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NOISE ERROR OF PARTICULAR SAMPLING METHOD

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Abstract: The paper presents one of errors of particular sampling method. The method basis on taking samples at particular time moments which enables us to calculate the value of chosen harmonic component in vector form. Additive and multiplicative noises have been analysed and averaging influence on the final result as well.

Keywords: particular sampling method, noises, errors

1   INTRODUCTION

Paper proposed is a continuation of authors' work on error analysis of particular sampling method, invented by Prof. Sawicki from Technical University of Gdañsk. Resent results of the research are presented in numerous papers [1..5].

In the present paper analysis of noise influence on the sampling method is presented. This method gives us possibility to calculate amplitude and phase of fundamental (or another) harmonic component with taking small number of samples (from 16 per period) at particularly chosen time moments [6,7]. The method can be treated as a kind of digital filter of very good selectivity, for instance, all even harmonic components are totally skipped while calculating value of the fundamental harmonic component.

Essential feature of noise is its distribution. Some of noises like thermal or shot noises are of normal distribution, other like burst or avalanche noises can be of different kind of distribution, so in our analysis we assumed uniform distribution of noises, as the worst case resulting in biggest errors.

2   ERROR ANALYSIS

Noises can be part of input signal or can be generated in the measuring instrument itself. For the performed analysis purpose all noises were referred to the input of the instrument.

Error analysis was performed for additive and multiplicative noises. Additive noise was defined as an amplitude random waveform of amplitude measured in fraction of the fundamental harmonic amplitude. To check the worst case, the random waveform was of uniform distribution instead of normal one. This random waveform was added to the waveform under test. Multiplicative noise was defined as random changes of the instrument gain (of uniform distribution). Besides the noise analysis there were made simulation how averaging of the samples influences on the final result. In the paper are presented results of the estimation of noise errors for one of sampling methods, which measures fundamental harmonic and eliminates DC, all even, 3rd and 5th odd components [1,7]. The below input waveform was taken for the tests:

$$Y_t = \sum_{k=1}^{5} A_1 \cdot \frac{1}{k^2} \cdot \sin(k \cdot \boldsymbol{w} \cdot t) \qquad (1)$$

were: A_1 - fundamental harmonic amplitude of the distorted waveform under test
   k - order number of a harmonic component

Errors of particular sampling method depend on the start moment of the sampling cycle. Example of amplitude and phase errors of distorted waveform caused by additive noises as a function of the start moment (in respect to the beginning of the period) of the sampling cycle are shown in Fig 1.

The example was chosen in such a way to obtain errors values similar to maximal ones. Amplitude error is less then 0.8% and phase error less then 0.4deg (0.1% of the period). It means small sensibility of phase value to noise interference, so we can apply the method to measure such vector quantities like power or components of impedance.
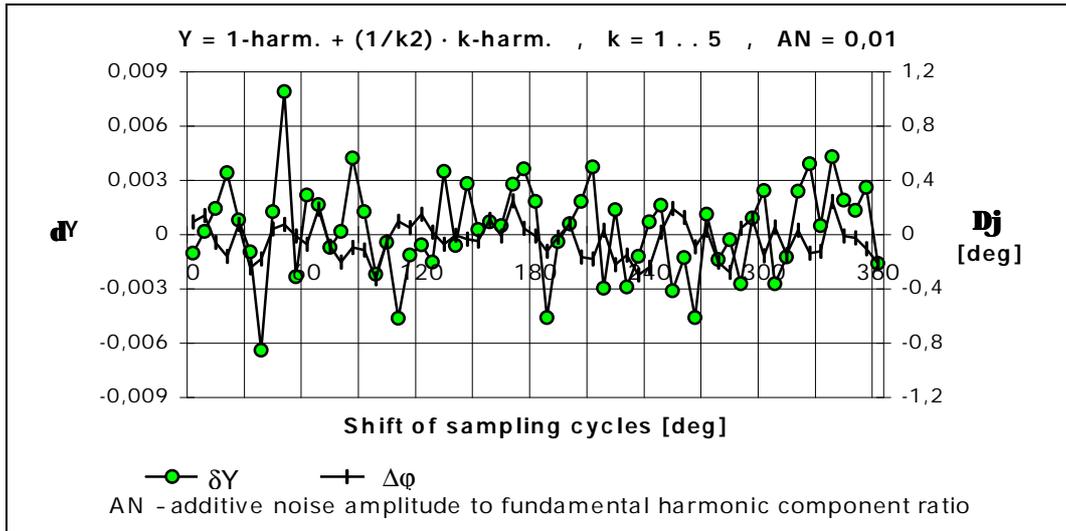
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Figure 1. Amplitude and phase errors caused by additive noise in respect to starting moment of the sampling cycle.

