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Analysis of Narrow Band PLC Technology Performance in Low-Voltage Network

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***Abstract*—Although the PLC technology is increasingly used mainly in low voltage networks, causes of interference of signal transmission have not been, as yet, sufficiently explained. It is very important for the wider use of this technology in practice. The paper presents and discusses the results of simulation analysis of transmission efficiency for narrow band PRIME standard obtained for specially developed for this purpose simulation model of the real low voltage network. This model allows both the mapping of the network parameters in the desired range as well as the modelling of physical phenomena occurring in it that may practically affect the narrow-band transmission quality. On the basis of the results the suitable conclusions for practical applications have been formulated.**

***Index Terms*—Power Line Communication, narrow band technology, low voltage network phenomena, simulation of transmission efficiency.**

I. INTRODUCTION

A priority direction in development of electrical power networks and systems tends to application of variety of smart solutions mainly in metering and control. One of such trends is the use of PLC technology (power line communication), both narrow and broadband [1]–[3]. However, the effectiveness of this technology is not fully utilized because of the hitherto unexplained causes of unwanted interferences and power losses. The authors have attempted to explain those reasons based on the simulation results obtained, and experimental studies. With many different telecommunication technologies the most popular in use are DCSK, PRIME and BPL [4], [5]. The authors focused on PRIME technology and conducted a survey of its performance in the low voltage network. Therefore, corresponding simulation model in Matlab Simulink was developed to allow mapping of both network parameters and analysis of phenomena occurring in it that could potentially interfere with the PLC transmission. On the basis of the results the suitable conclusions for application in practice have been formulated.

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II. INVESTIGATION PROCEDURE

The investigations were carried out for narrow band (2 kHz–98 kHz) PRIME technology when employed in low voltage network operated under normal as well as disturbed conditions. All types of modulations were examined such as (Fig. 1):

– DBPSK – differential binary phase shifting key;
– DQPSK – differential quadrature phase shifting key;
– D8PSK – differential octet phase shifting key.

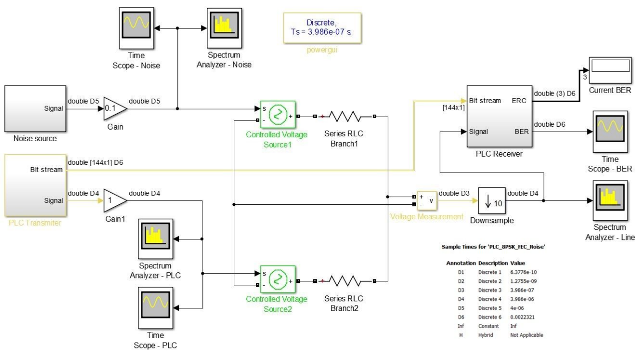

Fig. 1. General idea of simulation PRIME PLC over power system network.

The general idea of simulation environment is presented in Fig. 1. On the left we can see the PLC transmitter with two outputs. One is the SIGNAL going to the network, the other (BIT STREAM) is the reference for receiver to calculate BER (on the right). BER is being calculated by a simple comparison of two bits streams over the total no. of bits received. The simplified diagram is presented in Fig. 2.

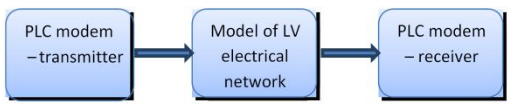

Fig. 2. Simplified block diagram of PLC communication performance testing model.

Models of the receiver and transmitter PLC modems were developed according to parameters described in standard “PRIME standard: Recommendation ITU-T G.9904” [1]. Model of the low voltage network has been designed so that with acceptable level of complexity they could ensure reliability of the calculations in real line under normal conditions (no disturbances or faults).

For the calculations real low-voltage grid was selected which simplified electric diagram is shown in Fig. 3. Fig. 4 illustrates its model representation developed in Matlab.

Selected for the analysis the real low-voltage network of 0.4 kV is a single line supplied (20 kV) via transformer 20/0.4 kV with 10 m of YKXS 3 × (4 × 1 × 200) cable and 1 × 120 mm^2 grounding. It is loaded with 11 cable feeders drawing various active power values from 10 kW up to 83 kW respectively (Fig. 3). Way of connection of modems and network models under testing of PLC performance is shown in Fig. 5.

