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MV Line Communications - Loss Parameter Analysis

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Abstract – The possibility to use the MV and LV electrical networks as a multi-purpose medium (for energy distribution/supply, voice and data transmission for the electricity company operating needs and for outside telecommunication services) is a consequence of the actual demands in the communications field. Design of a communication system respectively the power line communication networks planning mean to use a well channel modelling, taking into consideration the hostile properties of it.
In this sense two possible methods for the power line communication channel modelling (Carson method and /or D'Amore & Sarto method) are taken into account. The "ParaComPLC" is a software program proposed as a useful "tool" for the analysis of the power line communication channel behaviour. The actual version of this program is addressed to the overhead lines.
Keywords: power line communication channel, modelling, broadband

I. INTRODUCTION

The amount of power installations - that form the National Power System - and the number of the various entities responsible for their administration, operation and maintenance are considerable high, also being located in a great number of locations, spread on a wide area of the country (over 8,100,000 in Romania's case) [1,2,3].
In this context, there are a lot of locations that either do not posses any communication link or have to pay high costs or do not answer the needs/requirements of electrical companies.

II. THE POWER SUPPLY LINE – PHYSICAL SUPPORT FOR COMMUNICATIONS

During the last years, the power line communications became an alternative solution, from the viewpoint of telecommunications physical support [1,2], for telephony, Internet, video transmissions etc.
One of the possible communication solutions, applied on an extremely small scale because of several completely unsolved technological problems consists in the communications using medium voltage (MV) and low voltage (LV) power lines.
In this sense, the new generation of communication systems based on medium and low voltage power conductors, briefly named as PLC systems (Power Line Communication), could have a larger field of applicability. This appears is a consequence of the fact that data transmissions backbone infrastructures, with various rates and capacities are available in all industrialized countries [1,2,3]. However, currently the data flows distribution towards the clients is still an unsolved problem, PLC, wireless LANs and xDSL for "last mile" zone being in competition. In this context, the MV and LV power lines respectively can be an alternative solution for the following network zones (see fig.1):

- Distribution zone (between backbone and access network);
- „Last-mile" zone (the "access" network);
- „Last-inch" zone (the "in-home" network).

III.- MV AND LV POWER DISTRIBUTION NETWORKS BEHAVIOUR

The MV and LV electrical power lines, as components of electrical network [1,2,3], have the following features:

- supply a hostile channel for data transmission;
- impose, to communication channels that are using this media, several characteristics/ constraints which cannot be modified, such as: the location, the power network frequency; the lines length and type (overhead lines, old cables, new cables etc.); the fluctuant topology of the power network; the disturbances caused by switching operations etc.;
- have temporally and frequency fluctuant impedances/loads, in nodes and at ends respectively;
- can be connected at disturbing loads, and
- the indirect influence of the other power network components (power transformers, capacitor batteries, voltage and current measuring transformers, etc.), which, when telecommunication signals are passing through can show a peculiar behaviour, must be taken into account in case of modelling.

