PLC Impulsive Noise in Industrial Zone: Measurement and Characterization

Trung H. Tran, Dung D. Do, and Tue H. Huynh

***Abstract*—Noise in PLC is of relatively complex structure of which the most important component is the asynchronous impulsive noise. Based on measurements realized in an industrial zone, this paper shows the heavy tail phenomenon observed in experimental measures. Consequently, the alpha stable model is the most natural to be used in describing the statistics of PLC impulsive noise in industrial zones. Furthermore, the inter-arrival time is of Pareto distribution while the duration of impulses follows a mixed exponential distribution. All parameters of the alpha stable model as well as the Pareto parameters and the mixed exponents are statistically estimated. The variation of these parameters with time is also discussed.**

***Index Terms*—Power line communication, impulsive noise, measurement and characterization.**

I. INTRODUCTION

To design a good performance data transmission system that operates on the power line networks (PLC), it is necessary to know all impairments induced by the PLC networks used as communication channels. It is well known that PLC networks are complicated communication channels [1]. Due to many interconnections and taps, it is quite natural to model this kind of channels as random multipaths [2]-[4]. Furthermore, the mechanism generating additive noise is much more complex; based on experimental measurements as well as on physical modeling, additive noise on PLC is divided into different categories of which the most important component is the asynchronous impulsive noise that causes serious flaw to the data transmission systems that employ PLC as communication medium. The last few decades, many researchers have given many tries to model this noise component [5]-[7]. In our work, we are interested in measuring, analyzing and modeling this impulsive noise component in an industrial zone. Our measurements have shown that in such environment, the general characteristics are still observed (high amplitude, bursty) but in industrial zone, impulsive noise is of heavy tail. We organized a very intensive and complete campaign of measurement in order to obtain a very rich set of quite representative noise samples. Based on this experimental result, the heavy tail phenomenon is evident. Due to this conclusive observation, we propose to use the alpha stable distribution as model for impulse amplitude. Our approach is different from the known ones which often use Gaussian mixture to model this kind of noise [8]. In our work, we study the time varying characteristics of noise parameters, including amplitude statistic parameters, duration and inter-arrival time.

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II. MEASUREMENT

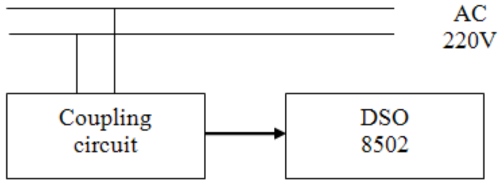

Fig. 1. Measurement set-up

We have conducted a measurement campaign in Do Son Industrial Park for 2 weeks, three times per day (i) from 8AM to 10AM; (ii) from 11AM to 1PM, and (iii) from 2PM to 4PM. Firstly, the electrical signal is extracted from the AC 220V 50Hz power line by an isolated coupling circuit and sampled at the rate of 500MHz by DSO8502, which can store 1,045,487 samples in its 2MB RAM. To avoid recording too much data, the trigger level is set to 960mV and the recording time of each measurement is 524μs. Results are then transferred to a PC and processed by a Matlab program.

III. MEASUREMENT RESULTS

A. Patterns of Measured Pulses

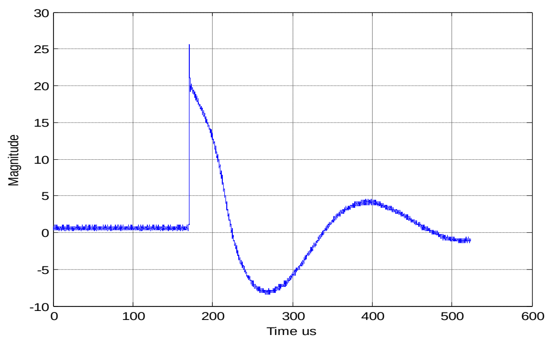

Fig. 2. A single decayed impulse

Fig. 2 shows a single decayed impulse. It has a vertical jumping at start and reduces by the exponentially-decaying-bound sinusoidal function. The pulse peak measured is up to 25V. We have observed 871

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pulses of this form during an hour and 48 minutes, which corresponds to a frequency of 0.1344 impulses/minute. The appearance of 25V-peak pulses at such high frequency can be seen as of heavy tail.