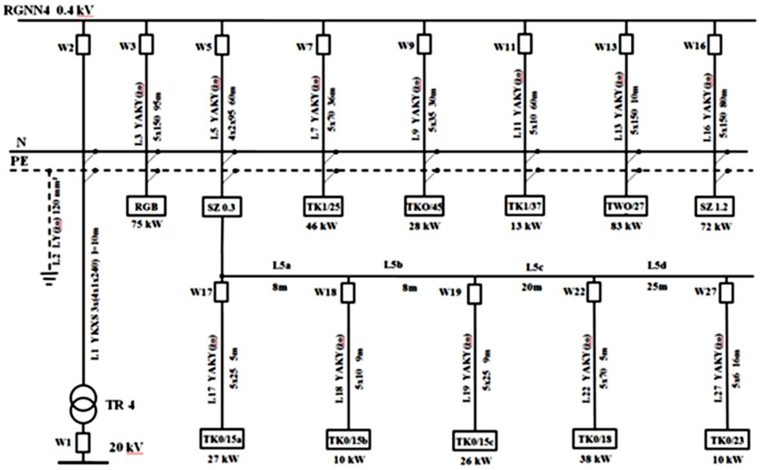

Fig. 3. Simplified scheme of LV electrical network selected for modeling.

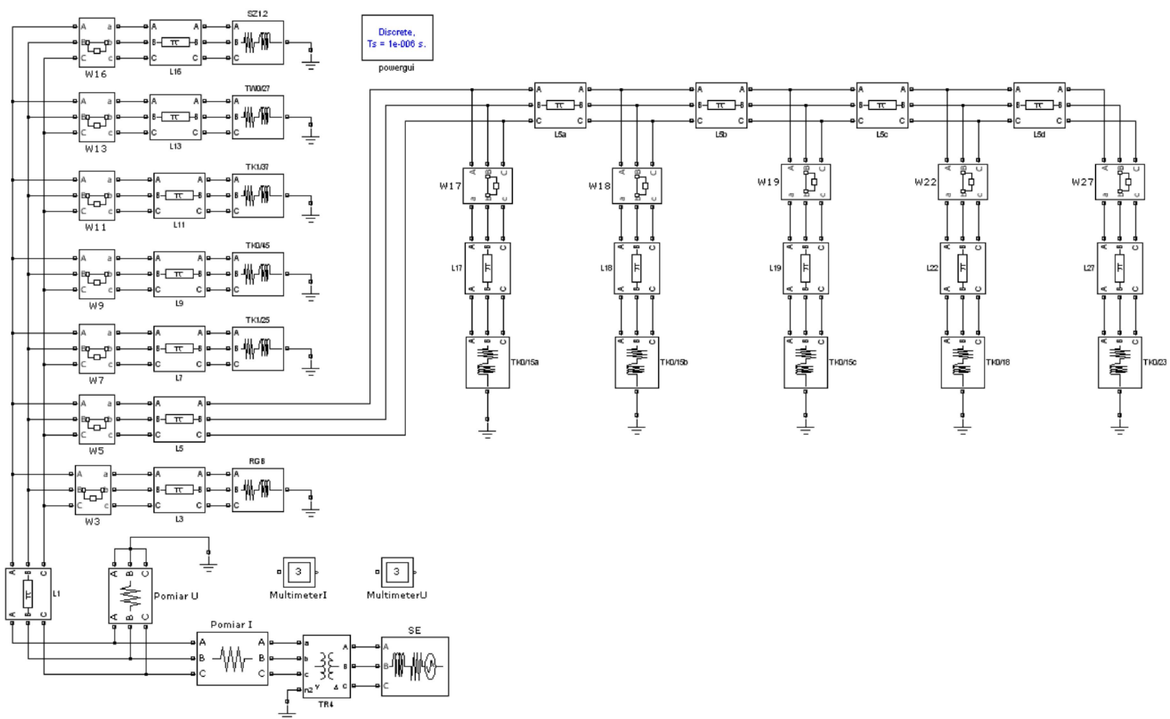

Fig. 4. Matlab model of selected LV electrical network.