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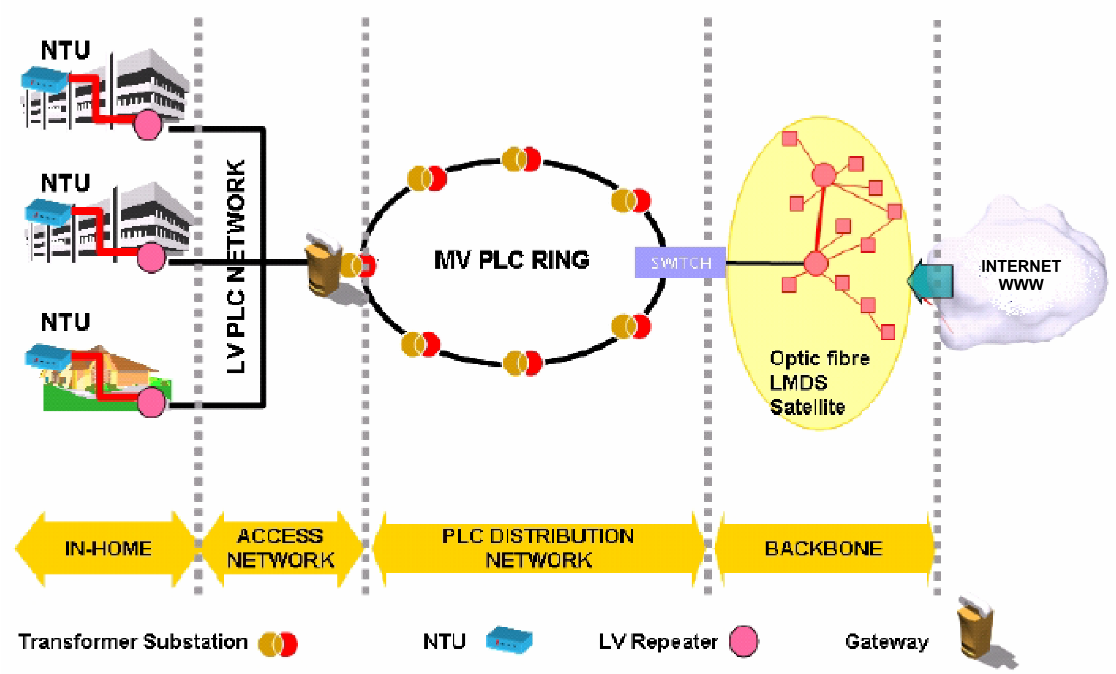


NTU - Network terminal Unit
LMDS - Local Multipoint Distribution Service

Fig.1. PLC network structure diagram [1,2,3,4]

In this context, the MV and LV power lines communication channel study in the range 0,1 ÷ 100 MHz deserves attention.

IV.- THE MODELLING OF A MV OHL COMMUNICATION CHANNEL

A great amount of work is dedicated to understand and study this channel type, the high frequency range (around 1÷30 MHz) being preponderant. According to paper [6], still does not exist an internationally recognized model for this kind of channel, the results of measurements being sometimes inconsistent or contradictory.

Two methods for the overhead power lines (OHL) transmission parameters calculation are presented in paper [1].

The first one is based on Carson relations. These relations, both the initial and the generalized ones as presented in detail, [5,6,7,8,9], take into account the depth below the ground surface of the equivalent return path, as a function of frequency, and ground resistivity, respectively.

The second method, presented and analyzed in paper [1], as an alternative to Carson method, is D'Amore & Sarto method, a relatively new method (1996). Amirshahi P. and Kavehrad M. [10,11] have considered that this method performs a better approximation of the OHL parameters at high frequencies, without providing information regarding accuracy level of the involved formulas.

V.- THE „ParaComPLC" CALCULATION/ SIMULATION PROGRAM

The "ParaComPLC" program [1,2,3] is based on both methods (i.e.,Carson method and D'Amore & Sarto method) and it was set up for analyzing the influence of several parameters fluctuation (signal frequency, phase conductor diameter, phase conductor height relative to the ground, ground resistivity and permeability etc.) on MV OHL transmission parameters.
The MATLAB programming language was involved. In this sense, the drafted software programs are of „*.m" files type; MATLAB facilities/ block sets, and MATLAB Simulink models respectively were not used.
This basic analysis once performed, other multiple analyses can further be made by program extension with additional modules.
For highlighting several additional details on the way the modelling program was performed, figure 2 shows the logical diagram of „ParaComPLC" program".

