Laboratory Setup for PLC/BPL Devices Testing

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Abstract

The paper introduces a prototype of a remotely controlled PLC/BPL communication channel emulator that was designed, assembled and tested using industrial components. Radio communication channel of a mobile network and wired channel of a cable network can be emulated. Communication technologies for Smart Grid can be tested and verified using the emulator. The test setup and remotely controlled attenuator design are described in the paper.

Index Terms

BPL; technology testing; remote control; Smart Grid.

I. INTRODUCTION

WITHIN our collaboration with industrial companies involved in Smart Grid technologies and solutions, we have developed, designed, assembled and tested a prototype of a remotely controlled emulator of a PLC/BPL communication channel. Although its first version is a laboratory sample, its design relies on standard industrial components, thus assuming its future application in real operational environments. Its capabilities include emulation of a radio communication channel for mobile networks, as well as "wired" channel usual in cable networks. The primary purpose of the system is to test and verify specific communication technologies that should be used in Smart Grids.

II. TESTING SETUP DESIGN

To set up the testing workplace, it is recommended to use open and freely available IP testing tools – Iperf for TCP/IP tests and FlowPing (https://flowping.fel.cvut.cz) for UDP/IP. Instead of using expensive measuring devices, we suggest using a miniPC powered by Linux, equipped with a tailored measurement application relying on the mentioned tools with centralized control and processing of results (working designation: FlowTester).

In particular, the following parameters (their time distribution and statistics) shall be measured:

- Throughput (TP, in Mbit/s),
- Round-trip time (RTT, in ms),
- Packet loss ratio (PLR, in %).

The tests shall include the following stages:

- Load tests to determine throughput limits (saw wave increase of UDP traffic for different packet sizes – the saw wave is generated until the congestion state together in both directions, and the resulting throughput of the system is sought);
- Long-term connection stability tests (constant transmission rate);
- TCP traffic test (maximum data throughput and its fluctuation in time);
- Parallel TCP streams test – real traffic emulation (mutual influence of the streams is observed).

For each type of test, testing time sequences and the limits of the monitored parameters shall be determined to meet the given requirements.

The basic principle of BPL modems testing is shown in Figure 1.

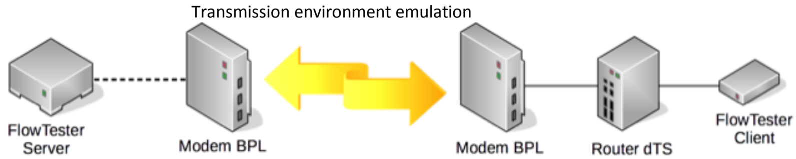

Fig. 1 Basic principle of BPL modems testing

The device is used for insertion of attenuation in the range of 3 to 63 dB into a high-frequency (0 to 2.4 GHz) transmission path. It is designed to emulate a PLC/BPL channel. The attenuator can be equipped for different limits of maximum attenuation and maximum transmitted power. Interference and noise are injected into special ports using a universal tributary generator.

Fig. 2 First demo of the testing setup

A. Attenuator design

The attenuator consists of two sections to achieve the required attenuation range. Attenuation adjustment based on TTL levels is provided by a mini PC that performs a conversion from a TCP/IP network (Ethernet interface) connected to the laboratory's central system for control and remote setup.

The control module is built on the OLIMEX RT5350F embedded platform, which can be expanded with additional interface modules (RS-485, RS-232, TTL, etc.) extending its functionality for different needs of the testing center. The platform and its software allow remote updating.

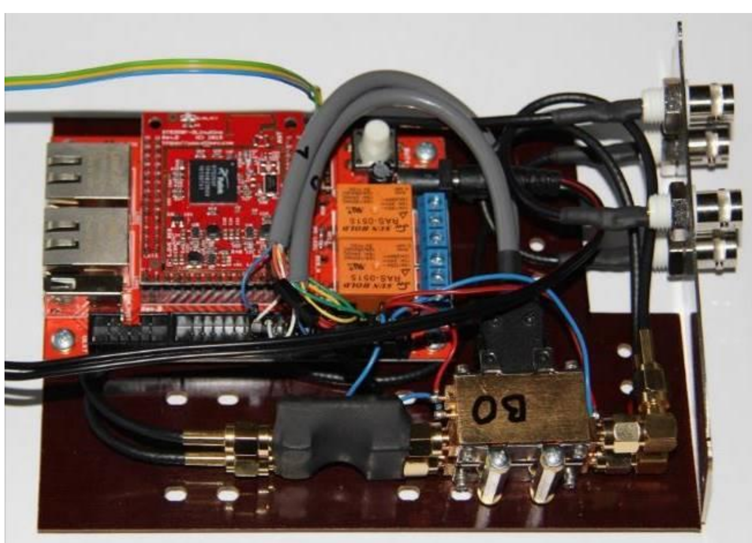

Fig. 3 Prototype of remotely controlled attenuator

For the purposes of control and monitoring of the connected devices, special software (firmware) was developed that performs conversion from abstract language (JSON), which is used for communication by the laboratory's central system, to specific commands used by the controlled technology (attenuator, generator, analyzer, etc.). The software is also responsible for collecting data from individual peripherals and transmitting them to the central system.

As the most appropriate solution, affordable and proven attenuators (www.minicircuits.com) with parallel control based on TTL levels have been selected. Recommended type for frequencies up to 2.4 GHz and output power up to 24 dBm is ZX76-31R5-PP+. Its advantage is a low price (about a tenth compared to commercial products equipped with programming over an Ethernet port). In the signal part (RF) of the PLC version, there are included couplers providing links to noise and interference generators (NOISE port).