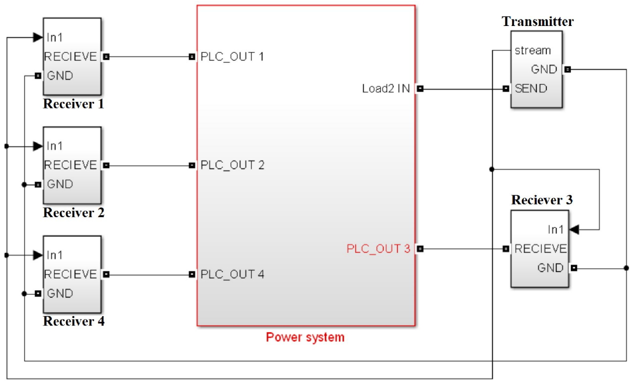

Fig. 5. Block scheme for testing the PLC performance in Mathwork Matlab Simulink.

Under testing it was equipped with a set of one PRIME transmitter modem and four receiving modems respectively. For each selected measuring point (in LV network at distance of 52 m, 68 m, 128 m and 136 m respectively) the transmission efficiency studies were carried out under influence of six different disturbances namely:

– performance of PRIME PLC communication without FEC (forward error correction) for white noise equal to 10 % SNR (signal noise ratio),

– performance of PRIME PLC communication with use of FEC (forward error correction) for white noise equal to 10 % SNR (signal noise ratio),

– performance of PRIME PLC communication without FEC (forward error correction) during 1 kV impulse disturbance,

– performance of PRIME PLC communication with use of FEC (forward error correction) during 1 kV impulse disturbance,

– performance of PRIME PLC communication without FEC (forward error correction) during 10 kV impulse disturbance,

– performance of PRIME PLC communication with use of FEC (forward error correction) during 10 kV impulse disturbance.

III. INVESTIGATION RESULTS

Transmission capability of tested modulation was specified using BER (bit error rate) value. It determines the number of bit errors that occurred over specific time interval. For digital transmission it is equal to the number of received bits of data stream over a communication channel (in this case it is a low voltage network) that have been altered due to noise, interference, distortion etc. Authors tested three types of signal modulation (BPSK, QPSK, 8PSK), all of them are used under PRIME technology for Power Line Communication. Full band noise as well as impulse signals were introduced as transmission disturbance. Level of white noise was set to 10 % (0.1 Vrms) of PLC signal level. Disturbance impulse was introduced as 1 kV and 10 kV pulse respectively [6].

The study showed that a significant impact on the transmission efficiency is due to the presence of parallel feeders over the signal flow path. It results in the most probable from signal leakage involved and its attenuation as well; however, the effect of interference [7] is also very important as it can be seen from Fig. 6–Fig. 9.

TABLE I. BER VARIATION UNDER 10 % VALUE OF WHITE NOISE FOR PLC SIGNAL AMPLITUDE EQUAL TO 1 VRMS WITH FEC APPLIED.

Modulation TYPE	Distance from TRANSMITTER [m]	BER [%]
8PSK	52	1,3
QPSK	52	1,3
BPSK	52	0,5
8PSK	68	1,8
QPSK	68	1,3
BPSK	68	1,4
8PSK	128	41
QPSK	128	28
BPSK	128	2
8PSK	136	47
QPSK	136	48
BPSK	136	47

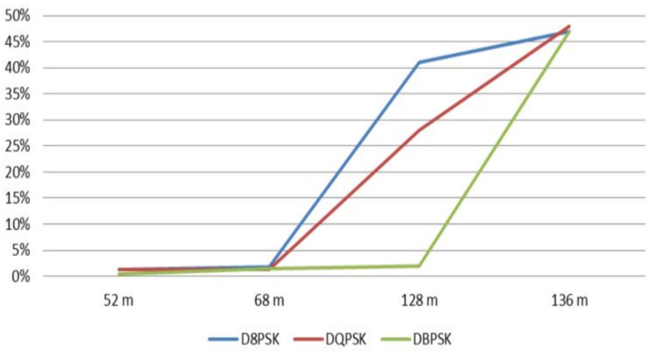

Fig. 6. Variation of BER value for PLC communication in selected LV network structure under 10 % full band noise and with FEC applied.