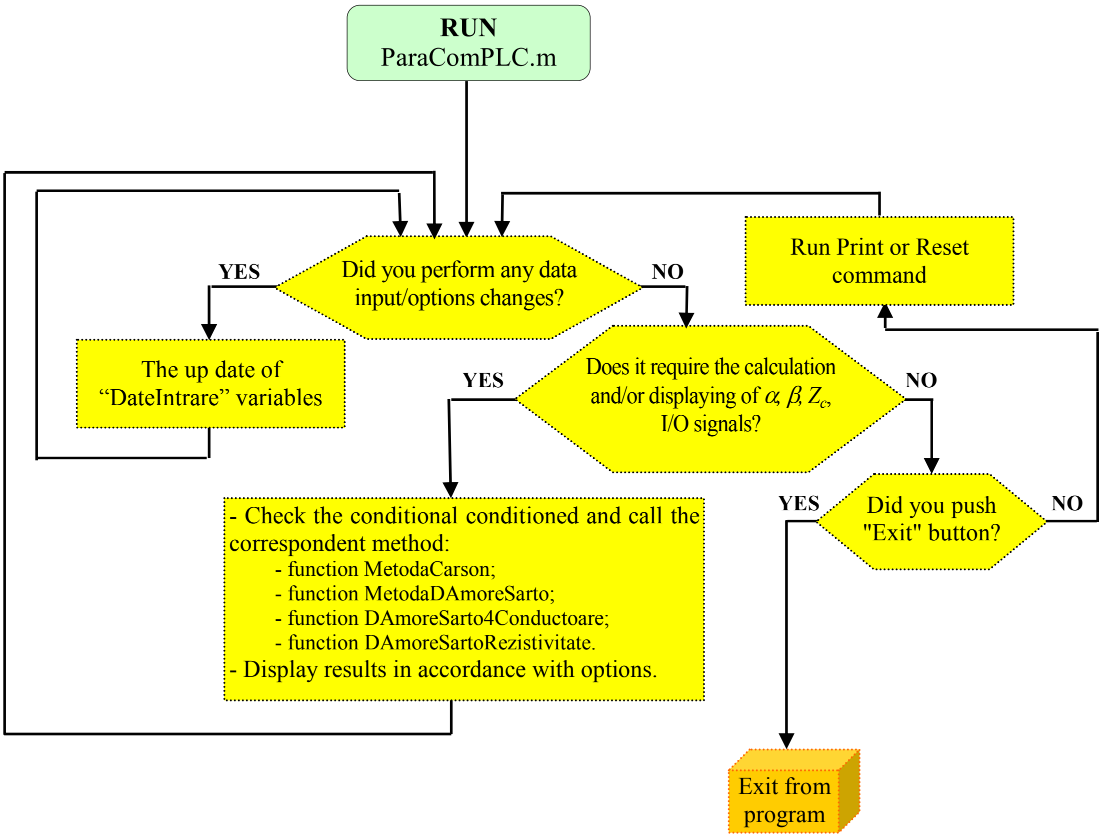


Fig. 2. The logical diagram of „ParaComPLC" program

VI.- THE COMPARATIVE ANALYSIS OF LOSS PARAMETER IN TERMS OF APPLIED METHOD (CARSON METHOD AND D'AMORE & SARTO METHOD)

The comparative analysis of the results obtained by the above mentioned methods highlights several important aspects which plead for the application of either Carson method, or D'Amore & Sarto method, in the analysis of the communication channel behaviour under debate.

