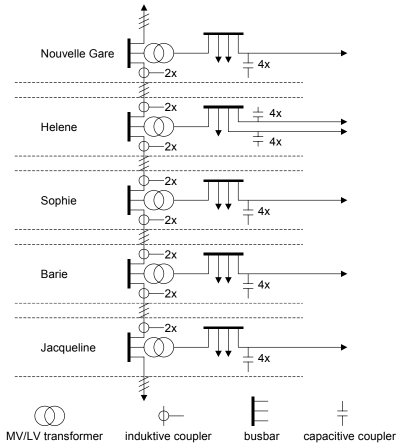

Fig. 2. Topology of the experimental network

IV. CHARACTERIZATION OF THE PHYSICAL LAYER

Let us consider first the MV side where some point to point channels can be defined, each one being located between two near substations. For each channel, we carried out a complete study of the physical layer including some path loss measurements and some impedance measurements. The obtained attenuation has been normalised according to the injected power. A network analyser has been used to obtain the complex impedance at the emission port.

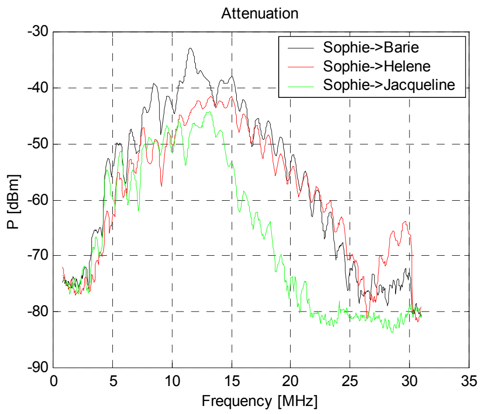

Fig. 3. Attenuation of the network on the MV side

Figure 3 shows some examples of the obtained attenuations on the MV side, a generator has been set in Sophie substation whereas a spectrum analyser has been set in Barie, Helene and Jacqueline substations. Some attenuation levels between 35 and 70dB may then be found and only some frequencies in the [5-20MHz] are recommended for some optimal data rates. Note than the high attenuation below 5MHz is due to the inductive couplers we used to transmit the signal on the MV side whereas the attenuation above 20MHz corresponds to the ohmic losses of the power cables. As the distances for the links Sophie-Barie and Sophie-Helene are comparable, the attenuation level is quite the same.

Figure 4 shows the complex impedance including magnitude and phase on the LV side. Many propagation modes have been investigated between the different conductors (L1:Phase1, L2:Phase2, L3:Phase3 and N:Neutral). Note that the neutral conductor is connected to the ground for safety reasons in the substation, therefore each propagation mode using the neutral conductor leads to a common propagation mode and not a pure differential one (see e.g [9] [10]).

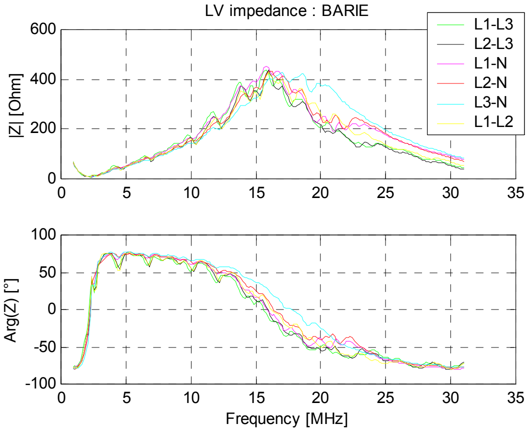

Fig. 4. Impedances of the network on the LV side

A resonance has been found in the obtained measurements and they are independent of the type of propagation mode. This means that the considered impedance is more inductive (resp. capacitive) in the lower (resp. higher) frequencies.

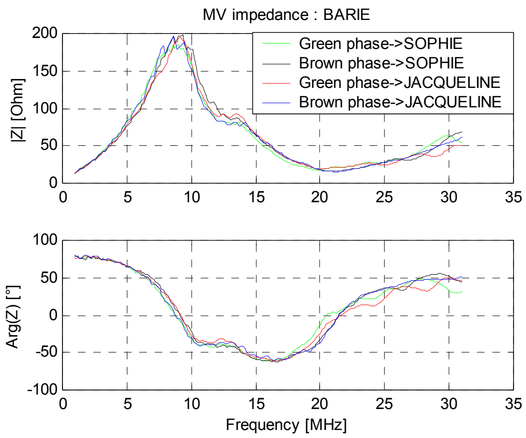

Fig. 5. Impedances of the network on the MV side

Considering figure 5, we can observe that the same shape can be found whereas the resonance frequency does not have the same location in the spectrum. The behaviour of the network is also slightly different since an inductive effect may be noted for the higher frequencies. We can conclude that the impedance is independent of the phase conductor and the feeding.

V. CHARACTERIZATION OF THE APPLICATION LAYER

We used some PLC modems using an OFDM chipset in order to perform some data throughput tests on both the MV and the LV networks. All these tests have been carried out using IPERF software to generate a traffic on the network to estimate some data rates according to a UDP and TCP protocols. We have obtained the results shown in table (1) for some UDP tests with a buffer size of 512KByte for the link Sophie- Helene.

Called bandwidth	Ping	Data rate	Loss
5Mb/s	0.17ms	5Mb/s	0.02%
10Mb/s	1.08ms	10Mb/s	0.01%
15Mb/s	0.82ms	15Mb/s	0.01%
20Mb/s	0.75ms	20Mb/s	0.12%
30Mb/s	0.69ms	18.9Mb/s	24%

Table 1

	Upstream	Downstream
UDP	7Mb/s	27.5Mb/s
TCP	11Mb/s	24Mb/s

Table 2

The UDP test results are pretty good, a fast backhaul could therefore be connected at Sophie substation. Moreover, we carried out these tests in both directions and found that the data rates are pure symmetrical on the MV side. TCP tests are interesting to estimate the obtained data rates without specifying any called bandwidth, we have performed some tests between Helene substation and a raiser close to some final users, the distance is about 100m between the emission and the reception ports. Table (2) shows the obtained results for both UDP and TCP tests.

These results on the LV side (see table (2))are first consistent with the ones obtained on the MV side even if the data rates are absolutely not symmetrical.

Some improvements have to be done to enhance the performances of the upstream otherwise the whole network performances will be limited even if the backhaul and the MV side provide some very fast speeds. It is possible to develop some wideband impedance matching algorithms based on Tchebycheff functions to minimize the reflected power at the emission port (see e.g [4]). If some significant changes of the channel properties occur versus time, some dynamic wideband impedance matching have to be developed (see e.g [5] [6]).

It is crucial for the enhancement of the speed of the transmitted data to implement some wideband impedance matching algorithms. At the same time, a backhaul providing some more important data rates could be used and the associated radiated emissions could be reduced drastically (see e.g [7] [8]). This last issue has to be taken into account in an electromagnetic compatibility (EMC) context and especially for the standardisation of the products installed on the network.

VII. CONCLUSIONS

In this paper, we investigated the channel capacities of an experimental distribution networks using experimental data only. All the presented measurements come from an in situ measurement campaign on an energized medium and low voltage networks. Therefore, we had some real experimental conditions and not only laboratory or simulation conditions. Besides, we pointed out that the studied network is not optimal in the sense that no wideband impedance matching algorithm is implemented in the PLC modem.

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