By measuring the attenuator, calibration curves for different settings of attenuation values were obtained. Figure 4 shows attenuations between RF ports (signal path) as well as between NOISE and RF ports (path bringing the interference to the signal). All ports are assumed to be terminated with 50 ohms impedance.

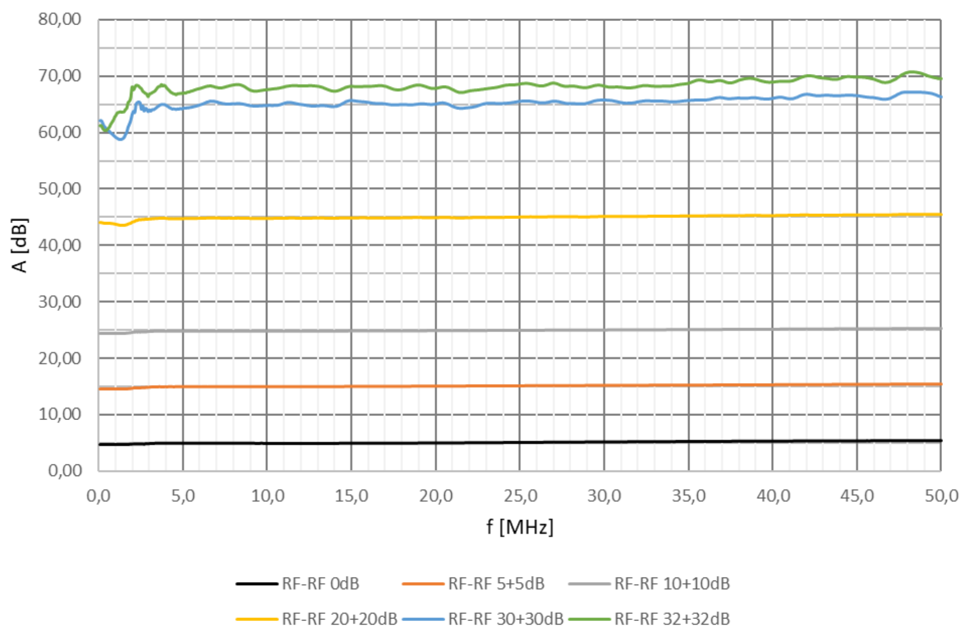

Fig. 4 Frequency dependence of attenuation for different settings

Generator control consists of an interface converter, also built on the embedded OLIMEX RT5350F platform. As for the generator, the conversion of commands between the laboratory's central system and commands that are compatible with the arbitrary generator is solved. The device is therefore sufficient just with a mounted board and firmware that translates the commands. The point is to simplify the control performed by the control system, which is basically sufficient just with the options of AWGN white noise (Additive White Gaussian Noise) and REIN impulse noise (Repetitive Electric Impulse Noise), activating/deactivating the noise and setting the noise amplitude.

Fig. 5 Next version of the testing laboratory setup

B. Throughput testing example

FlowTester device (https://flowtester.fel.cvut.cz) is used to test transmission performance. In Fig. 6 an example of a test is demonstrated.

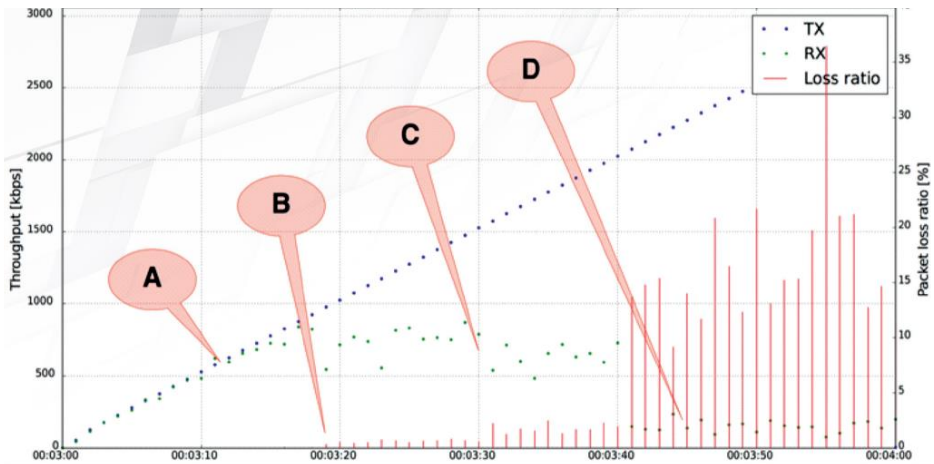

Fig. 6 Data throughput measurement – ramp test

FlowTester has the ability to verify performance parameters and the reliability of the entire communication network or its section with respect to a particular service or application (such as SLA compliance). The results can be further used for communication network dimensioning or for detection of performance degradation. FlowTester can be adapted for various applications deployed in the world of IoT as it supports intelligent testing of Smart Grids using traffic simulation according to standards IEC 60870-5-104, 61850 or DLMS.

An example of data throughput measurement by ramp test is shown in Fig. 6 (graphical visualization of maximum throughput detection for a measured network connection). This measurement is based on the incremental increase of offered traffic load and monitoring of real network throughput. Letters A—D denote important areas of the graphical visualization. Point A indicates the saturation threshold. Point B shows the moment when the first packets are lost. Point C shows the maximum network throughput just before another threshold and causing an increase in packet loss. A highly overloaded connection is shown in area D.

III. CONCLUSION

The equipment was verified by testing of BPL modems for low-voltage AMM applications (communication between a concentrator and a smart meter), as well as by testing of BPL modems designed for medium-voltage (testing between RF ports of modems without coupling to the medium-voltage line).

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