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Projet SInERT

SOLUTIONS INNOVANTES POUR L'INTÉGRATION DES ÉNERGIES RENOUVELABLES DISTRIBUÉES SUR LE RÉSEAU ÉLECTRIQUE TUNISIEN

LINE IMPEDANCE MEASUREMENT FOR PLC CHANNEL CHARACTERIZATION WITH COMMERCIAL SMART METERING PLATFORMS

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Power line communication (PLC) is widely used in power systems, for automatic meter reading and its use has been also investigate for other smart grid applications, such a secondary substation automation, remote control of distributed generator, and so on. To fully exploit the technology and face the problems related to disturbances and signal attenuations, it is important to characterize the communication channel, in the used PLC range, in terms of frequency response and line impedance, in the PLC frequency range of interest. This can allow individuating the best frequency bands for signal transmission, avoiding using those with higher levels of attenuation and/or noise. PLC line impedance depends on network topology, cables and loads and it can be time-varying; moreover, its measurement can be strongly affected by noise. Furthermore, the measurements are carried out in the absence of mains voltage, and they entail the use of and high-cost instrumentation (network analyzers or dedicated measurement systems based on data recording and processing software) and the grid topology knowledge.

This paper investigates the feasibility of an alternative approach, which allows to measure the lie impedance by means of the typical electronic boards, equipped with a PLC modem, which are currently used for smart metering purposes; the proposed solution exploits the PLC signal itself as test signal for the impedance measurement. In this way, no dedicated measurement equipment is needed and the impedance measurement can be theoretically obtained for each signal transmission.

The developed "Line Impedance Calculator" (LIC, [1]) is based on the injection of a G3-PLC signal superimposed on mains voltage and the measurement of voltage and current in the frequency range of interest, i.e. for CENELEC A, B and FCC band. The PLC signal preamble is used as characterization signal over the whole frequency range of interest. The impedance calculation is carried out by means of an interpolated FFT analysis, which does not require high computational capabilities. A LIC prototype has been developed by using an EVALKITST8500-1 board for PLC signal injection, a ST NUCLEOF446RE for signal acquisition and impedance calculation. The scheme of the boards connections and the LIC flow chart are shown in Fig. 1. The developed LIC prototype is shown in Fig. 2. The LIC functionality has been added to the EVALKITST8500-1 PLC Field Analyzer tool, developed in [2] and it was included on the Graphical User Interface (GUI) called Smart Grid LabTool from ST Microelectronics (see Fig. 1).

The developed prototype has been tested by connecting loads of known values. In detail, a resistive-inductive and a resistive-capacitive load were considered. The loads values were selected in order to have a typical frequency trend that can occur in a power line. The LIC measurements have been compared with those measured with a Keysight ENA E5080A Vector Network Analyzer (VNA, accuracies of 0.1 dB and 1° for magnitude ad phase measurements, after calibration, in the frequency range 9 kHz – 10 MHz). Several tests with different load impedance values were carried out, in both CENELEC-A/B and FCC frequency bands. Some results of mean magnitude and phase errors between LIC and VNA are summarized in Table I. In all tests, LIC and VNA measurements resulted compatible. Thus, the developed diagnostic tool can be usefully exploited for the channel characterization, as well as for detecting the frequency bands with a higher level of attenuation or noise and select the most suitable frequency bands for optimal transmission.

[1] Artale, G. et al, "A Line Impedance Calculator Based on a G3 PLC Modem Platform", (2022) IEEE Transactions on Instrumentation and Measurement, 71, DOI: 10.1109/TIM.2022.3146629
[2] Artale, G. et al. "Implementation of a PLC Field Analyzer on a G3 Modem Platform", (2021) Conference Record - IEEE Instrumentation and Measurement Technology Conference, 2021-May, art. no. 9459937.

Table I. Experimental Results

Frequency band	Load Impedance	Mean Errors (Magn./Phase)
CENELEC-A (35 ÷ 90 kHz)	R = 3.3 Ω	0.24 Ω 0.96 °
	RL series R = 10 Ω, L = 33 μH	0.68 Ω 1.57 °
	RC series R = 10 Ω, C = 330 nF	0.60 Ω 0.37 °
CENELEC-B (95 ÷ 125 kHz)	R = 10 Ω	0.20 Ω 1.79 °
	RL series R = 24Ω, L = 100 μH	0.45 Ω 1.79 °
	RC series R = 24 Ω, C =15 nF	1.90 Ω 0.39 °
FCC (150 ÷ 490 kHz)	R = 10 Ω	0.16 Ω 2.25 °
	RL series R = 24 Ω, L = 10 μH	0.99 Ω 1.24 °
	RC series R = 24 Ω, C =47 nF	0.77 Ω 1.21 °

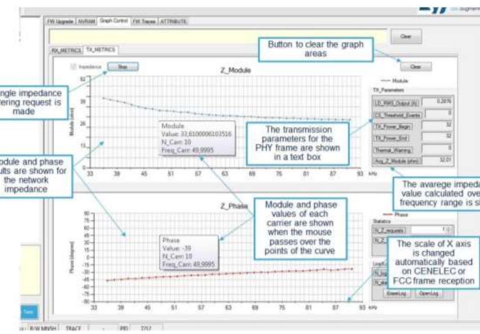

Fig. 1 LIC front panel (Smart Grid LabTOOL)

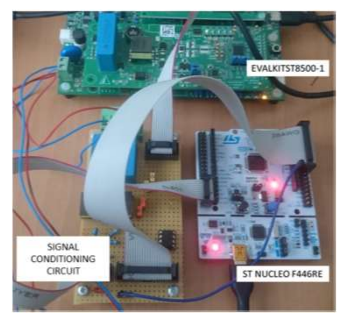

Fig. 3 LIC prototype

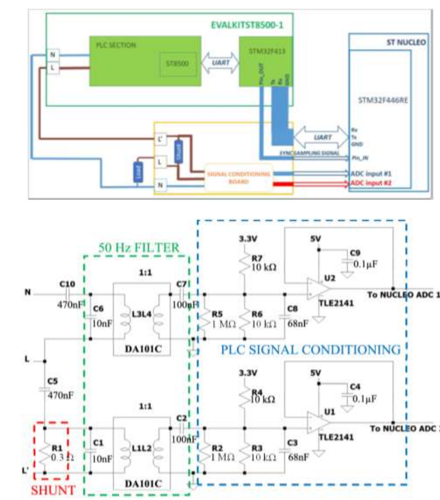

Fig. 2 LIC Scheme and connection diagram of EVALKITST8500-1, NUCLEO board and signal conditioning circuit

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