Next Fig 2 shows a sample of amplitude and phase errors in case of noise multiplicative errors as a function of start sampling moment. Noise - meant as a random changes o instrument gain - was equal to 1% of the amplitude of fundamental harmonic. As in above example, presented errors were similar to maximal ones. Amplitude and phase errors caused by multiplicative noises are a little bit smaller then in additive noise case, and their values are equal to 0.6% and 0.3deg, res.
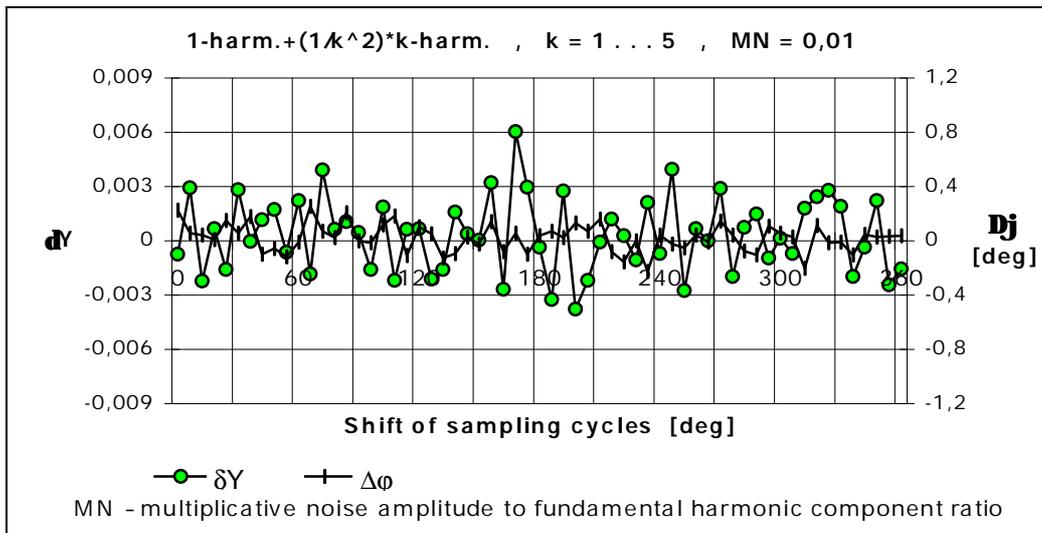

Figure 2. Amplitude and phase errors caused by multiplicative noise in respect to starting moment of the sampling cycle.

Because the noise errors are random, some calculations were performed to find maximal values of the errors. Additionally, the influence of averaging number of the samples on the maximal errors was estimated. Averaging was made on successive n cycles of sampling within 1000 cycles of 16 samples each. The results of the analysis of maximal additive and multiplacative noises as a function of number of averaging cycles are presented in Fig 3 and Fig4, res.

As we can see, averaging by 3 is very effective, next reasonable averaging value is 10.