Simulated BER data for PRIME technology presented in Table I–Table IV were calculated for each transmitted – received bit set as a correlation of these two values [8]. Application of forward error correction (FEC) in tested PRIME communication appeared to have slightly degrading effect on transmitter signal what is manifested in the respective increase in the BER value (Table I–Table IV).

TABLE II. BER VARIATION UNDER 10 % VALUE OF WHITE NOISE FOR PLC SIGNAL AMPLITUDE EQUAL TO 1VRMS WITHOUT FEC.

Modulation TYPE	Distance from TRANSMITTER [m]	BER [%]
8PSK	52	0,5
QPSK	52	0,3
BPSK	52	0,3
8PSK	68	0,9
QPSK	68	0,4
BPSK	68	0,4
8PSK	128	2,5
QPSK	128	15
BPSK	128	1,5
8PSK	136	47
QPSK	136	47
BPSK	136	46

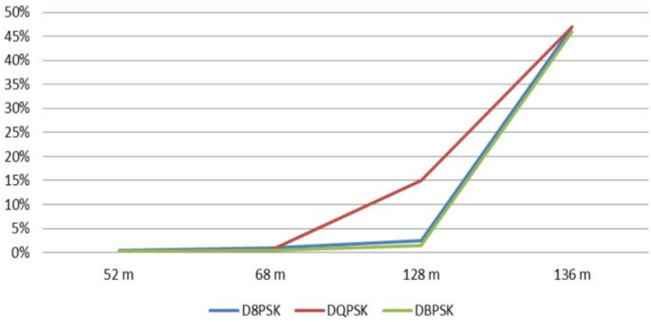

Fig. 7. Variation of BER value for PLC communication in selected LV network structure under 10 % full band noise and without FEC.

TABLE III. BER VARIATION WITH AND WITHOUT FEC UNDER 1 KV IMPULSE DISTURBANCE FOR PLC SIGNAL AMPLITUDE EQUAL TO 1 VRMS.

Modulation TYPE	Distance from TRANSMITTER [m]	BER [%] 1 kV impulse FEC	BER [%] 1 kV impulse no FEC
8PSK	52	3	2
QPSK	52	2	2
BPSK	52	2	2
8PSK	68	2	2
QPSK	68	3	2
BPSK	68	3	2
8PSK	128	37	24
QPSK	128	27	15
BPSK	128	4	3
8PSK	136	47	47
QPSK	136	47	46
BPSK	136	46	45

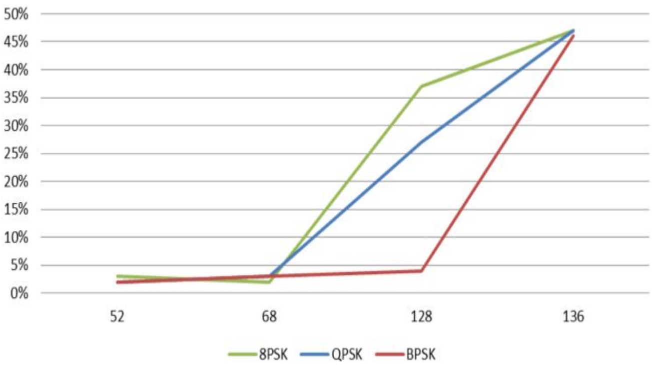

Fig. 8. Variation of BER value for PLC communication in selected LV network structure under influence of 1 kV impulse disturbance with FEC applied.

TABLE IV. BER VARIATION WITH AND WITHOUT FEC UNDER 10 KV IMPULSE DISTURBANCE FOR PLC SIGNAL AMPLITUDE EQUAL TO 1 VRMS

Modulation TYPE	Distance from TRANSMITTER [m]	BER [%] 10 kV impulse FEC	BER [%] 10 kV impulse no FEC
8PSK	52	3	2
QPSK	52	2	2
BPSK	52	2	2
8PSK	68	2	2
QPSK	68	3	2
BPSK	68	3	2
8PSK	128	37	24
QPSK	128	27	15
BPSK	128	4	3
8PSK	136	47	47
QPSK	136	47	46
BPSK	136	46	45