As example, figures 3 and 4 show several results

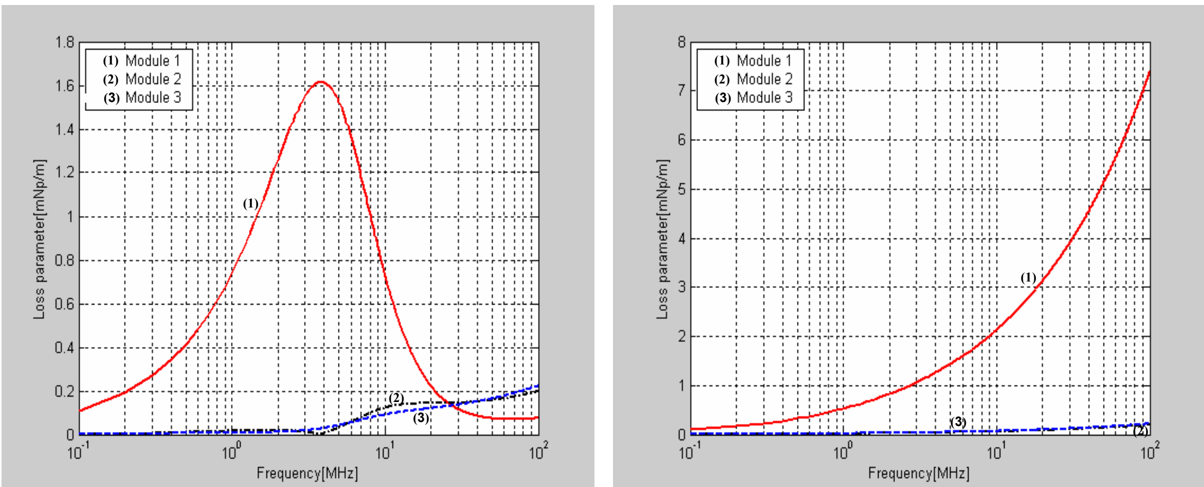
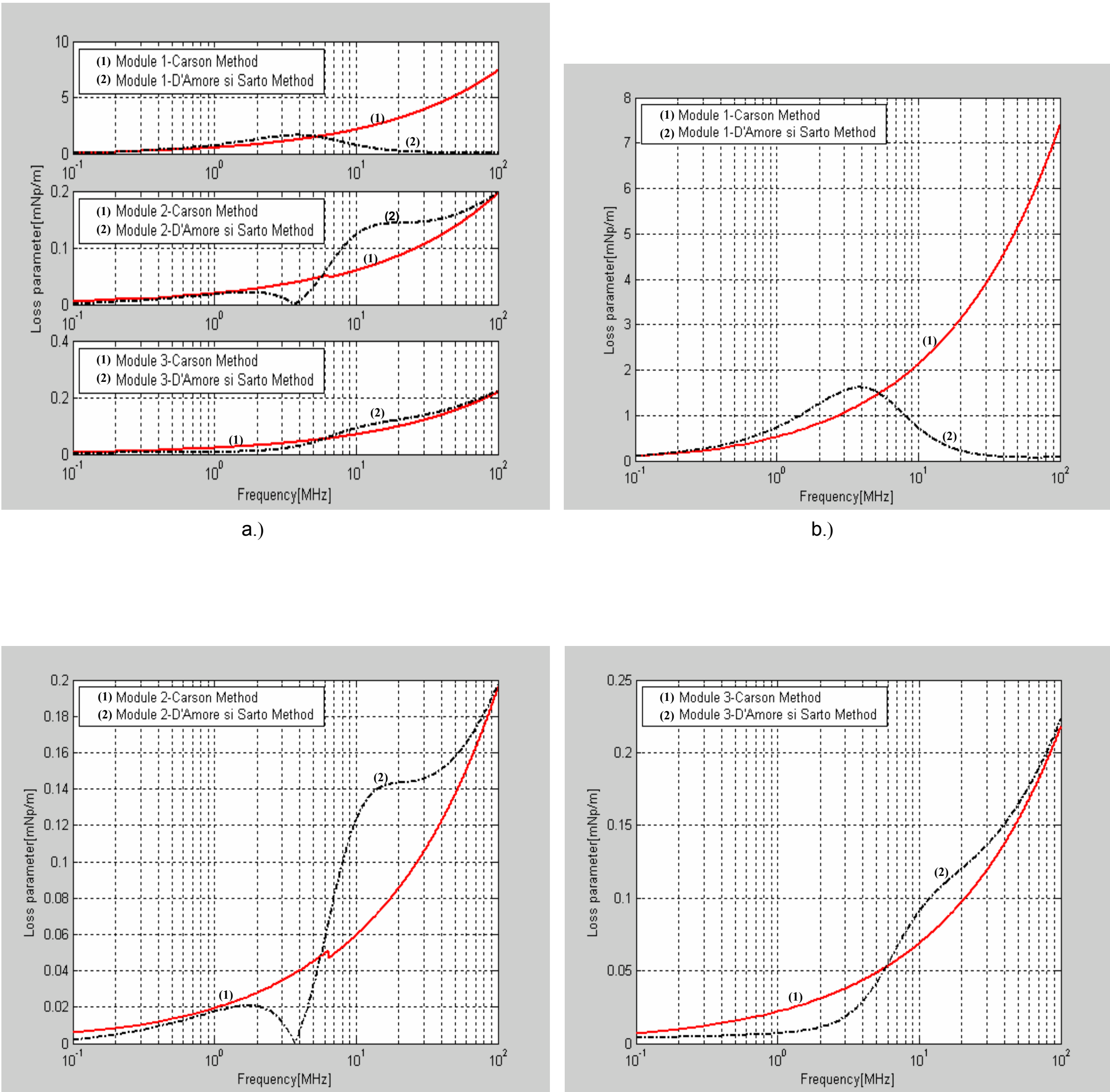