Next figures present relation of maximal error values in respect to the value of the noise. Calculations were performed for averaging by 3 and without averaging. The method under test is not sensitive to noises, noise of 3% of amplitude causes errors of 1% value.
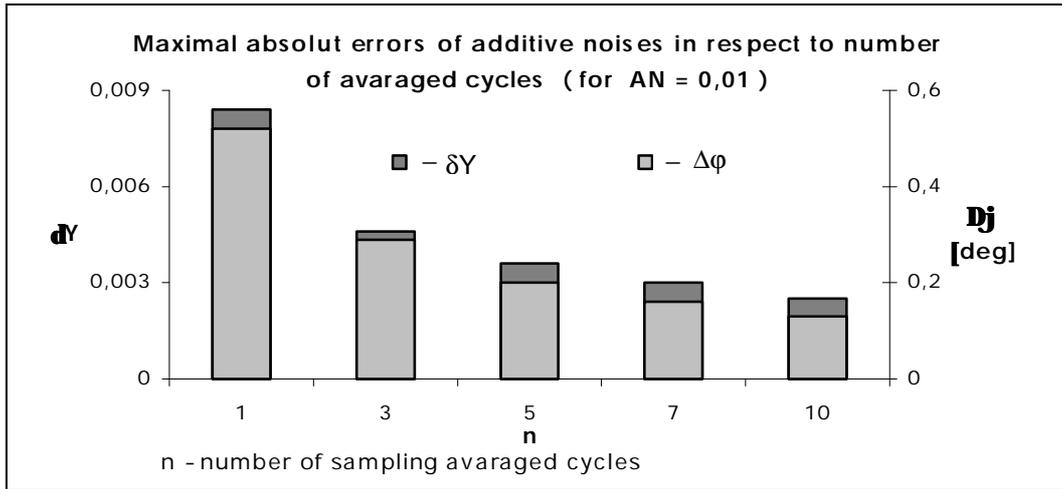
Figure 3. Maximal errors cause by additive noise as a function of averaging number.
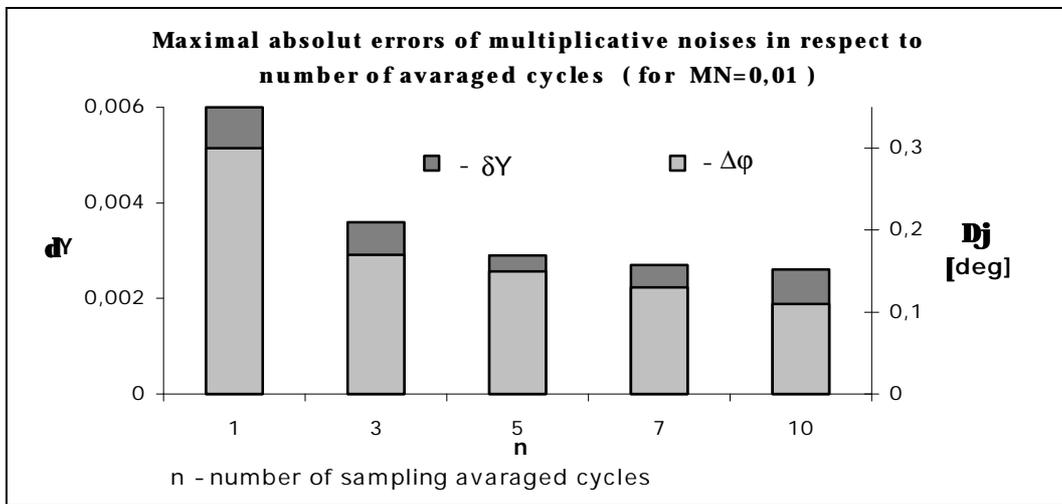