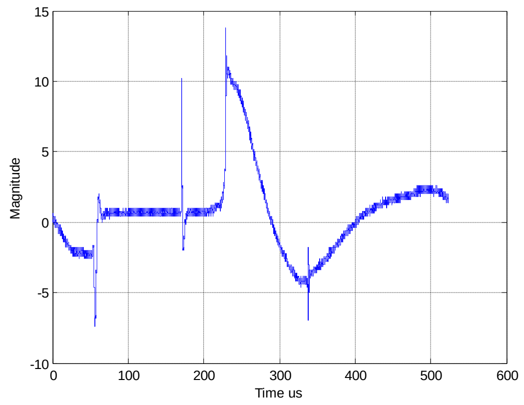

Fig. 3. Example of frequency of impulse

An observed sample (see in Fig. 3) shows us 3 impulses with interval time between each of them is rather small, from 100 μs to 200 μs. As the results of the measurement, we found that the industrial zone has affected strongly by impulsive noise with the high frequency of occurrence and the high magnitude. It can be considered as of heavy tail.

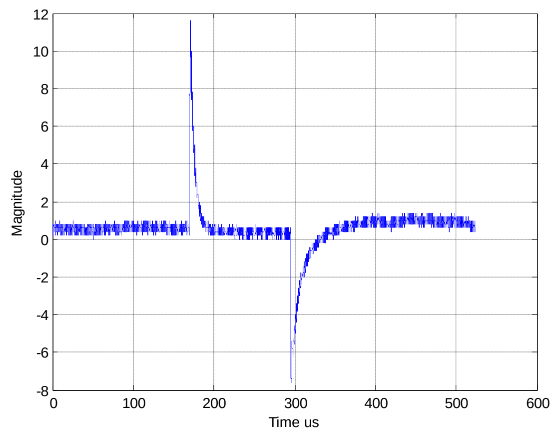

Fig. 4. Negative impulse

Fig. 3 shows a negative impulse. This impulse does not have the form of decreasing-bound impulse as described in [1], [4]. The existing of negative impulses requires us to study on A_{imp-} and A_{imp+} seperately while building a magnitude distribution model.

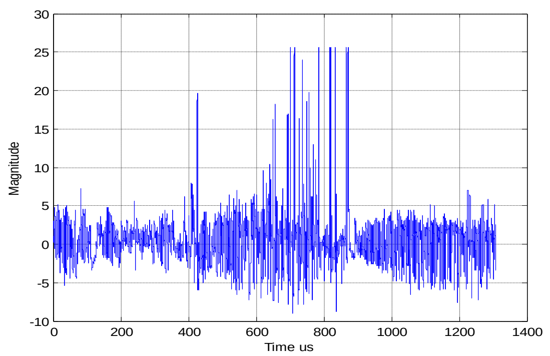

Fig. 5. Bursty impulsive noise

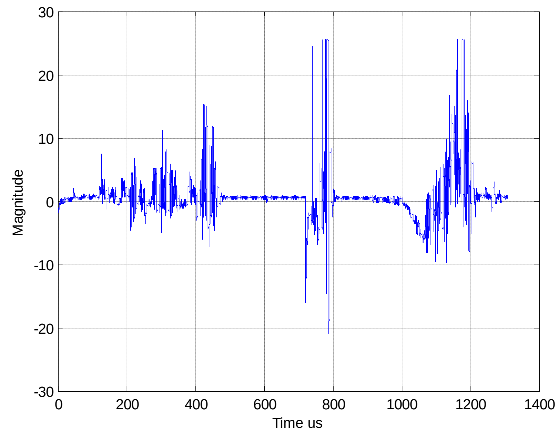

Fig. 6. Occurrence frequency of bursty impulsive noise

Fig. 4 and 5 show bursty impulsive noises whose form is not clearly determined[9], [10]. It composes of many single impulses and their magnitude can be high up to 25V. These high-magnitude impulses can seriously affect the performance of PLC systems.