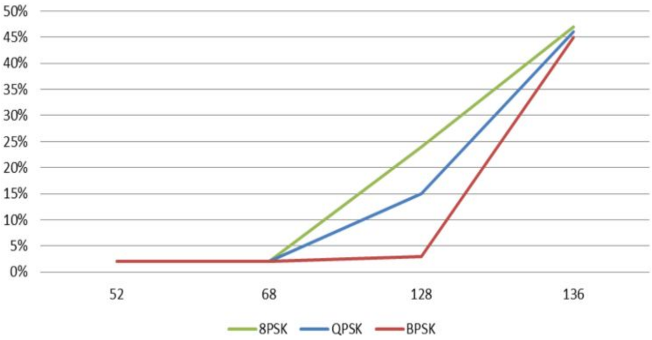

Fig. 9. Variation of BER value for PLC communication in selected LV network structure under influence of 1kV impulse disturbance without FEC applied.

IV. CONCLUSIONS

The research conducted for a selected low-voltage network of a radial structure has shown that despite of implemented disturbances the lowest BER values were achieved for the slowest modulation, i.e. BPSK, without FEC application. Only for the most distant receiver none of the modulation types provided acceptable level of PLC signal. Under influence of 10 % value of full band noise (with respect to PLC signal amplitude) the transmission based on PRIME technology can be fully effective only up to approximately 130 m. Application of forward correction (FEC) negatively effects the transmission using 8PSK and QPSK modulation types resulting in decrease of the transmission quality. It was found that electrical parameters of the low voltage network and its structure has a significant impact on the quality and range of the PLC transmission. Especially for the network of the radial structure the signal energy leakage and its attenuation seems to play an important role. It was also observed that operation of the FEC doesn't depend on disturbance nature. Research also showed that voltage impulses that drastically excide voltage level of tested electrical network have much more degrading influence on PLC than implemented white noise. Therefore full transmission is achieved only up to 70 m for all modulations. Only BPSK type modulation can be effective up to 130 m. With use of QPSK one can provide also communication up to 130 m but with BER at level of 15 % (BER at level of 50 % means total loss of transmission).

However, more study is required to answer the question why using FEC give worst result than without FEC. PRIME specification states that simple ½ rate Convolution Codes are used as FEC with Interleaving over given equations. There is a lack of information how it was estimated as well as if it‘s the best possible solution. More simulation will be performed in this area as the future work.

REFERENCES

[1] *PRIME Standard: Recommendation ITU-T G.9904.* [Online] Avaliable: http://www.itu.int/rec/T-REC-G.9901-201211-I/en

[2] M. Carcelle, *Power Line Communication in Practice.* Groupe Eyrollers: Paris, France, 2006.

[3] R. Smolenski, J. Bojarski, A. Kempski, P. Lezynski, "Time-domain-based assessment of data transmission error probability in smart grids with electromagnetic interference", *IEEE Trans. Industrial Electronics*, vol. 61, no. 4, pp. 1882–1890, 2014. [Online]. Available: http://dx.doi.org/10.1109/TIE.2013.2263772

[4] B. Adebisi, A. Treytl, A. Haidin *et al.*, "IP-centric high rate narrowband PLC for smart grid applications", *IEEE Communications Magazine*, vol. 49, no. 12, pp. 46–54, 2011. [Online]. Available: http://dx.doi.org/10.1109/MCOM.2011.6094005

[5] S. Stosovic, B. Dimitrijevic, N. Milosevic, Z. Nikolic, "OFDM/DPSK system performance improvement in the presence of frequency offset using a reconfigurable detection algorithm", *Elektronika ir Elektrotechnika*, no. 3, pp. 35–38, 2012. [Online]. Available: http://dx.doi.org/10.5755/j01.eee.119.3.1359

[6] B. Miedzinski, D. Pyda, M. Habrych, "Selection of energizing quantities for sensitive ground fault protection of MV electric power networks", *Elektronika ir Elektrotechnika*, no. 7, pp. 57–60, 2012. [Online]. Available: http://dx.doi.org/10.5755/j01.eee.123.7.2374

[7] E. Kabalci, Y. Kabalci, "A measurement and power line communication system design for renewable smart grids", *Measurement Science Review*, vol. 13, no. 5, pp. 248–252, 2013.

[8] S. Hosoya, M. Tokuda, T. Matsuo, "Conducted interference immunity test to high-speed power line communication system", in *Proc. 20th Int. Zurich Symposium on Electromagnetic Compatibility*, 2009, pp. 365–368.