Fig. 3. The loss parameter (α) variation as a function of frequency (f = 100 kHz ÷ 100 MHz)
a.- D'Amore & Sarto Method, b.- Carson Method
$\rho_g = 200\ \Omega\cdot$m; $\varepsilon_g = 13\cdot\varepsilon_0$; d_i= 0,008 m; h_i = 10 m, 3 modes

obtained by „ParaComPLC” running. As can be noted, the loss parameters (α) values, obtained by the two methods in question, are significantly different, even in the low frequency range [1,3,5].



a.) b.)

c.) d.)

Fig. 4. The loss parameter (α) variation as a function of frequency (f = 100 kHz ÷ 100 MHz)
a.- Modes 1, 2 and 3; b.- Mode 1; c.- Mode 2; d.- Mode 3;
ρ_g = 200 Ω·m; $\varepsilon_g = 13 \cdot \varepsilon_0$; d_i= 0,008 m; h_i = 10 m

Amirshahi himself appreciated that at low frequencies both methods (Carson and D’Amore & Sarto) give close results.

Analysis of the data shown in figures 3 and 4 shows different results between the two methods for frequencies up to 5 MHz (up to 50 %, in case of mode 1 - fig.4.b, and up to 60 % in case of modes 2 and 3 respectively - fig.4.c and fig.4.d).

In the peculiar case of D'Amore & Sarto method it can be observed that for the common mode (mode 1) the loss parameter curve has a bell shape. As a consequence, this kind of shape denotes a significant decrease of loss parameter at higher frequencies.

Additionally, there are considered as noteworthy several aspects resulted from the analysis presented in paper [1], regarding loss parameter, such as:

a).- For the same frequency, the loss parameter increases when the ground resistivity becomes higher; this increase is more evident with mode 1. In case of using D'Amore & Sarto method, for mode 1, the higher values of ground resistivity lead to increase of the loss parameter maximum value and to its displacement to the left (the "bell" curve moves to the left).

A ground resistivity change can lead, depending on the frequency range subject under debate, to a major change of loss parameter. Thus, from the analysis performed in paper [1], an increase of the ground resistivity from 100 Ω·m up to 1000 Ω·m, leads to an loss parameter increase up to 100 %, in case of Carson method, and up to 200 %, in case of D'Amore & Sarto method respectively.

b) A change of diameter phase conductor from 0,008 m to 0,014 m (usual values for MV OHL) does not lead to a significant change of loss parameter (according to the analysis performed in paper [1], the loss parameter for mode 1 increases with approximately 3-5 %).

c) For the same frequency, the loss parameter decreases when the phase conductor height increases; this increase is more acute for mode 1. In case of using D'Amore & Sarto method, for mode 1, the phase conductor height increase leads to the increase of the loss parameter maximum value and to its displacement to the left (the "bell" curve moves to the left).

A change of phase conductor height can lead to a major change of loss parameter, depending on the frequency range subject under debate. Thus, from the analysis performed in paper [1], an increase of the phase conductor height from 6 m to 10 m, leads to an loss parameter decrease as low as 40 %, in case of Carson method, respectively up to 70 %, in case of D'Amore & Sarto method.

VII.- CONCLUSIONS

The high speed/rate communication systems, on MV and/or LV networks, posses the necessary potential for becoming a successful technology in Europe, but the associated costs will be higher in comparison with USA because of the voltage and architecture differences. In this context, it is interesting to study the communication channel which uses the power lines, the calculation of the transmission parameters being necessary, especially with high frequency ranges (approximately 1÷30 MHz).

By using "ParaComPLC" program, the effects of each (or cumulative) input parameter change can be studied. As a consequence the sensitivity level (higher or lower) of the communication channel connected to these parameters will result.

The comparative analysis of the results obtained with Carson method, as against D'Amore & Sarto method, for the MV OHL loss parameter, revealed significant differences between the two methods in question.

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