Figure 4. Maximal errors cause by multiplicative noise as a function of averaging number.
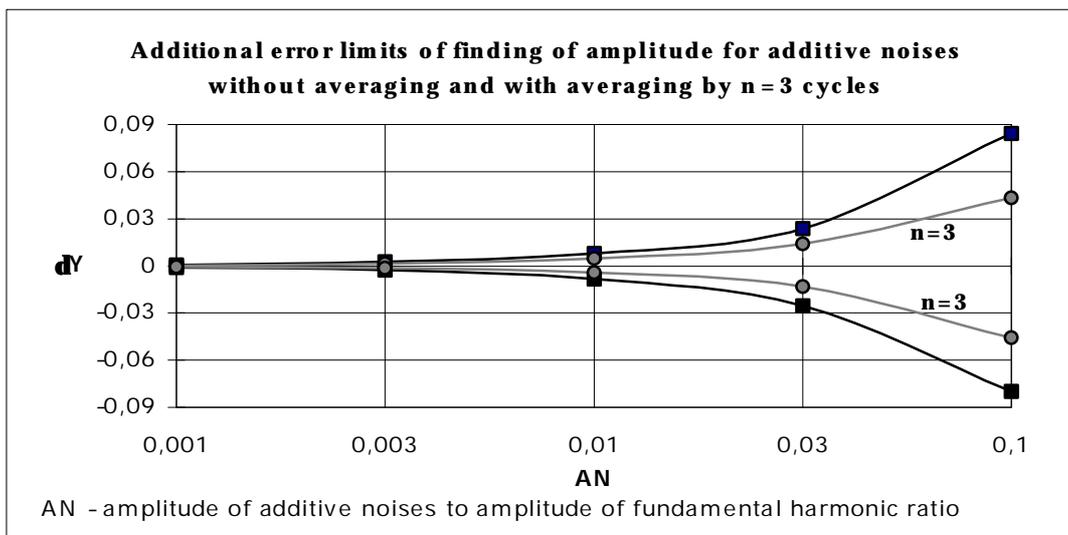

Figure 5. Maximal noise error of one sample cycle in respect to averaging by n=3 periods as a function of additive noise value.
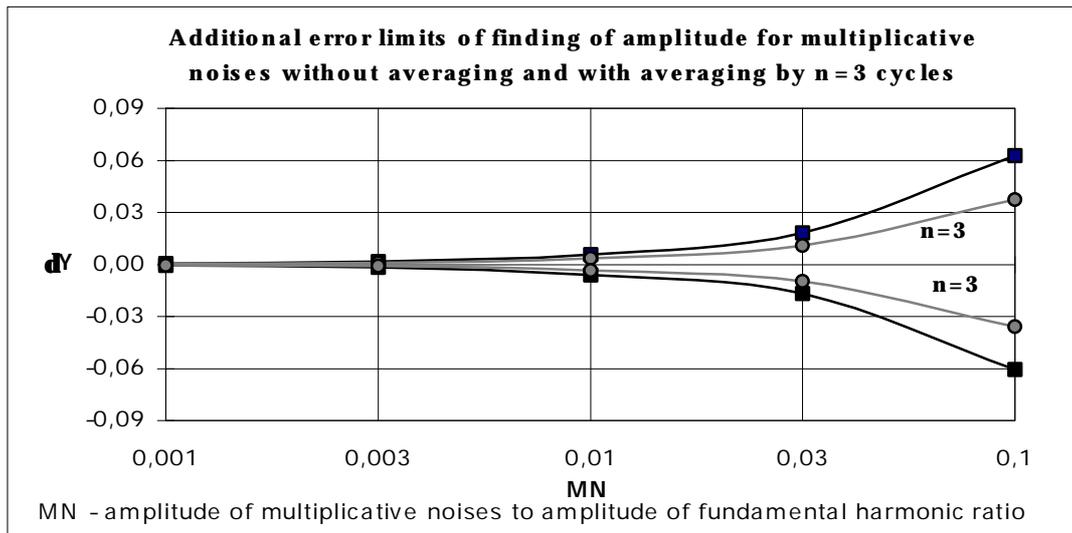
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Figure 6. Maximal noise error of one sample cycle in respect to averaging by n=3 periods as a function of multiplicative noise value.

3   CONCLUSIONS

Obtained results show that values of the noise errors are less then amplitude of causing them noises. Especially phase errors are small (relative maximal error is by 10 times less then amplitude of the noise).

Averaging gives additional reduction of the errors. It is enough to perform averaging by 3 or 4 cycles to obtain prominent reduction of the errors. This is really 'good news' because it enables us to sustain the basic advantage of the method: speed. Due to the small numbers of the samples to be taken, the all averaging can be performed practically in one period of the waveform under test (successive sampling cycles can be shifted by a fraction of the period). It is worth mentioning that the presented calculations were performed with random waveform of uniform distribution. In practical situation there will be probably noise of normal distribution, so its influence on the result will be less. Presented analysis shows that discussed errors are of small importance so they not limit application of the particular sampling method in real situation, where noises are inevitable.

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