B. Magnitude of Impulse

As previously discussed, given the heavy tail characteristic of impulsive noise in our measrement, we propse to use the alpha model [11] for industrial zone PLC impulsive noise. Characteristic function φ(t) of alpha stable model is defined as follow:

$$\varphi(t)=\begin{cases}\exp\left\{-\gamma^{\alpha}.[t]^{\alpha}.[1-i\beta sign(t).\tan\frac{\pi\alpha}{2}]+i\delta t\right\} & \alpha\neq 1\\ \exp\left\{-\gamma.[t].[1+i\beta\frac{2}{\pi}sign(t).\ln(t)]+i\delta t\right\} & \alpha=1\end{cases}$$

where $\alpha\in(0,2];\beta\in[-1,1];\gamma\geq 0;\delta\in R;$

$$sign(t)=\begin{cases}1 & t>0\\ 0 & t=0\\ -1 & t<0\end{cases}$$

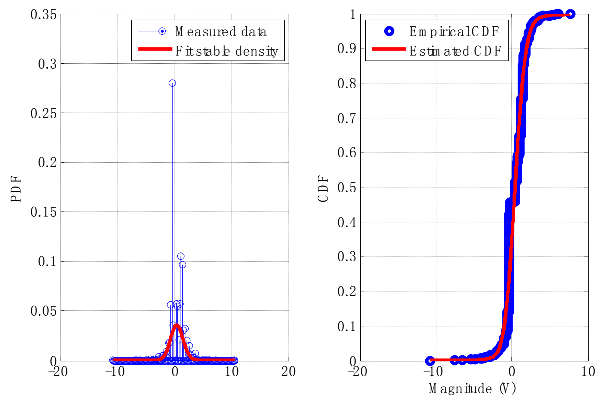

Fig. 7. PDF and CDF of magnitude of impulse measured from 11:00 to 13:00 at 29/7/2011

Using the Maximum likelihood technique, we estimated the impulsive noise PDF function. The obtained values of the alpha stable distribution are α_0=1.8236, β_0=0.3109, γ_0=0.78691, δ_0=0.46598. This distribution with β_0 >0 expresses the deviation clearly tended to the positive direction.

TABLE I: THE FITTING RESULTS USING ALPHA DISTRIBUTION FOR DATA RECORDED DURING 29/JULY/2011 AT DIFFERENT TIME PERIODS.

Time	α_0	β_0	γ_0	δ_0
8:00 - 10:00	1.25924	0.758641	0.344402	0.675493
11:00 - 13:00	1.8236	0.3109	0.78691	0.46598
14:00 - 16:00	1.8284	1.42397	0.455938	0.45939

Table I shows the location parameter δ_0 does not change much while the deviation β_0 change values according to different time periods. The slight change of parameters of α_0, expresses that the distribution shape is not very sensitive to time frames.

The distribution of total magnitude at different time periods is shown in Fig. 8.

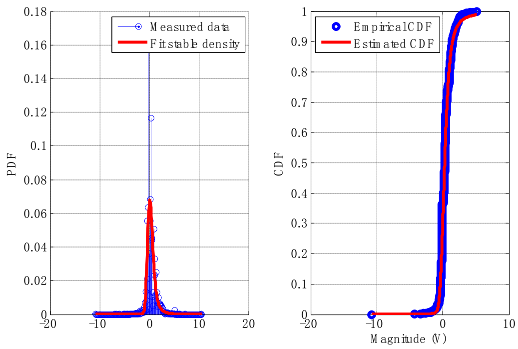

Fig. 8. Amplitude distribution for data obtained on the 29/7/2011

TABLE II: THE FITTING RESULTS WITH DATA RECORDED IN DIFFERENT DAYS

Date	α_0	β_0	γ_0	δ_0
28/7	1.11063	0.027578	0.265596	0.285798
29/7	1.47117	0.895837	0.415185	0.583091
31/7	0.853063	0.657667	0.113396	-0.382411

C. *Duration of Impulse*

Analyzing the behavior of the impulse duration, it is clear that histogram of the impulse duration follow different exponential shape. To show that this type of mixed exponential distribution can be used with confidence, we have fitted many different situations of which the fitted result have shown that this model is a good choice. Fig. 9 shown a sample of the duration of impulse where we have proposed the sum of two exponential functions to fit the result.

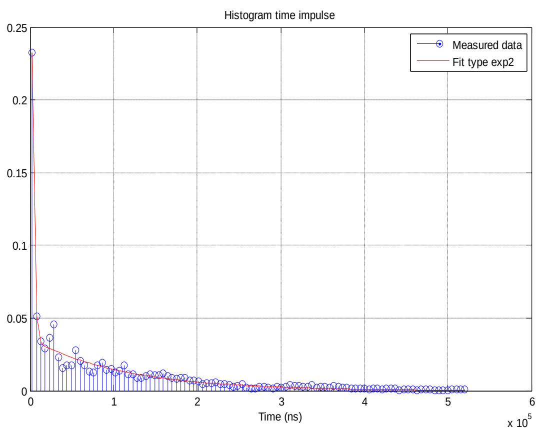

Fig. 9. Pdf of impulse duration

The parameters of the function y=a×exp(b×t)+c×exp(d×t) are *a*=0.6601, *b*=-0.0004575, *c*=0.03579, *d* =-8.866e-006.

D. *Inter-Arrival Time*

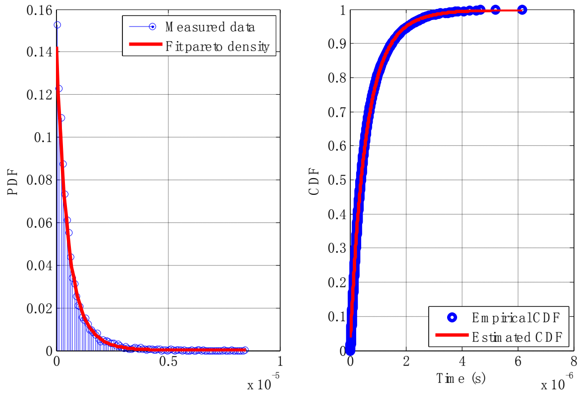

Fig. 10. PDF and CDF of inter-arrival time

The pdf of the inter-arrival time of the results measured from 8AM to 10AM, as shown in Figure 10, is appropriate to the Pareto distribution with K=0.099353 và σ=3.1652e-7.

TABLE III: THE PARETO-FITTED RESULTS OF INTER-ARRIVAL TIME OF THE DATA RECORDED DURING 3 DAYS (28, 29 & 31/JULY/2011).

Date	K	Σ
28/7 (Working day)	0.02112	3.9791e-7
29/7 (Working day)	-0.02759	3.8172e-7
31/7 (Sunday)	0.1059	7.5649e-7

IV. CONCLUSION

We have organized a very intensive campaign of measurement of PLC asynchronous impulsive noise in an industrial zone. Through the experimental measurement results, we have observed the heavy tail phenomenon for the impulsive noise amplitude. For this observation, we proposed to use the alpha stable model for the amplitude distribution and the Pareto distribution for the inter-arrival time. We have also proposed a mixed exponential distribution for the impulse duration. When fitting with estimated parameters, the concordance between measured data and the theoretical curves is good

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